

Originally Processed With FOIA(s):
1999-0582-F; 2005-0336-F

FOIA Number:
2005-0336-F

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Record Group/Collection: George H.W. Bush Presidential Records
Collection/Office of Origin: Science and Technology Policy, Office of (OSTP)
Series: Bromley, D. Allan, Files
Subseries: International Files - Country Files

OA/ID Number: 62066
Folder ID Number: 62066-002

Folder Title:
International: Japan [2 of 3] [1991]

Stack:

Row:

Section:

Shelf:

Position:

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United States Department of State

Washington, D.C. 20520

September 18, 1991

MEMORANDUM FOR BRENT SCOWCROFT
THE WHITE HOUSE

Subject: Memorandum to Dr. Bromley on JHLC Invitation

Transmitted herewith is a letter of regret from the Under Secretary of State for International Security Affairs regarding an invitation from Dr. Bromley to attend the Joint High Level Committee (JHLC) meeting to be held in Tokyo on October 17-18, 1991.

for [Signature] Kearney
W. Robert Pearson
Executive Secretary

Attachment:
As stated



United States Department of State
Under Secretary for International Security Affairs
Washington, D.C. 20520

September 18, 1991

Allan
Dear Dr. Bromley:

I am writing in response to your invitation of September 4, 1991 regarding my participation at the upcoming Joint High Level Committee meeting in Tokyo, October 17-18, under the U.S.-Japan Science and Technology Agreement. Unfortunately, I will be traveling elsewhere that week and will not be able to attend.

Dr. John Boright, Deputy Assistant Secretary for Science and Technology Affairs in the Bureau of Oceans and International Environmental and Scientific Affairs, will be attending the upcoming meeting for the Department, along with a possible representative from the Bureau of East Asian and Pacific Affairs. Dr. Boright was the U.S. delegation Chair for the fourth meeting of the Joint Working Level Committee, which met last July to prepare for the upcoming October meeting.

I wish you a productive and worthwhile trip to Japan and hope that your discussions continue to bear fruit from one of our most important science and technology relationships.

Yours truly,

Reginald Bartholomew
Reginald Bartholomew

The Honorable
D. Allan Bromley,
Assistant to the President
for Science and Technology,
The White House.

THE WHITE HOUSE
WASHINGTON

9116296

September 4, 1991

Dear Ambassador Bartholomew:

You are invited to be a member of the U.S. Delegation for the Third Joint High Level Committee (JHLC) meeting in accordance with the U.S.-Japan Agreement on Cooperation in Research and Development in Science and Technology. The meeting will be held in Tokyo on October 17 and 18, 1991. Your participation in this meeting is important.

As you know, the U.S.-Japan Science and Technology Agreement is one of only two current such agreements at the head-of-state level to which the U.S. is a signator. As a comprehensive umbrella agreement, the research and development activities pursued under the agreement, and the policy issues discussed at the Joint High Level Committee, influence the cooperative activities of all agencies. In addition, this particular meeting of the JHLC will be instrumental in preparing for the President's planned trip to Tokyo in November.

The Joint Working Level Committee, chaired on the U.S. side by John Boright, Deputy Assistant Secretary for Science and Technology Affairs, began preparations for our October meeting when it met in Tokyo in July. We will review the reports of the Working Level Committee as well as the Chairmen's Summary of the Joint High Advisory Panel, which met in April in Japan. Several issues discussed at that Joint Working Level Committee meeting, and upon which my staff has further expanded, are enclosed for your consideration. If you have any thoughts on these, or other topics, please let me know.

We are still awaiting a proposed agenda from the Government of Japan, but our tentative schedule is to depart from Washington, D.C. on October 15, arriving Tokyo October 16, followed by two full days of meetings. This will be preceded by a delegation meeting on October 9 at 10:00 am in the Council of Environmental Quality's conference room, 722 Jackson Place.

September 4, 1991

Page 2

Enclosed you will find a copy of the proposed delegation membership. It is very important for our science and technology relations and for the President's upcoming trip that we have a strong delegation at this meeting. Please let me know as soon as possible whether you will be able to join us in Tokyo. Sara Bowden on my staff will be handling preparations for the trip. If you have any questions or comments, please feel free to contact her on (202) 395-4626.

I look forward to a productive and worthwhile trip to Japan.

Sincerely,

A handwritten signature in black ink, reading "D. Allan Bromley". The signature is fluid and cursive, with the first name "D. Allan" and the last name "Bromley" clearly distinguishable.

D. Allan Bromley
The Assistant to the President
for
Science and Technology

Enclosures

Ambassador Reginald Bartholomew
Under Secretary
International Security Affairs
U.S. Department of State
2201 C Street, N.W.
Washington, D.C. 20520-7512

JOINT HIGH LEVEL COMMITTEE MEETING U.S. ISSUES

S&T AGREEMENT RENEWAL: The STA will expire in June 1993. The Joint High Level Committee (JHLC) has been meeting approximately every 18 months, therefore, the October meeting may present the first and last opportunity for the Committee to discuss the issue of renewal. Both sides will wish to renew the agreement, but there may be varying opinions as to whether changes to the agreement are necessary and if so, the nature of the changes. In any case, a thorough discussion of related issues is warranted. Issues to be addressed might include:

- effectiveness of the agreement in meeting its stated objectives,
- effectiveness of the administrative structure,
- evaluation of the areas for cooperation outlined in Annex I
- scope of the agreement and relationship to other bilateral agreements.

The scope question may be the most important. It relates to how well the umbrella agreement has coordinated and facilitated all bilateral and multilateral cooperation between the United States and Japan, and whether improvements toward this end can be made to insure a more integrated United States Government science and technology interaction with Japanese technical agencies.

The JHLC discussion should result in a firm commitment to renew the agreement, some preliminary views on the issues listed above and others, and instructions to the JWLC to engage in a thorough review of the agreement with recommendations on how to proceed toward renewal.

MEGAPROJECTS: During the May 1990 meeting, the JHLC discussed international cooperation in megaprojects in the sciences. The U.S. side agreed to provide a paper outlining some initial thoughts on the topic. A draft discussion paper has been prepared (outlining the issues but not presenting positions of the USG) that would serve as a useful backdrop to further discussions with the Japanese on this topic. The draft document should be sent to the Japanese no later than one month prior to the meeting to allow ample time for Japanese consideration. A discussion draft will be available for comment by U.S. delegation members shortly.

In addition to the broad discussion of megaprojects, the U.S. should be prepared to give a complete briefing to the Japanese on the Superconducting Super Collider. In return, the Japanese could provide a briefing on the Human Frontiers Science Program. Both sides could report on international planning for the next phase of the International Thermonuclear Experimental Reactor. The intent is to engage in a discussion of how the two sides can cooperate in these programs with a view toward a head of state announcement in November. There may be other topics which the U.S. side would like to discuss, including Human Genome research.

ENVIRONMENTAL PACKAGE: As part of preparations for the President's trip to Japan in November, the U.S. may table a comprehensive package of environmental proposals, including cooperation in environmental technology development, global change research center for the Pacific rim, and cooperation in aid and development related activities. The package will probably be presented to the Japanese by late September. Should this occur, the JHLC meeting will provide an excellent opportunity to discuss the proposals further, iron out differences, and prepare for an announcement during the head of state meeting.

IMS, NIPT, OTHERS: Intelligent Manufacturing System (IMS) and New Information Processing Technology (NIPT) are two MITI initiatives that are already being discussed within the context of Annex I of the Agreement. The GOJ should be prepared to give a status report on implementation of these programs, both domestically and internationally. To the extent possible they should also give the U.S. side information on other MITI initiatives which may be downstream, such as one relating to micromachines. The U.S. side should be prepared to ask questions about downstream projects as well as provide an update on our deliberations on IMS and NIPT.

**JOINT HIGH LEVEL COMMITTEE MEETING
PROPOSED U.S. DELEGATION**

OSTP

Dr. D. Allan Bromley
Dr. J. Thomas Ratchford

NATIONAL SECURITY COUNCIL

Mr. Douglas Paal

U.S. TRADE REPRESENTATIVE

Mr. Jules Katz

DEPARTMENT OF STATE

Amb. Reginald Bartholomew
Dr. John Boright (Chairman of the JWLC)
Mr. Richard H. Solomon

DEPARTMENT OF ENERGY

Mr. Henson Moore

DEPARTMENT OF DEFENSE

Dr. Victor Reis

DEPARTMENT OF COMMERCE

Dr. Robert White
Mr. J. Michael Farren

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Dr. Bernadine Healy

DEPARTMENT OF AGRICULTURE

Dr. Charles Hess

NSF

Dr. Walter Massey

NASA

Dr. Richard Truly

EPA

Mr. Henry Habicht

AID

Dr. Richard Bissell



United States Department of State

Washington, D.C. 20520

September 18, 1991

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THE WHITE HOUSE

Subject: Memorandum to Dr. Bromley on JHLC Invitation

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for [Signature] Keaney
W. Robert Pearson
Executive Secretary

Attachment:
As stated



United States Department of State
Under Secretary for International Security Affairs
Washington, D.C. 20520

September 18, 1991


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Dr. John Boright, Deputy Assistant Secretary for Science and Technology Affairs in the Bureau of Oceans and International Environmental and Scientific Affairs, will be attending the upcoming meeting for the Department, along with a possible representative from the Bureau of East Asian and Pacific Affairs. Dr. Boright was the U.S. delegation Chair for the fourth meeting of the Joint Working Level Committee, which met last July to prepare for the upcoming October meeting.

I wish you a productive and worthwhile trip to Japan and hope that your discussions continue to bear fruit from one of our most important science and technology relationships.

Yours truly,


Reginald Bartholomew

The Honorable
D. Allan Bromley,
Assistant to the President
for Science and Technology,
The White House.

THE WHITE HOUSE
WASHINGTON

9116296

September 4, 1991

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September 4, 1991

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I look forward to a productive and worthwhile trip to Japan.

Sincerely,

A handwritten signature in dark ink, appearing to read "D. Allan Bromley". The signature is fluid and cursive, with the first name "D. Allan" and the last name "Bromley" clearly distinguishable.

D. Allan Bromley
The Assistant to the President
for
Science and Technology

Enclosures

Ambassador Reginald Bartholomew
Under Secretary
International Security Affairs
U.S. Department of State
2201 C Street, N.W.
Washington, D.C. 20520-7512

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**JOINT HIGH LEVEL COMMITTEE MEETING
PROPOSED U.S. DELEGATION**

OSTP

Dr. D. Allan Bromley
Dr. J. Thomas Ratchford

NATIONAL SECURITY COUNCIL

Mr. Douglas Paal

U.S. TRADE REPRESENTATIVE

Mr. Jules Katz

DEPARTMENT OF STATE

Amb. Reginald Bartholomew
Dr. John Boright (Chairman of the JWLC)
Mr. Richard H. Solomon

DEPARTMENT OF ENERGY

Mr. Henson Moore

DEPARTMENT OF DEFENSE

Dr. Victor Reis

DEPARTMENT OF COMMERCE

Dr. Robert White
Mr. J. Michael Farren

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Dr. Bernadine Healy

DEPARTMENT OF AGRICULTURE

Dr. Charles Hess

NSF

Dr. Walter Massey

NASA

Dr. Richard Truly

EPA

Mr. Henry Habicht

AID

Dr. Richard Bissell

"CORRESPONDENCE TRACKING"

TYPE: INFORMATION DOCUMENT NUMBER: 9124094
ORIGINATOR: 02 STATUS C DIRECTORATE STATUS

FROM: BARTHOLOMEW, Reginald: Under Secretary for International
Security Affairs, DEPARTMENT OF STATE

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 09/18/91

SUBJECT: HE IS UNABLE TO PARTICIPATE IN THE UPCOMING JOINT
HIGH LEVEL COMMITTEE MEETING IN TOKYO, BUT DR. JOHN
BORIGHT WILL BE ATTENDING FOR THE DEPARTMENT.

DIRECTORATE STAFF
ASSIGNED: ASSIGNED:

ACTION STAFF
REQUIRED: ACTION:

SENDER'S DUE DATE:
OSTP DUE DATE: STAFF DUE DATE
DATE COMPLETED: DATE COMPLETED/DEPT:

COPIES TO: D. Allan Bromley
INTERNATIONAL/POLICY

WHITE HOUSE TRACKING #: CONTACT PERSON:
REMARKS: PHONE: EXT:

OSTP RECEIVED: 09/19/91 FILE: P-INTERNATIONAL-JAPAN
DEPT RECEIVED:

4094



RECEIVED

91 SEP 19 PM 12:19

OFFICE OF THE
DIRECTOR
Allen

United States Department of State
Under Secretary for International Security Affairs
Washington, D.C. 20520

September 18, 1991

Dear Dr. Bromley:

I am writing in response to your invitation of September 4, 1991 regarding my participation at the upcoming Joint High Level Committee meeting in Tokyo, October 17-18, under the U.S.-Japan Science and Technology Agreement. Unfortunately, I will be traveling elsewhere that week and will not be able to attend.

Dr. John Boright, Deputy Assistant Secretary for Science and Technology Affairs in the Bureau of Oceans and International Environmental and Scientific Affairs, will be attending the upcoming meeting for the Department, along with a possible representative from the Bureau of East Asian and Pacific Affairs. Dr. Boright was the U.S. delegation Chair for the fourth meeting of the Joint Working Level Committee, which met last July to prepare for the upcoming October meeting.

I wish you a productive and worthwhile trip to Japan and hope that your discussions continue to bear fruit from one of our most important science and technology relationships.

Yours truly,

Reginald Bartholomew
Reginald Bartholomew

The Honorable
D. Allan Bromley,
Assistant to the President
for Science and Technology,
The White House.

"CORRESPONDENCE TRACKING"

TYPE: INFORMATION DOCUMENT NUMBER: 9124045
ORIGINATOR: 02 STATUS C DIRECTORATE STATUS

FROM: DIETRICH, W.S.

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 09/15/91

SUBJECT: A COPY OF THE BOOK, "IN THE SHADOW OF THE RISING
SUN: THE POLITICAL ROOTS OF AMERICAN ECONOMIC
DECLINE."

DIRECTORATE STAFF
ASSIGNED: ASSIGNED:

ACTION STAFF
REQUIRED: ACTION:

SENDER'S DUE DATE: STAFF DUE DATE
OSTP DUE DATE: STAFF DUE DATE
DATE COMPLETED: DATE COMPLETED/DEPT:

COPIES TO: D. Allan Bromley
INTERNATIONAL/POLICY

WHITE HOUSE TRACKING #: CONTACT PERSON:
PHONE: EXT:
REMARKS: Enclosure to DAB.

OSTP RECEIVED: 09/17/91 FILE: P-INTERNATIONAL-JAPAN
DEPT RECEIVED:

4045
RECEIVED

W. S. DIETRICH
500 GRANT ST.
PITTSBURGH, PA 15219

September 15, 1991

91 SEP 17 AIO: 43

OFFICE OF THE
DIRECTOR
The Honorable Allan Bromley
Office of Science & Technology
The White House
1600 Pennsylvania Avenue NW
Washington, DC 20500-0001

Dear Mr. Bromley:

As the President's top science advisor, I am sure you share my concerns about the future of the U.S. economy, and about what I call "the Japanese question/decline of America problem."

I have written a book entitled: In the Shadow of the Rising Sun: The Political Roots of American Economic Decline. It has been published by Penn State Press. Along with the book I am enclosing a biographical data sheet and a bullet type summary of the argument. As a businessman I have a strong "bottom line" orientation, and the bottom line of this book is: fundamental political reform or continued economic decline. As the prospects for political reform are remote--to say the least--economic decline appears to be in the cards for the United States.

This book sets for itself the very ambitious task of fingering the root cause of American economic decline. The argument probably deserved a bigger book with more profound scholarship, but regardless of the deficiencies of scholarship and presentation, I am convinced the argument is fundamentally sound. I hope you'll take a look at it.

If you're inclined to toss the book into a corner I'll ask only this: read the preface and the conclusion. Perhaps this will be enough to cause you to read further.

Sincerely,


W. S. Dietrich

William S. Dietrich II
Biographical Information

Personal: Age 53
Children - One Daughter
Anne Elizabeth Dietrich
Age 9

Education: AB - Princeton University, 1960
MA - University of Pittsburgh, 1980
Ph.D - University of Pittsburgh, 1984

Military
Service: United States Marine Corps Reserve
1960-1966

Occupation: President,
Dietrich Industries, Inc.
500 Grant Street
Pittsburgh, PA 15219-2502

1961 -
President - 1968 - Present

Current Board
Service: Allegheny Trails Council of the
Boy Scouts of America
Chatham College
Historical Society of Western Pennsylvania
Pittsburgh Ballet Theatre
Pittsburgh Chamber of Commerce
Shadyside Hospital
West Penn Motor Club
Joseph M. Katz Graduate School of Business
The University of Pittsburgh Board of
Visitors
University of Pittsburgh

Clubs: Duquesne Club
Fox Chapel Golf Club
Laurel Valley Golf Club
Oakmont Country Club
Rolling Rock Club

Author: "In the Shadow of the Rising Sun: The
Political Roots of American Economic
Decline"--Penn State University Press
Fall 1991

*AMERICA FACES ECONOMIC DECLINE AND LOSS OF WORLD ECONOMIC AND POLITICAL LEADERSHIP.

*THE PROXIMATE CAUSES OF AMERICAN ECONOMIC DECLINE ARE SERIOUS MANAGERIAL, FINANCIAL, AND POLITICAL SHORTCOMINGS--THEY ARE SYSTEM WIDE.

*JAPAN HAS UNDERTAKEN A NATIONAL EFFORT TO ACHIEVE GLOBAL TECHNOLOGICAL, ECONOMIC, AND PERHAPS POLITICAL DOMINANCE.

*JAPANESE SUCCESS HAS BEEN BASED UPON THE COMPREHENSIVE USE OF INDUSTRIAL POLICY--THE EFFORT HAS BEEN SYSTEM WIDE.

*INDUSTRIAL POLICY IS THE STATE-INDUCED WILLFUL SHIFTING OF THE INDUSTRIAL STRUCTURE TOWARD HIGH TECHNOLOGY, HIGH VALUE ADDED INDUSTRIES.

*A STRONG CENTRAL STATE AND A TOP PROFESSIONAL BUREAUCRACY ARE ESSENTIAL PRECONDITIONS OF INDUSTRIAL POLICY.

*JAPANESE POLITICAL INSTITUTIONS ARE EUROPEAN IN ORIGIN AND ARE REPLICATED IN MOST ADVANCED INDUSTRIAL SOCIETIES.

*AMERICA IS TOTALLY LACKING THE STATIST TRADITIONS OF FRANCE, GERMANY, AND JAPAN--OUR POLITICAL DEVELOPMENT HAS BEEN CONDITIONED BY AN ANTI-STATIST TRADITION.

*AMERICAN POLITICAL INSTITUTIONS ARE
UTTERLY UNIQUE--ALONE AMONG THE
ADVANCED DEMOCRATIC SOCIETIES WE LACK
A STRONG CENTRAL STATE AND A TOP
PROFESSIONAL BUREAUCRACY.

*THE ONLY WAY AMERICA CAN COUNTER THE
JAPANESE CHALLENGE AND REGAIN WORLD
ECONOMIC LEADERSHIP IS THROUGH THE
COMPREHENSIVE USE OF INDUSTRIAL
POLICY.

*LACKING A STRONG CENTRAL STATE AND A
TOP PROFESSIONAL BUREAUCRACY--THE TWO
PRECONDITIONS OF INDUSTRIAL POLICY--
AMERICA IS DOOMED TO ECONOMIC
DECLINE.

*THERE IS ONE WAY AND ONLY ONE WAY OUT
OF OUR CURRENT PREDICAMENT:
FUNDAMENTAL INSTITUTIONAL CHANGE.

WILLIAM S. DIETRICH

IN THE SHADOW
OF THE RISING SUN



The Political Roots of
American Economic Decline

Logged

"CORRESPONDENCE TRACKING"

TYPE: ACTION DOCUMENT NUMBER: 9124059
ORIGINATOR: 02 STATUS I DIRECTORATE STATUS

FROM: TRULY, Richard H.: NASA

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 09/12/91

SUBJECT: A THANK YOU FOR THE INVITATION TO PARTICIPATE IN THE
JOINT HIGH LEVEL COMMITTEE MEETING IN JAPAN. HE IS
UNABLE TO ACCEPT, BUT WOULD LIKE MARGARET FINARELLI
TO REPRESENT HIM AT THE MEETING.

DIRECTORATE STAFF
ASSIGNED: INTERNATIONAL/POLICY ASSIGNED: SB

ACTION STAFF
REQUIRED: DRAFT FOR DAB ACTION:

SENDER'S DUE DATE:
OSTP DUE DATE: 09/23/91 STAFF DUE DATE 9/21/91
DATE COMPLETED: DATE COMPLETED/DEPT:

COPIES TO: D. Allan Bromley

WHITE HOUSE TRACKING #: CONTACT PERSON:
REMARKS: PHONE: EXT:

No response necessary. Finnerelli accepted thru phone conversation
between Sara Bowden & Woody Turner, NASA.
SB

OSTP RECEIVED: 09/17/91 FILE: P-INTERNATIONAL-JAPAN
DEPT RECEIVED:



National Aeronautics and
Space Administration

Washington, D.C.
20546

Office of the Administrator

September 12, 1991

RECEIVED
91 SEP 17 11:43
OFFICE OF THE
DIRECTOR
The Honorable D. Allan Bromley
Assistant to the President
for Science and Technology and
Director, Office of Science and
Technology Policy
Executive Office of the President
Washington, DC 20506

Dear Dr. *Allyn* Bromley:

Thank you for your invitation to participate in the Joint High Level Committee (JHLC) meeting in Japan next month. Unfortunately, I will be unable to travel to Tokyo this fall due to schedule constraints. However, with your concurrence, I suggest that Mrs. Margaret Finarelli, NASA's Associate Administrator for External Relations, represent me at the meeting. Mrs. Finarelli, who was involved in the development of the original U.S.-Japan science and technology agreement, has an excellent background for this activity.

This meeting will no doubt be an important one as the time approaches for renewal of the U.S.-Japan Agreement on Cooperation in Research and Development in Science and Technology. NASA looks forward to working with you and your office during the renewal process.

Sincerely,

Richard H. Truly
Richard H. Truly
Administrator

"CORRESPONDENCE TRACKING"

TYPE: ACTION

ORIGINATOR: 02

DOCUMENT NUMBER: 9124059

STATUS I

DIRECTORATE STATUS

FROM: TRULY, Richard H.: NASA

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 09/12/91

SUBJECT: A THANK YOU FOR THE INVITATION TO PARTICIPATE IN THE
JOINT HIGH LEVEL COMMITTEE MEETING IN JAPAN. HE IS
UNABLE TO ACCEPT, BUT WOULD LIKE MARGARET FINARELLI
TO REPRESENT HIM AT THE MEETING.

OK

DIRECTORATE

ASSIGNED: INTERNATIONAL/POLICY

STAFF

ASSIGNED:

ACTION

REQUIRED: DRAFT FOR DAB

STAFF

ACTION:

SENDER'S DUE DATE:

OSTP DUE DATE: 09/23/91

STAFF DUE DATE

DATE COMPLETED:

DATE COMPLETED/DEPT:

COPIES TO: D. Allan Bromley

WHITE HOUSE TRACKING #:

CONTACT PERSON:

REMARKS:

PHONE:

EXT:

OSTP RECEIVED: 09/17/91
DEPT RECEIVED:

FILE: P-INTERNATIONAL-JAPAN

"CORRESPONDENCE TRACKING"

TYPE: INFORMATION DOCUMENT NUMBER: 9124128
ORIGINATOR: 02 STATUS C DIRECTORATE STATUS

FROM: MORI, Wataru: PRIME MINISTER'S COUNCIL FOR SCIENCE AND
TECHNOLOGY

TO: DR. D.A. BROMLEY

DATE OF
CORRESPONDENCE: 09/12/91

SUBJECT: RE: THE SECOND MEETING OF THE CARNEGIE GROUP AND THE
ISSUE OF SCIENTIFIC AND TECHNOLOGICAL COOPERATION
WITH EASTERN EUROPE AND THE SOVIET UNION.

DIRECTORATE STAFF
ASSIGNED: ASSIGNED:

ACTION STAFF
REQUIRED: ACTION:

SENDER'S DUE DATE: STAFF DUE DATE
OSTP DUE DATE: STAFF DUE DATE
DATE COMPLETED: DATE COMPLETED/DEPT:

COPIES TO: D. Allan Bromley
INTERNATIONAL/POLICY

WHITE HOUSE TRACKING #: CONTACT PERSON:
REMARKS: PHONE: EXT:

OSTP RECEIVED: 09/20/91
DEPT RECEIVED:

FILE: P-INTERNATIONAL*DAB-MEM-CARNEG

PRIME MINISTER'S
COUNCIL FOR SCIENCE AND TECHNOLOGY

Kasumigaseki 2/2/1, Chiyoda-ku, Tokyo, 100 JAPAN

Phone: (81) (3) 3581 1357, 03
Fax: (81) (3) 3581 307

OFFICE OF THE
DIRECTOR

September 12, 1991

Dr. D. Allan Bromley
Assistant to the President
for Science and Technology
the White House
Washington

Dear Dr. Bromley:

I am writing in response to your letter of Aug. 15, 1991 concerning the second meeting of the Carnegie Group on October 4-6, 1991.

After I received your letter, I have been studying issues which are appropriate for discussion at our coming meeting. I think it appropriate to discuss issues on scientific and technological cooperation with Eastern Europe and the Soviet Union which are in transition to market economy. I hope my suggestion is helpful to you.

I enclosed my curriculum vitae.

I am looking forward to seeing you in October.

Sincerely yours,

Wataru Mori

Wataru Mori

Council for Science and Technology

PRIME MINISTER'S
COUNCIL FOR SCIENCE AND TECHNOLOGY
Tokyo
WATARU MORI

Wataru Mori is a member of the Prime Minister's Council for Science and Technology (CST) which is chaired by Prime Minister himself and composed of 10 members; *ex officio* four Ministers concerned and President of Science Council of Japan, and other five distinguished expert members appointed by Prime Minister with the approval of the Diet. Wataru Mori, who is the senior of two full-time expert members of the Council, is appointed to the Chairman of the Committee on Policy Matters which functions actually as the Executive Board of the Council in order to ensure continuous, timely and flexible activity of the Council.

He is the Professor Emeritus and Ex-President of the University of Tokyo. He completed his four-year term as President of the University of Tokyo from 1985 to 1989. Before that, he had been the Professor and Chairman of the Department of Pathology and then the Dean of the Faculty of Medicine.

Born in Tokyo, Japan, he received the M.D. degree in 1951, and the Ph.D. degree (Doctor of Medical Science) in 1957, both from the University of Tokyo. He has experienced two studies abroad of rather long period, 2-1/2 years in Yale University, U.S.A., from 1956 to 1959, and exactly one year in University of Cambridge, U.K., from 1966 to 1967. His major field of study is pathology, human and experimental. His main interests in pathology were in liver diseases, originally, which later expanded widely to tumor pathology in general firstly intending to know the cause of primary liver cancer, and also to immunology mainly to investigate the cause of acute necrosis of the liver. The pineal hormone, melatonin, is another field of his study, partly as a hobby. He has published more than 500 papers in medical sciences.

He was actually the head (Secretary General) of the Japanese Pathological Society from 1983 to 1989, and played a major role in conducting the whole society during the time of large changes in concept, methodology, and application of pathology itself, and the surrounding world. His activities in science policy communities have been shown not only in the field of pathology but also in general medicine widely, e.g., serving as the Vice-President of the Japanese Association of Medical Science for six years up to the present. He is also playing some role internationally in this field, namely, is in the position of Vice-President of the International Council of Societies of Pathology. He was elected a foreign associate member of the Institute of Medicine, National Academy of Sciences, U.S.A., in 1990. According to the university law which forbids reappointment, Dr. Mori

served as the President of the University of Tokyo for only one term, four years. In this rather short period of time, however, he made a considerable contribution to his university; e.g., improved the environment of the campus cleaning away all the remnants of student riots which had been remaining for almost 15 years since early 70s, on the one hand, and started a unique system in his university placing greater importance on post-graduate courses, on the other. As the President of the Association of National Universities in Japan, at the same time, he got through many difficulties lying between universities and politicians as well as the general public, especially concerning the very hot issue of entrance examination to universities. He formerly served as a council member, and now is the Vice-President of International Association of Universities.

Prior to his present appointment, and also up to now, Dr. Mori has been serving as a member of more than several, important Committees of the Japanese Government, some examples are:

Chairman, The Medical Ethics Council (Ministry of Health and Welfare)

Vice-Chairman, Provisional Commission for the Study of Brain Death and Organ Transplantation

Member, The Science Council (Ministry of Education, Science and Culture)

Co-Chairman, U.S.-Japan Joint High Level Advisory Panel on Science and Technology

Member, U.S.-Japan Cooperative Medical Science Program

August 1, 1991

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TO: DR. D.A. BROMLEY

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CORRESPONDENCE: 09/04/91

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OFFICE OF THE
DIRECTOR

September 4, 1991

Dr. D. Allan Bromley
Assistant to the President
for Science and Technology
Office of Science and Technology
Policy
New Executive Office Building
Washington, DC 20506

Dear Dr. Bromley:

Enclosed is a copy of our latest report.

We have several interesting reports in process and will send you
copies as soon as they become available.

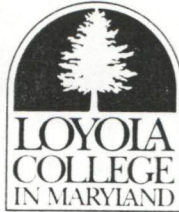
We hope these reports are useful to you and your staff.

Best wishes.

Sincerely,

Geoffrey M. Holdridge
Director

4501 North Charles Street
Baltimore, Maryland 21210-2699
(301) 323-1010, ext. 2876
FAX: (301) 532-5123
BITNET:SBG@LOYVAX



JAPANESE TECHNOLOGY EVALUATION CENTER

August 1, 1991

Dear Colleague:

This is a letter of transmittal for the *JTEC Panel Report on Construction Technology in Japan*. Additional copies will be available from the National Technical Information Service (NTIS) of the Department of Commerce, but let me know if there is someone who should get one right away.

The report has an acknowledgement section, but I would like to add my thanks to our NSF sponsors: Ken Chong, Robert Hanson, Shih Chi Liu, and Paul Herer; and to the panel: Richard Tucker, John Fisher, Daniel Halpin, Reed Nielsen, Boyd Paulson, Jr., George Watson, and Richard Wright. I would also like to extend our special thanks to David Hudson and John Montalvo of the Construction Industry Institute for their tireless work in producing and perfecting the camera-ready copy of the report. And, of course, we are most grateful of all to our Japanese hosts; without their generous and open hospitality, this study would not have been possible.

JTEC is now planning a new round of Japanese studies, starting with a study on display technology in Japan. Duane Shelton remains the principal investigator of the JTEC grants, responsible for technical issues and client liaison, and will be the Director of the World Technology Evaluation Center (WTEC). WTEC will be initiating JTEC-style studies of technology in Europe, and possibly other parts of the world, in the coming year, following our successful first experiment with applying the JTEC methodology to Europe in the JTEC Panel on European Nuclear Instrumentation and Controls Technology. That Panel will be issuing its final report in the next few weeks.

We also expect final reports in the coming months from the JTEC panels on x-ray lithography, bioprocess engineering, database systems, and machine translation. Please let me know if you have a particular interest in any of those forthcoming reports.

Sincerely yours,

Geoffrey M. Holdridge
Director

4501 North Charles Street
Baltimore, Maryland 21210-2699

h:\data\construc\rpttr.gmh (301) 323-1010, ext. 2876

FAX: (301) 532-5123
BITNET:SBG@LOYVAX



Japanese Technology Evaluation Center

JTEC

JTEC Panel Report on

Construction Technologies In Japan

R. L. Tucker, Chairman
J. W. Fisher
D. W. Halpin
R. Nielsen
B. C. Paulson, Jr.
G. H. Watson
R. N. Wright

June 1991

Coordinated by



Loyola College in Maryland
4501 North Charles Street
Baltimore, Maryland 21210-2699

JAPANESE TECHNOLOGY EVALUATION CENTER

- SPONSOR** The Japanese Technology Evaluation Center (JTEC) is operated for the Federal Government by Loyola College to provide assessments of Japanese research and development (R&D) in selected technologies. The National Science Foundation (NSF) is the lead support agency. Other sponsors include the Defense Advanced Research Projects Agency (DARPA), the National Aeronautics and Space Administration (NASA), the Department of Commerce (DOC), the Department of Energy (DOE), and the Office of Naval Research (ONR).
- PURPOSE** JTEC assessments contribute to more balanced technology transfer between Japan and the United States. The Japanese excel at acquisition and perfection of foreign technologies, but the U.S. has relatively little experience with this process. As the Japanese become leaders in research in targeted technologies, it is essential that the United States have access to the results. JTEC provides the essential first step in this process by alerting U.S. researchers to Japanese accomplishments. JTEC findings can also be helpful in formulating governmental research and trade policies.
- APPROACH** The assessments are performed by panels of about six U.S. technical experts in each area. Panel members are leading authorities in the field, technically active, and knowledgeable about Japanese and U.S. research programs. Each panelist spends about one month of effort reviewing literature, making assessments, and writing reports on a part-time basis over a twelve-month period. All recent panels have conducted extensive tours of Japanese laboratories. To provide a balanced perspective, panelists are selected from industry, academia, and government.
- ASSESSMENTS** The focus of the assessments is on the status and long-term direction of Japanese R&D efforts relative to those in the United States. Other important aspects include the evolution of the technology, key Japanese researchers and R&D organizations, and funding sources.
- REPORTS** The panel findings are presented to workshops where invited participants critique the preliminary results. Final reports are distributed by the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161 (703-487-4650). The panelists also present technical findings in papers and books. All results are unclassified and public.
- STAFF** The Loyola College JTEC staff members help select topics to be assessed, recruit experts as panelists, organize and coordinate panel activities, provide literature support, organize tours of Japanese labs, assist in the preparation of workshop presentations and in the preparation of reports, and provide general administrative support. Mr. Cecil Uyehara of Uyehara International Associates provided literature support and advance work for the panel.

Dr. Duane Shelton
Principal Investigator
Loyola College
Baltimore, MD 21210

Mr. Geoff Holdridge
Director
JTEC/Loyola College
Baltimore, MD 21210

Dr. George Gamota
Senior Advisor to JTEC
Mitre Corporation
Bedford, MA 01730

JTEC Panel on

CONSTRUCTION TECHNOLOGIES IN JAPAN

FINAL REPORT

June 1991

R. L. Tucker, Chairman

J. W. Fisher

D. W. Halpin

R. W. Nielsen

B. C. Paulson, Jr.

G. H. Watson

R. N. Wright

This document was sponsored by the National Science Foundation (NSF) under NSF Grant ECS-8922947, awarded the Japanese Technology Evaluation Center at Loyola College in Maryland. The views expressed herein are solely those of the authors and do not necessarily reflect those of the United States Government, the authors' parent institutions, or Loyola College.

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FOREWORD

This report is one in a series of reports prepared through the Japanese Technology Evaluation Center (JTEC), sponsored by the National Science Foundation (NSF) and administered by Loyola College in Maryland. The report describes research and development efforts ongoing in Japan in construction technologies.

Many U.S. organizations support substantial data gathering and analysis efforts directed at nations such as Japan, but often the results of these studies are not widely available. On the other hand, government and privately sponsored studies that are in the public domain tend to be "input" studies. That is, they provide enumeration of inputs to the research and development process, such as monetary expenditures, personnel data, and facilities, but do not provide an assessment of the quality or quantity of the outputs obtained. Studies of the outputs of the research and development process are more difficult to perform as they require a subjective analysis performed by individuals who are experts in the relevant technical fields. It takes experts in the technologies even to assemble expert panels to perform such assessments.

The National Science Foundation staff includes professionals with expertise over a wide range of technologies. These individuals provide the technical expertise needed to assemble panels of experts who can perform competent, unbiased, technical reviews of research and development activities. Further, a principal activity of the Foundation is the review and selection for funding of technical proposals. Thus, the Foundation has both experience and credibility in this process. The JTEC activity builds on this capability.

Specific technologies, such as telecommunications, biotechnology, and nuclear power, are selected for study by individuals in government agencies who are able to contribute to the funding of the study. A typical assessment is sponsored by two to four agencies. In cooperation with the sponsoring agencies, NSF selects a panel of experts who will conduct the study. Administrative oversight of the panel is provided by Loyola College in Maryland, which operates JTEC under an NSF grant.

Panelists are selected for their expertise in specific areas of technology and their broad knowledge of research and development in both the United States and Japan. Of great importance is the ability of the panelists to produce a comprehensive,

informed, and unbiased report. Most panelists have traveled frequently to Japan. Nonetheless, as part of the assessment, the panel as a whole travels to Japan to spend one full week visiting research and development sites and meeting with Japanese researchers. These trips have proven to be highly informative, and the panelists have been given broad access to both researchers and facilities. Upon completion of their trip, the panel conducts a one-day workshop to present its findings. Following the workshop, the panel completes a written report that is intended for widespread distribution.

Study results are distributed to the widest feasible audience. Representatives of the Japanese hosts and members of the media are invited to attend the workshops. Final reports are made available through the National Technical Information Service (NTIS). Further, publication of results is encouraged in the professional society journals and magazines, and articles have appeared in *Science*, *IEEE Spectrum*, *Chemical and Engineering News*, and others. Upon completion of the first six studies, the results were compiled into a book entitled *Gaining Ground*, co-authored by George Gamota and Wendy Frieman. More recently, additional distribution media are being tested, including videotapes.

Over the years, the assessment reports have found their way into the policy-making process of many agencies and organizations. A sizeable fraction of the reports are used by foreign governments and corporations. Indeed, the Japanese have used the reports to their advantage, as they provide an independent perspective of their research.

Although Japan has been the primary focus of this study activity, many other countries have traditions of excellence in science and technology. The methodology developed and applied to the study of research and development in Japan may be equally relevant to other countries, such as the leading industrial nations of Europe. In general, the United States can benefit from a better understanding of cutting edge research that is underway outside its borders. Improved awareness of international developments can significantly enhance the scope and effectiveness of international collaboration and can thus benefit all our international partners in collaborative research and development efforts.

Extra copies of this report can be ordered by contacting the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161, USA, phone (703) 487-4650.

George A. Hazelrigg
Paul J. Herer
National Science Foundation
Washington, D.C.

ACKNOWLEDGEMENTS

The authors would like to express appreciation to the many Japanese hosts for their cooperation and access to their researchers and facilities, which proved to be highly informative. All of the organizations visited were not only gracious hosts, but also freely provided information and attempted to answer all questions.

Particular thanks are appropriate for three Japanese engineers, who assisted in arranging many of the visits. Mr. Junichi Inoue helped to organize the visit to Nippon Steel. Mr. Toshiaki Fujimori of Shimizu Corporation met early with Panel and made many valuable suggestions for potential visits. Mr. Ken Minemasa of Shimizu assisted in many arrangements in Japan and provided much information and numerous contacts.

The panelists would also like to thank Bob Williams, Dr. Duane Shelton, and the JTEC staff for their assistance in helping organize the panel visit and preparing the final report. Mr. Cecil H. Uyehara not only handled most of the logistics, but also served as interpreter for many of the visits.

The authors would like to express further thanks and appreciation for the contributions of Dr. Ken P. Chong, Dr. Robert D. Hanson, and Dr. Shirley S. Tucker, who accompanied the Panel as observers and contributed significantly to the information gathering.

The preparation of the report for submission to the publisher was made easier by the assistance of David Hudson and John Montalvo, graduate students in civil engineering at The University of Texas at Austin.

Gratitude and appreciation is also expressed to the many others who informally contributed by passing on their personal insights and experiences to the panelists.

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EXECUTIVE SUMMARY

The purpose of this study is to evaluate the innovation and effectiveness of R&D in Japanese construction technologies. The JTEC panelists focused on three basic areas of interest: processes, materials, and systems. From within these broad areas the panelists examined R&D; materials; field operations; and automated equipment, building systems, and structural systems. They also examined management systems, safety, environmental technologies, and public/private interactions. Panel members gained information from review of existing literature and from visiting 29 sites in Japan. The sites visited include construction projects, housing manufacturers, government and private research facilities, universities, and professional societies. The appendices to the report contain a write-up of each site visit and a short biography of each panel member.

The Japanese Ministry of Construction (MOC), which has no U.S. equivalent, is a government agency that provides assistance to the industry as part of its mandate. Its efforts are complemented by the Ministry of International Trade and Industry (MITI) and two subsidiary organizations, the Building Research Institute (BRI), and the Public Works Research Institute (PWRI). MITI confines its construction focus to housing-related matters. The MOC establishes criteria for qualifying contractors to bid public works projects, promotes R&D through the BRI and PWRI, and maintains the national building code. The United States has no such common code; rather, many codes exist throughout the nation.

The Japanese construction industry builds approximately \$500 billion worth of domestic projects per year, slightly more than its U.S. counterpart. In terms of GNP, however, this represents about 18 percent versus 9 percent for the United States. Like the United States, Japan has about 500,000 contractors, but has fewer large contractors. The largest Japanese contractors concentrate on buildings and heavy construction, whereas their U.S. counterparts concentrate on industrial projects. Japan's less developed infrastructure may account for the different market emphasis; public utilities and highways currently serve only 42 percent of the population in Japan compared to 72 percent in the United States.

Japanese culture favors harmony and the long term, manifested by lifetime employment and long-term relationships with customers. A private contract is usually negotiated, while a government contract is awarded to the low bidder from a technologically prequalified group. Design-build contracting is common in private work, but design-then-build dominates public sector projects. Japanese construction companies are led by engineers and architects who are familiar with specific technology used on their projects. They, like their U.S. counterparts, are concerned about productivity and safety. To attack these problems, the large Japanese contractors conduct substantial research and development. They feel that the marketing, educational, and trouble-shooting benefits arising from their R&D capability are of equal importance to the actual technological developments produced.

Japan's strong construction R&D capability has received considerable publicity in the United States, yet substantial misunderstandings remain about the funding and organization of this research, the incentives that stimulate it, the type of work that is done, the focus and priorities, and the results. Of Japan's annual construction volume (\$500 billion), a gross amount of 0.51 percent is spent on construction R&D (compared with under 0.1 percent in the U.S. for comparable sectors). As a matter of national policy, the Japanese see continued and increased R&D investments as important to upgrading housing, renewing and expanding their public infrastructure, and to keeping their industrial capital base efficient and up-to-date. Industry, government, and universities for the most part work independently, yet there is a level of cooperation in setting goals and working on certain priority areas that seems to work well for their mutual benefit.

Of particular importance, Japanese construction companies have well-established, in-house research and development programs, generously funded mainly from their own internal sources, and including well-equipped laboratories, on a level that is almost absent in U.S. construction companies. Partly through the application of their research findings, they have moved ahead of their U.S. counterparts in many areas, including soft-ground tunneling, design and construction of intelligent buildings, deep foundation construction, construction robotics, long-span bridge construction, and in performing urban construction in a much less disruptive manner. In almost every area, they are doing more R&D and are thus likely to keep moving ahead more rapidly in the future.

Government laboratories have good and approximately equal capabilities for construction R&D in both countries, and are moving ahead at about the same rate. Only in universities does it appear that the United States has an advantage. In construction, Japanese universities seem isolated from the mainstream of industry and government R&D, and they have few if any counterparts to the NSF-funded engineering research centers and the industry-supported centers at leading universities in the United States. The R&D by construction materials and equipment suppliers might be judged about the same in the United States and Japan at present, but the past decade's losses in the supplier R&D research capability in the United States means that the Japanese are likely to start moving ahead even in areas where they are not ahead now.

Construction materials have a critical influence on the performance and cost of constructed facilities. In 1988, Japan's construction volume was \$445 billion, and the amount for construction materials was \$100 billion (calculated using 150 yen per dollar). Improved materials technologies may reduce first cost by providing a lower cost substitute for a conventional material or by reducing costs of installation or reducing time required for construction. Improved materials may reduce life cycle costs through longer service lives, reduced maintenance requirements or energy conservation. Improved materials may increase safety and reduce property losses through better resistance to fires, earthquakes, extreme winds, and other environmental hazards. Construction materials are important in international trade as well as for the domestic construction industry. In 1989, the United States had a trade deficit in non-lumber construction materials of \$1.9 billion in comparison to a 1981 trade surplus of \$744 million.

Japan's government, manufacturing industry, and engineering-construction industry laboratories are giving extensive, sustained, collaborative attention to the improvement of construction materials. Research and development findings elsewhere in the world are monitored carefully, and useful results are licensed in Japan. Government research activities are more extensive than those in U.S. government laboratories. Japanese manufacturing industry has increased R&D, while U.S. building materials manufacturers are abandoning product development research in order to cut current expenditures. Japanese engineering-construction firms have large-scale construction materials research efforts that are generally

unmatched by U.S. counterpart companies. University professors and researchers are collaborating in these efforts, but at a lesser scale than their U.S. counterparts.

Thus, Japan generally leads or matches the U.S. in implementation of state-of-the-art construction materials technology, and has growing leadership in research. Strong research and implementation activities by the Japanese steel industry give clear leadership in weldable and fire-resistant, high-strength structural steels. A major cooperative government, industry, and university program for high-performance concrete research is likely to give Japan leadership in this internationally significant area of construction technology.

Japanese companies have also invested heavily in developing automated equipment, although they have produced very few practical pieces to date. Much of their motivation to automate stems from their desire to improve the unsafe, dirty, and unsophisticated reputation construction has among workers. A poor safety record can be cause for an owner to exclude a contractor from bidding his projects for a period ranging from 30 days to several months. Nevertheless, very few young workers are entering construction, leaving companies with an aging work force. The companies believe that automating construction equipment will make construction safer and give it a more technical aura. Additionally, technological innovation can be used to help sell both existing customers and new prospects.

Despite their push toward automation of construction equipment, Japanese companies do not use computers as widely as U.S. companies for schedule or cost control, relying instead on manual methods for the most part. However, Japanese companies are actively exploring ways to transfer information from CAD models to field equipment, including manipulation of that information and data from the surrounding environment using artificial intelligence. The reduced incidence of claims in Japanese construction may partially explain the less frequent use of computers in project controls.

One reason for reduced claims is the long-term relationships between the owner and contractor and between the contractor and his subcontractors. Japanese prime contractors rarely perform the work with their own forces, but rather subcontract the work to others. However, the primes appear to be more actively involved with their subs than do their U.S. counterparts. Although work is normally scheduled for five 8-hour days per week, Saturday and other overtime work is common. Contractors often pay the additional overtime costs from their own pocket and trust that the owner will makeup their loss on a future project. Although cost receives less emphasis in Japanese construction, it is important. And space is at a premium. Prefabrication and "just in time" delivery are two techniques used to reduce cost and save space.

Improving Japan's infrastructure depends upon the efficient development and utilization of space. The Japanese seek new space by building up, building out, and building down. They are attacking the construction of office and apartment buildings from a new perspective: the building is a system and needs systems solutions. The concept of the intelligent building is key to this strategy.

Briefings at the Ministry of Construction emphasized that one of its key objectives for the '90s is to achieve "good-quality housing and infrastructure that suit the needs of the nation (Tazaki, 1990)." The boom in office building and home construction markets offers an excellent opportunity to improve the amenities of such space. In addition, it provides the opportunity to apply high-technology concepts to building construction so as to improve the working and living environment.

The quality of the buildings and support systems observed in Japan equals that of new buildings being constructed in the United States. Most of the systems observed are

adaptations or syntheses of existing technology. However, this is leading to a unique "fusion of technology." Emphasis on automation, robotics, and new structural as well as construction systems to support super high-rise buildings may lead to new breakthrough technologies in the building systems area by the year 2000.

A wide range of structural systems are being systematically developed with a focus on factory automation and the use of robots and intelligent tools. Both government and construction industry laboratories and engineering research and development staffs are involved with these efforts. Extensive use is made of CAD/CAM systems for design, manufacture, and construction of structural systems. Although the United States is ahead in R&D efforts in these areas, implementation is at least equal, or even ahead, in Japan.

The development and availability of thermomechanical process control (TMPC) steels in Japan place the Japanese well ahead of the United States in applying these special steels to structural systems. The Japanese experience indicates that these materials make steel structural systems more competitive for building and bridge applications. Concrete structural systems in Japan seem on a par with those in the United States for precast structural elements. In high-strength concrete for structures and high-rise construction, Japan appears to be lagging the United States.

Research and development efforts and trial implementation of active control damping systems for earthquake and wind resistance far exceed U.S. efforts in this area. This is a promising way to create more efficient structural systems for high-rise structures taller than those built today. Other passive control damping systems, such as base isolated structures and special dampers, are being actively studied with trial implementations underway.

As the material in the various chapters shows, the Japanese have one of the most advanced construction industries in the world today. Japan has long acknowledged the U.S. contribution to their technological and managerial practices. They have blended these practices into their culture, and the result is a robust construction industry that contributes significantly to the welfare of Japanese society. The U.S. construction industry may in turn find some of the directions pioneered and the lessons learned by Japanese companies welcome grist for its own mills.

CHAPTER 1

OVERVIEW OF STUDY

R. L. Tucker

PURPOSE AND SCOPE

This JTEC study of Japanese construction technologies examines specific technology developments, research funding and organization, and implementation. It attempts to compare the current state of construction technology in Japan with that in the United States — a formidable task in so complex a field. Panelists chose to focus on three basic areas within the field—processes, materials, and systems—and on ten related topics:

1. Automation
2. Materials
3. Structural Systems
4. Intelligent Structures, Materials, Systems
5. R&D Funding and Administration
6. Construction Field Operations
7. Construction Management Systems
8. Safety
9. Environmental Technologies
10. Public/Private Interactions.

In addition, aspects of public policy and industrial policy and management were included where important to a topic.

GENERAL GUIDELINES

Members of the JTEC panel were responsible for preparing the chapters contained in this report for their own areas of expertise. Panelists have made every attempt to adhere to the

guidelines established for JTEC panels. As stated in Ref. 1.1, panelists should...

- Assess and describe the current state of the art achieved in Japan in the topical area(s).
- Explicitly compare the state of the art in Japan with that in the United States.
- Extrapolate from the current state of the art the future technologies and applications that might result from the research discussed.
- Assess the impact and implications of Japanese research accomplishments (present and anticipated) for the United States. This should be done in an objective manner, without taking an advocacy position.

Panel members used existing literature along with information gathered from the various agencies in drafting the chapters for this report. In addition to the agencies' answers to the generalized list of questions, the different agencies provided the panelists with numerous reports, brochures, pamphlets, and other documents. Each panel member also used personal observations from the site visits along with his past experience and knowledge.

AGENCIES VISITED

The JTEC panelists visited and gathered information from eight different types of sources while touring the Japanese construction industry during the week of July 16-20, 1990:

- Government organizations
- Government research facilities
- Private research facilities
- Housing manufacturers
- Intelligent buildings
- Construction projects
- Universities
- Professional societies

Teams of three or four panel members each visited a total of twenty-nine sites (see Appendix A). Team members were chosen for their expertise in the major technology area(s) that typified each site or agency. Generalized lists of questions and panel schedules were sent to the sites and agencies prior to the visits in order to give our hosts an opportunity to plan for our visit and gather the information requested. Each site visit normally lasted half a day and was conducted in an informal atmosphere in order to facilitate the free flow of information.

LIMITATIONS OF STUDY

The JTEC panel members were aware of various constraints placed on the study due to time, distance, language, and culture barriers. Time constraints limited

- The amount of time the panelist had to spend planning the agency visits and actually analyze the information gathered (combination of other responsibilities and JTEC deadlines).
- The number of sites the panelists could actually visit, thus a great deal of the success and failure of this study hinged on proper site selection.

- The amount of time spent visiting a site, normally half a day, which in turn limits the time for questions and answers, personal observations, and ultimately reduces the amount of information and material that can be gathered.

The sheer distance between Japan and the United States also limited the study to one fact-finding visit. The physical separation of the team members both prior to and upon their return from the agency visits limited information sharing and insight swapping to sporadic oral and written correspondence.

Equally important, if not more so, were the language and cultural barriers between JTEC panelists and the Japanese hosts. Although normal conversing was straightforward, technical translations occasionally proved difficult.

The large size and fragmented nature of the Japanese construction industry, a characteristic shared with their U.S. counterpart, also served to limit assessing the breadth of industry practices and attitudes. As with the U.S. construction industry, such measurement would demand a much more exhaustive effort than time and resources permitted.

SUMMARY

Despite the difficulty of quickly examining and analyzing a complex industry far from home in a country having both a language and culture that differs from our own, the panelists believe they have provided a better understanding of similarities and differences in practices and philosophies between the Japanese and U.S. construction industries.

As the material in the following chapters shows, the Japanese have one of the most advanced construction industries in the world today. The U.S. construction industry may find some of the directions pioneered and the lessons learned by Japanese companies welcome grist for its own mills.

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CHAPTER 2

JAPANESE CONSTRUCTION INDUSTRY

R. L. Tucker

CONTEXT OF JAPANESE CONSTRUCTION

In order to fully understand and appreciate the intricacies and complexities of the Japanese construction industry, one must first understand something of Japan's historical and geographical constraints—Japan is an island nation that has relied upon its natural isolation to both protect it from enemies and to prevent "contamination" of its culture from outside influences. Japan's resistance to outside influences in its construction industry ended in 1868, the beginning of the Meiji Period, when Western architectural and construction techniques were eagerly welcomed. During this period, the Meiji government "pursued an aggressive policy of building administrative offices, railroads, stations, and other infrastructures as part of its effort to modernize Japan. At first, the government undertook the construction projects as a sort of self-appointed contractor, hiring foreign architects and managers, but as the volume of necessary construction work expanded, government contracts were given to private contractors" (Ref. 2.1). This increase in government contracts, combined with the Western influences, helped to spark the growth of the modern Japanese construction industry.

Until the 1950s, all planning, design, and construction management activities were conducted in-house by the owner's engineers, while the contractors concentrated on construction under the supervision of the owner's engineers. However, the economic growth which started in the 1960s produced a quantitative expansion of the construction industry. It became difficult for the owners' engineers to carry out all of the design, engineering, and construction management activities. Thus, contractors began to assume the construction management role and later to share a part of the design and engineering tasks. Such a transition was natural, since the Japanese contract system has traditionally been established on the basis of mutual reliance between owners and contractors. With increased responsibility for both design and construction, the contractors began to feed back the expertise of execution to the design process, with resulting improvements in cost and quality. As these benefits were recognized, owners began to award contracts on the basis of design and construction. Now, contractors are involved even in helping owners plan their projects (Ref. 2.2).

Japan comprises an area about the size of Montana, yet its shoreline is comparable to that of the continental United States. The topography of Japan is composed mostly of mountainous terrain. Because of this, 130 million people are forced to live in the approximately 30 percent that is habitable, with the result that Japan has the seventh largest concentration of population in the world. This shortage of habitable space led to the present building philosophy, which consists of the following four points:

- Build up
- Build out
- Build down
- Improve the quality of space

SIZE OF THE INDUSTRY

The Japanese domestic construction industry is large. At an annual volume of approximately \$500 billion, it is the largest of any nation. (Although the U.S. dollar volume is slightly smaller, the lower prices in the United States may translate to a larger volume in terms of physical facilities.) The Japanese construction industry represents about 18 percent of the gross national product, about twice the percentage for the U.S. construction industry.

The Japanese construction market is distributed slightly differently than that in the United States, as illustrated in Table 2.1. The distribution in construction effort is due in part to the heavy population density and geography of Japan. Thus, Japan's infrastructure, which includes the highway and expressway systems, housing standards and public sewage systems (public sewage systems serve only 42 percent of the Japanese population, compared with 72 percent for the U.S.), is comparatively underdeveloped in relation to Western standards. Thus, there is a growing demand for a "substantial elevation of the nation's infrastructure level, as a principal means to stimulate Japanese domestic demand and thus alleviate trade collisions with other countries" (Ref. 2.1, p. 5). This development of the infrastructure is also perceived as being the key to improving the "quality of life" of the Japanese people and the key to maintaining and improving the nation's manufacturing competitiveness. Although no definitive data were obtained, it was stated that the Japanese manufacturing industry expects to renew its facilities at a much faster rate than is common for the U.S. manufacturing industry.

The differences in distribution of construction volume between Japan and the United States are also reflected in the character of the construction firms. Whereas the total number of Japanese contractors exceeds 500,000 (about the same number as U.S. contractors), the largest Japanese firms focus on buildings and heavy construction; the largest American companies focus on industrial construction.

The size of the Japanese construction firms drops rapidly, with only 50 firms having annual volumes greater than \$70 million (in contrast to several hundred of that size in the United States). Indeed, most researchers reference the "Big Six"—Shimizu, Kajima, Taisei, Ohbayashi, Takenaka, and Kumagai—when making comparisons between Japan and other nations. Approximately 30 Japanese companies have formed research and development institutes, although only about 10, including the "Big Six," have institutes with more than 100 researchers.

Table 2.1
Construction Market Distribution

	JAPAN	USA
HOUSING	30%	40%
BUILDING	30%	25%
INDUSTRIAL	10%	25%
HEAVY	30%	10%

The Japanese construction industry faces many problems similar to those in the United States and other industrialized nations. The construction work force is aging, and significant worker shortages are predicted. A shortage of engineers is also a current and growing problem. Construction safety is of great concern and is gaining increasing attention, as is the entire issue of construction productivity.

THE ROLE OF GOVERNMENT

The Japanese construction industry, unlike that of the United States, has a great amount of public and private interaction. Various governmental organizations, such as the Ministry of Construction (MOC) and the Ministry of International Trade and Industry (MITI), provide assistance to the Japanese industry. The Building Research Institute (BRI) and the Public Works Research Institute (PWRI), which are subsidiary organizations of MOC, collaborate with industry on research.

The Ministry of Construction has no counterpart in the United States. It is a large organization with many divisions. It not only oversees the nation's public works projects, but also develops the national building code. MOC projects the nation's construction volume and establishes long-range plans for both the public and private sectors. It performs R&D, principally through its two subsidiary laboratories, BRI and PWRI. It also encourages construction research by the private sector and uses such research as a criterion for bidding on government projects. It has a role in approving new technology and issues certificates of approval for construction innovations.

The role of MITI is similar to that of the Ministry of Construction, except that MITI is larger and has a broader scope. MITI confines its construction industry activities to housing. It plays an aggressive role in research and innovation to develop affordable housing as well as improved materials and energy efficiency.

Japan has a national building code (Building Law) which is developed and amended by the Ministry of Construction. (No nationwide building code exists in the United States, although a growing number of states have statewide building codes and most building codes of state and local governments are based on one of three model building codes [Ref. 2.3].) Japan also has an organization, The Building Center of Japan (BCJ), whose mission is to give fair appraisal of new technology and to review the design of any construction 60 meters high or higher. The BCJ also provides a vehicle for research for government and private companies and acts as the center of information of construction technology. The BCJ has a staff of slightly less than 100 persons, with several standing committees that perform appraisals of Japanese construction projects. Although funding is not received directly from the government, the BCJ works closely with the Ministry of Construction.

Government involvement in construction projects is significant, particularly in the planning and approval stages. It appears that the permitting process is longer than in the United States and often requires several years. However, construction is viewed as vital to the nation's success and thus is given strong government encouragement at every level. In that regard, the Japanese government's role in the construction industry may be referred to as that of "coach," in contrast to the role of the U.S. government as "referee." Innovation is encouraged, and use of proprietary techniques is considered healthy. An atmosphere of partnership between government and private firms is manifested.

CONTRACTUAL PRACTICES

The Japanese construction industry is extremely competitive, but in a different manner than the U.S. competitiveness that is based almost entirely on lowest first cost. The Japanese competitiveness is based on technology, quality, and customer satisfaction. The impact of the emphasis upon competitive issues other than first cost, combined with other Japanese cultural characteristics, results in two significant business practices.

First, the major Japanese firms are very technology-oriented. In contrast to many U.S. firms, where many upper executives have business and legal backgrounds, the Japanese firms are led by engineers and architects. Even more, the executives are active in their professional societies, for example the president of Kajima Corporation was recently president of the Japanese Society of Civil Engineers). These executives, as well as other personnel, are familiar with specific technological innovations emerging from their laboratories as well as technology applications to their specific projects.

Second, long-term relationships are developed and nurtured. Contractors have repeat clients as well as suppliers and subcontractors. Such relationships often span centuries. A lifetime employment mentality exists between firms and their employees. A general atmosphere of "partnering" exists throughout the industry. Most private contracts are negotiated, and even government projects are awarded based upon bid lists of selected contractors who have demonstrated their technical competence.

The net effects of the "total quality, long-term orientation" are significant. Most apparent is the creation of a nonadversarial environment at the project level. Representatives of the client, general contractor, designers, suppliers, and sub-contractors appear noncompetitive and mutually supportive. Technological innovations are encouraged, but with strong concern for quality and safety impacts. Much more project attention is given to planning, design, and construction matters than to business matters. Relatively less attention is given to cost control than in the United States. The role of consultants is small.

THE ROLE OF R&D

The most striking characteristic of the Japanese construction industry is its attitude toward research and development. Research is considered vital to a firm's long-term growth and success. The Japanese construction industry as a whole invests an average of 0.5 percent of its gross sales (approximately \$2.5 billion per year) in R&D; the larger companies invest at least 1.0 percent of their gross sales in R&D. The percentage is apparently rising, as shown in Figure 2.1. Many large firms have R&D budgets larger than their net profits.

The R&D emphasis is fostered by a number of factors. First, the long-term business culture encourages R&D as an investment that will ensure long-term growth, even at the expense of short-term profits. Second, R&D allows development of innovative technologies and marketable products for a changing world economy. It provides a major marketing tool for the highly competitive Japanese construction environment. Construction firms seek suggestions and guidance from their long-term clients for R&D activities and will often have jointly funded R&D projects (Ref. 2.2). For some large public works projects, a criterion for the select bidders list may be the research history of a company in technology related to that project.

GROSS DOMESTIC CONSTRUCTION INVESTMENT

($\times 10^3$ Bil. yen)

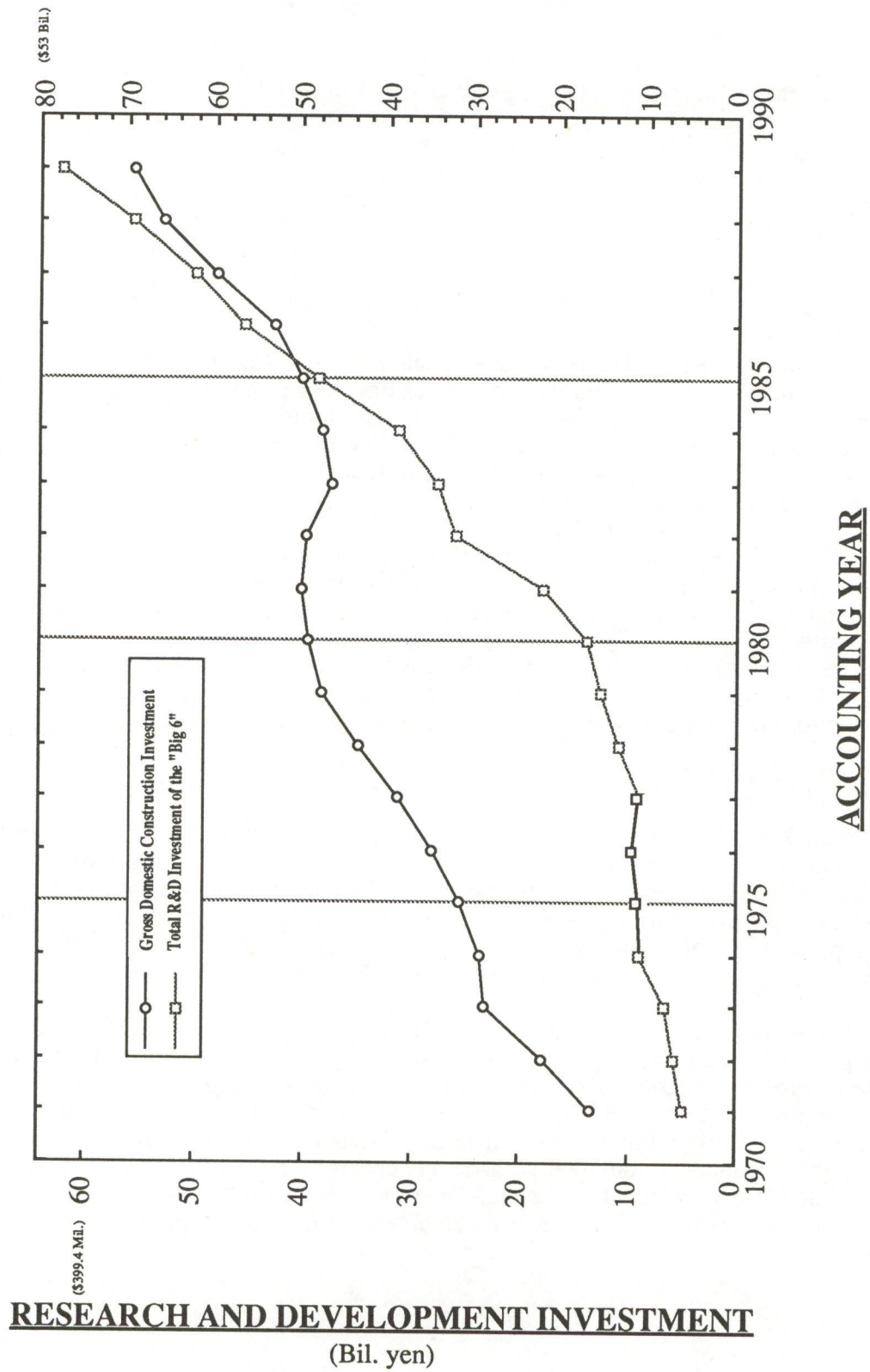


Figure 2.1. RELATIVE R&D INVESTMENT TRENDS OF JAPANESE FIRMS

The short-term benefits of R&D are also significant. Engineers and technical personnel are rotated through the research and technology centers to enhance their careers. Perhaps more significant is the trouble-shooting capability provided by the researchers. Problems on-site can be immediately addressed by experienced and knowledgeable personnel (Ref. 2.2).

The R&D objectives for a typical large Japanese company are given in Table 2.2. The largest portion relates to marketing, expressed as product innovation. Significant research involves specific projects that are in advanced planning stages and exploration of various technical options and innovations in the final product. Such research includes new materials, designs, and configurations. A second objective is that of improving the project delivery process and relates to both design and construction methodology. Educational and trouble-shooting benefits, although not quantified, are considered major.

Research institutes of the largest companies are campus-like settings involving numerous buildings and specialized facilities. The research staffs number in the hundreds, with specialized disciplines as shown in Table 2.3. The distribution of disciplines generally reflects the nature of the work mix in a company's current or anticipated future volume. Although the largest numbers of researchers have historically had architectural engineering and civil engineering backgrounds, the numbers with chemical engineering, humanities, and social science backgrounds is growing with an increasing awareness of environmental and people issues.

R&D is considered a vital marketing and business resource by the Japanese companies. As such, immediate research results are not expected, nor is duplication of efforts with competitors of great concern. The marketing, educational, and trouble-shooting benefits of the research efforts are considered of equal importance to the actual technology developments resulting from the research.

MAJOR JAPANESE AND U.S. DIFFERENCES

There are many similarities between the Japanese and U.S. construction industries. Specific activities in a design office or on a construction site do not differ significantly. The major differences are more subtle, and result from cultural and business practices.

The first major difference is the long-range view of Japanese companies. The long-range orientation places more emphasis on matters that will ensure a company's future stability and growth than on its short-term profits. This orientation has implications for all company activities.

The second difference is the Japanese emphasis on total quality rather than first cost. The long-term relationships are based upon mutual interdependencies and client satisfaction. Clients, while cost-conscious, are willing to pay appropriate fees to receive high-quality projects.

The third major difference is the partnering, or nonadversarial, environment that exists on projects. The presence of long-term relationships among project participants, coupled with an emphasis on total quality rather than cost, provides a focus for project success and allows a teamwork atmosphere to develop.

Table 2.2**R&D OBJECTIVES**

PRODUCT INNOVATION	50-60%
PROCESS INNOVATION	20-30%
MARKETING	10-20%
EDUCATION	
TROUBLE-SHOOTING	

Table 2.3

TYPICAL R&D STAFF

ARCHITECTURAL ENGINEERING	30%
CIVIL ENGINEERING	20%
PLANNING, INDUSTRIAL MANAGEMENT	20%
MECHANICAL ENGINEERING	10%
ELECTRICAL & COMPUTER ENGINEERING	10%
CHEMICAL ENGINEERING	5%
HUMANITIES & OTHERS	5%

The technology orientation of the Japanese firms, in contrast to the business orientation of U.S. firms, constitutes the fourth major difference. The technology orientation undoubtedly results from the cultural, long-term, and Japanese business practices which place a premium on project performance and total quality.

The most striking difference between the Japanese and U.S. construction industry is the Japanese emphasis upon research and development. Japanese companies view R&D as a vital part of their company activities, and its impacts affect all company personnel. The R&D emphasis as a way of life within a company reflects all of the other differences.

GENERAL TECHNOLOGY STATUS

Table 2.4 compares status and trends in R&D and implementation in the U.S. and Japanese construction industries in four major functional areas: facility design, design technology, construction technology, and management systems.

The Japanese construction industry is currently ahead of that of the U.S. in research and development of facilities design and is gaining ground in this area. The U.S. and Japanese industries are currently on par in implementation of facility design, but the Japanese appear to be gaining ground.

In the area of design technology, the United States is currently ahead of Japan in both R&D and implementation; however, Japan is gaining ground in this area.

Japan is currently ahead of the United States in both the R&D and implementation of construction technology and it is gaining ground.

The U.S. construction industry is currently ahead of the Japanese industry in both the R&D and implementation of management systems. The Japanese are gaining ground in implementation of management systems, but are holding constant in the R&D trend compared to the United States.

Table 2.5 illustrates the U.S. and Japanese construction industries in four major disciplines (architectural, civil, mechanical, and electrical), showing the current status and trend of R&D and implementation in these areas.

The Japanese construction industry is both currently ahead and gaining ground on the United States in research and development in the architectural and civil disciplines. Implementation within the architectural discipline is currently even, and the trend is holding constant. However, the Japanese are ahead of and gaining ground on the U.S. in the implementation of R&D in civil areas.

Research and development in the mechanical area is currently even; however, the Japanese construction industry is gaining ground. Although the United States is currently ahead of the Japanese in implementation, the Japanese are gaining ground.

The U.S. construction industry is currently ahead of the Japanese in both R&D and implementation in the electrical area. The trend in the Japanese construction industry is holding constant in both R&D and implementation.

Table 2.4

JAPAN / U.S.

FUNCTIONAL COMPARISON

ITEM	R&D		IMPLEMENTATION	
	STATUS	TREND	STATUS	TREND
FACILITY DESIGN	+	↗	O	↗
DESIGN TECHNOLOGY	-	↗	-	↗
CONSTRUCTION TECHNOLOGY	+	↗	+	↗
MANAGEMENT SYSTEMS	-	→	-	↗

Coding System			
Japan Compared to the United States			
Status		Trend	
<	Far Behind	↑	Pulling Ahead Strongly
-	Behind	↗	Gaining Ground
O	Even	→	Holding Constant
+	Ahead	↘	Falling Behind
>	Far Ahead	↓	Losing Quickly

Table 2.5

JAPAN / U.S.

DISCIPLINE COMPARISON

ITEM	R&D		IMPLEMENTATION	
	STATUS	TREND	STATUS	TREND
ARCHITECTURAL	+	↗	O	→
CIVIL	+	↗	+	↗
MECHANICAL	O	↗	-	↗
ELECTRICAL	-	→	-	→

Coding System			
Japan Compared to the United States			
Status		Trend	
<	Far Behind	↑	Pulling Ahead Strongly
-	Behind	↗	Gaining Ground
O	Even	→	Holding Constant
+	Ahead	↘	Falling Behind
>	Far Ahead	↓	Losing Quickly

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CHAPTER 3

JAPANESE RESEARCH AND DEVELOPMENT

B. C. Paulson, Jr.

INTRODUCTION

From the beginning of its written history, Japan has had a long and successful pattern of assimilating ideas from foreign lands, modifying and adapting them for its own needs, and advancing their development far beyond what the foreign originators had accomplished. These trends were accelerated in the Meiji restoration of 1868, at which time Japan turned abruptly from centuries of feudalism to emerge as a developing power among industrialized nations. In construction, Japan has evolved to technological leadership in many areas, and now has much to offer others (Refs. 3.1, 3.2, & 3.3).

In particular, Japan's strong construction R&D capability has received considerable publicity in the United States, yet substantial misunderstandings remain about the funding and organization of this research, the incentives that stimulate it, the type of work that is done, the focus and priorities, and the results. The JTEC panel visited eight company-based research institutes, two government research laboratories, and two universities in an effort to get a better picture. Panel members also discussed research and development policies and mechanisms in their visits to the offices of businesses, government agencies, and professional organizations, and looked carefully for results being applied during visits to construction project sites.

Given that R&D in Japan's construction industry is well established and integrated with the operations of the major companies (in marked contrast to its near absence in comparable U.S. companies) the panel members were not just interested in a technical assessment of the work going on, but also in learning what has stimulated this capability in companies that otherwise have more similarities than differences with their U.S. counterparts. This chapter will particularly focus on these types of issues, and leave all but the most general technical comparisons to the chapters that follow.

DISCUSSION OF TOPIC

Japan's construction industry accounts for about 18 percent of its GNP (compared to about 9 percent in the United States), which is high for an industrialized nation. A gross amount of 0.51 percent is spent on construction R&D (compared to under 0.1 percent in the United States for comparable sectors), which Japanese consider low relative to the R&D figure of 2.59 percent of gross for their industry as a whole. As a matter of national policy, the Japanese see continued and increased R&D investments as important to upgrading housing, renewing and expanding their public infrastructure, and to keeping their industrial capital base efficient and up-to-date. Industry, government, and universities for the most part work independently, yet there is a level of cooperation in setting goals and working on certain priority areas that seems to work well for their mutual benefit.

This section will concentrate first on industry-based R&D, and then comment more briefly on the role of government laboratories and universities.

Industry-Based R&D

Modern industry-based construction research and development patterns in Japan came about shortly after the end of World War II. Forty percent of its urban structures had been wasted by bombings and fires; industry had been crushed. For what was left of the construction industry, there was a massive rebuilding job ahead, and it desperately needed to advance its technology and procedures to incorporate the best of what was available in the world. In the early postwar years, a few of the largest construction companies established research facilities, and most of the major companies followed this pattern.

For the first decade or so, the research institutes lacked laboratories and concentrated instead on studying Japan's reconstruction needs and analyzing available technologies, both domestic and foreign, that could most effectively be assimilated and applied to the reconstruction effort. The experimental R&D laboratories, with their professional research staffs, began emerging in the mid-1950s and have since grown and become an integral part of the way the large companies conduct their business. Today, over 25 of the largest engineering and construction companies maintain laboratories specifically designated for construction research and development. Although 25 is small compared to the half million licensed contractors in Japan, their share of the market is disproportionately large (the top six companies have about 10 percent of the market). The influence of their research and the resulting government standards permeate down to the smaller firms, raising the overall state of construction technology in Japan.

The laboratories' staff sizes range from small ones with 10 - 20 research professionals, through several in the 100 - 200 range on up to a few with 300 or more people. Company R&D budgets range from under \$1 million to over \$80 million per year, and typically amount to 0.5% to 1.0% of revenues. A summary comparing R&D expenditures to overall revenues for the ten largest contractors is given in Table 3.1 (Ref. 3.4). The physical facilities of the industrial laboratories are often larger and better equipped than the largest university or government-based construction-oriented laboratories in the United States or elsewhere, and they deal with a broad range of disciplines.

Table 3.1
R&D vs Revenue for the Top 10 Contractors
(data for 1987)

CONTRACTOR	R&D (bill. ¥)	REVENUE (bill. ¥)
Shimizu	12.2	970
Taisei	7.0	950
Kajima	8.6	860
Takenaka	8.0	810
Ohbayashi	6.5	750
Kumagai	2.5	700
Fujita	1.7	450
Hazama	2.4	370
Toda	1.0	370
Maeda	1.3	320

Types of Research

Research activities of the Ohbayashi Technical Research Institute are typical of the larger institutes (Refs. 3.5 and 3.6):

- **CIVIL ENGINEERING (5 groups):** Geotechnical engineering; structural materials; tunneling technologies; offshore structures; observational methods
- **BUILDING CONSTRUCTION ENGINEERING (3 groups):** Building technologies, rationalized systems, building methods, construction robotics, structural materials, non-structural materials
- **STRUCTURAL ENGINEERING (3 groups):** Strength, deformation and design for buildings, nuclear plants, silos, LNG tanks, offshore structures, base-isolated structures, membrane structures, underground diaphragm walls, and foundations; earthquake engineering
- **SOIL FOUNDATION ENGINEERING:** Structures for deep foundations (including bearing capacity, settlement, liquefaction); earth retaining structures; fluidities of bulk solids
- **VIBRATION ENGINEERING:** Ground-structure interactions; vibration hazard prevention; machinery foundations; micro-vibration elimination for super-LSI factories
- **ENVIRONMENTAL ENGINEERING:** Facilities and environment impact on buildings; solar energy and heat storage; energy conservation; rainwater utilization; clean rooms; animal experimental facilities
- **BIO-ENVIRONMENTAL ENGINEERING:** Wastewater and air quality analysis; water treatment; bio-engineering; hazardous waste treatment and removal
- **ACOUSTICAL ENGINEERING:** Acoustical design for studios, concert halls, chapels, etc.; noise prediction and countermeasures; sound insulation systems
- **CHEMICAL ENGINEERING:** Materials properties and control of slurry walls; physico-chemical behavior and stabilization of soil and rock; metal corrosion, concrete deterioration, chemical pollution; new materials
- **COMPUTATIONAL ENGINEERING:** Computational engineering with supercomputer; static and dynamic response of structures, foundations, etc.; simulation analyses of offshore structures, fluid dynamics and acoustics

- **FLUID ENGINEERING:** Wind engineering analysis for buildings and bridges; hydrodynamic loadings and motions for large marine structures; marine environmental evaluation of surrounding field of marine structures
- **CONSULTING:** A new department to focus on inquiries from field construction sites, design operations, and external clients. Assembles expertise and coordinates response from Institute staff

This represents a very wide cross-section of disciplines, and is even broader than the construction-related activities that one would find across all the departments in a school of engineering (not just civil or architectural engineering) in a major U.S. university. A similar breakdown and range of activities can be found in most of the large contractor and government construction research laboratories in Japan.

Facilities

The construction industry's research activities are supported by sophisticated laboratory equipment and even full-scale buildings designed as advanced prototypes to demonstrate new technologies such as energy conservation and earthquake resistance. Typical facilities include

- Fully equipped geotechnical laboratories with computers for the control and monitoring of large-scale experiments, including dynamic testing of foundations, experimental tunnel bores, etc.
- Large tension and compression machines with massive reaction floors and abutment walls for both static and dynamic testing of large-scale and even full-scale models of structures and components
- Large (5-meters or more) shake tables for computer-controlled simulation of earthquake loading on structures
- Computer-controlled wind tunnels for experimental studies of bridge aerodynamics, smokestack diffusion, and microclimate analysis of altered wind patterns around urban building developments
- Large soundproof rooms for testing acoustical materials and designs for highway, railway, and industrial noise suppression, as well as more conventional architectural applications such as concert halls and auditoriums
- Solar energy systems for hot water space heating and cooling, as well as thermal analysis of various types of exterior materials for buildings
- Environmental simulation chambers where even full-size prototypes of houses can be subjected repetitively to artificial rain and snow storms and intense heat and cold to test the effectiveness and durability of various building materials and systems

- Facilities for developing and testing electrical and mechanical systems, especially for building lighting, heating, and air conditioning, with special emphasis on the so-called "intelligent buildings" that are fully implemented in various prototypes used as offices or laboratory buildings (Ref. 3.7)
- Materials laboratories for plain and reinforced concrete, masonry, soil grout compounds, etc.
- Hydraulics laboratories, with space for modeling dams, river channels, and coastal and offshore marine structures
- Supercomputers to support advanced analytical modeling, simulations, and computational mechanics
- Biochemical laboratories, with environmentally isolated rooms, electron microscopes, mass spectrometers, and related equipment for studies of both materials chemistry and pollution control
- Fire testing laboratories where not only material samples and building components can be tested, but full-scale houses can be instrumented and burned under careful study
- A prototype base-isolated building that has already demonstrated the developer's base-isolation system in a 1987 magnitude 6.7 earthquake by damping the vibrations to less than 25 percent of those felt in nearby buildings (Ref. 3.8)
- Prototype clean rooms designed for less than 1 particle of contaminants per cubic foot
- Robotics facilities (sometimes called "mechatronic development" laboratories), where new types of robots are being developed for a variety of construction applications

These physical facilities are staffed by researchers selected from the best graduates of the top universities. Most have advanced degrees, including many with doctorates from Japanese and foreign universities. They come from a broad range of scientific and engineering disciplines, and they engage in independent research and publication much like researchers in universities and in the advanced laboratories of other industries.

Funding and Expenditures

There are many misconceptions about the sources of funds (many Americans assume major government subsidies or tax benefits) and the nature of the research expenditures by the major company research laboratories (many assume that they are mainly focused on applied problem solving). As an illustration of research funding and allocation in the Japanese construction industry, the facts at Ohbayashi are shown in Table 3.2 (Ref. 3.9).

Regarding the sources of funds, it is typical that they come mostly from internal sources. There is very little in the way of direct government funding, and indeed the restrictions that come with government funding seem to make it unattractive.

Table 3.2
Source of Funds & Allocation
by Type of Research at Ohbayashi

SOURCE OF FUNDS	
Support From Company Overhead	89%
Fees From In-House Clients	6%
Fees From Outside Clients	5%
Government Subsidies	<1%

ALLOCATION BY TYPE OF RESEARCH	
Lab's Self-Proposed Projects	72%
In-House Client-Sponsored R&D	16%
Outside Client-Sponsored R&D	12%

The lab-proposed projects are a mixture of applied and basic research similar to that conducted in U.S. universities. The researchers do not appear to be hard-pressed for practical short-term results, which seems consistent with the longer-term view held by Japanese companies. In other cases, there is a definite push in a certain area, and this work will often be done in cooperation with other parts of the company's organization. For example, some recent robotics and automation efforts have been guided by corporate management's concern about the projected declines in Japan's skilled construction work force, and the laboratory researchers are just part of the resources that have been focused on finding solutions.

Client-sponsored R&D can range from consulting for solutions to specific problems to participation in a client-coordinated effort that has components in several contractor laboratories. An example of the latter was the Japan Gas Company's effort to advance technologies for the construction of deep tanks to store liquified petroleum gas (LPG), which had elements dealing with soil mechanics of deep excavations, concrete behavior at cold temperatures, and the mechanical and electrical systems for handling LPG (Ref. 3.10). Several contractors tackled different aspects of this problem. Spin-offs have since been applied to deep excavations for many different applications, including the Akashi Kaikyo Bridge anchorage that we visited on our trip (Refs. 3.11, 3.12, 3.13).

Organizational Context

The research institutes that we visited typically are administered under the technology divisions of their parent companies, which, in parallel with the major operating divisions, report directly to the company presidents. While the research institutes are certainly the locus of basic research and much of the companies' applied research, they still typically account for only about half of their companies' annual R&D spending. Other major efforts take place in technology departments under the operating divisions (perhaps 15 percent), in development groups within the engineering divisions (2 percent), in project-specific R&D groups that draw from several departments and divisions (say 20 - 35 percent), and others such as the machinery department and the materials department (perhaps 5 - 10 percent), which in turn may collaborate with manufacturers on building prototypes and products based on the R&D of the other types of groups.

The institutes enjoy high visibility and support from senior management, and the research institute director is usually also a director of the company. Top managers are usually well informed about their companies' research activities, and seem to anticipate incorporating research results into company operations.

Overall guidance is normally provided by a high-level policy committee drawn from top managers in various company divisions, and also by several technical committees in the various engineering disciplines that bring together researchers and experienced practitioners. A typical organizational diagram is shown in Figure 3.1. Through a somewhat involved process, proposals for desired research activities are submitted from various operating divisions of the company and also from the researchers themselves. The proposals are considered by the various technical committees and may receive recommendations, endorsements, and revisions. The real priority and budget decisions, however, appear to be made in the policy committee, which might meet formally only twice a year. The policy committee also considers proposals for sponsored research from outside clients. These procedures lead to plans for the year ahead for the actual allocation of resources, and extend out to a five-year horizon and beyond for planning and priorities. While there is considerable long-term stability and security for laboratory employees, the divisions within the laboratories evolve and change with the times and do not continue on obsolete paths of research simply because they are interested in an area and are already in place.

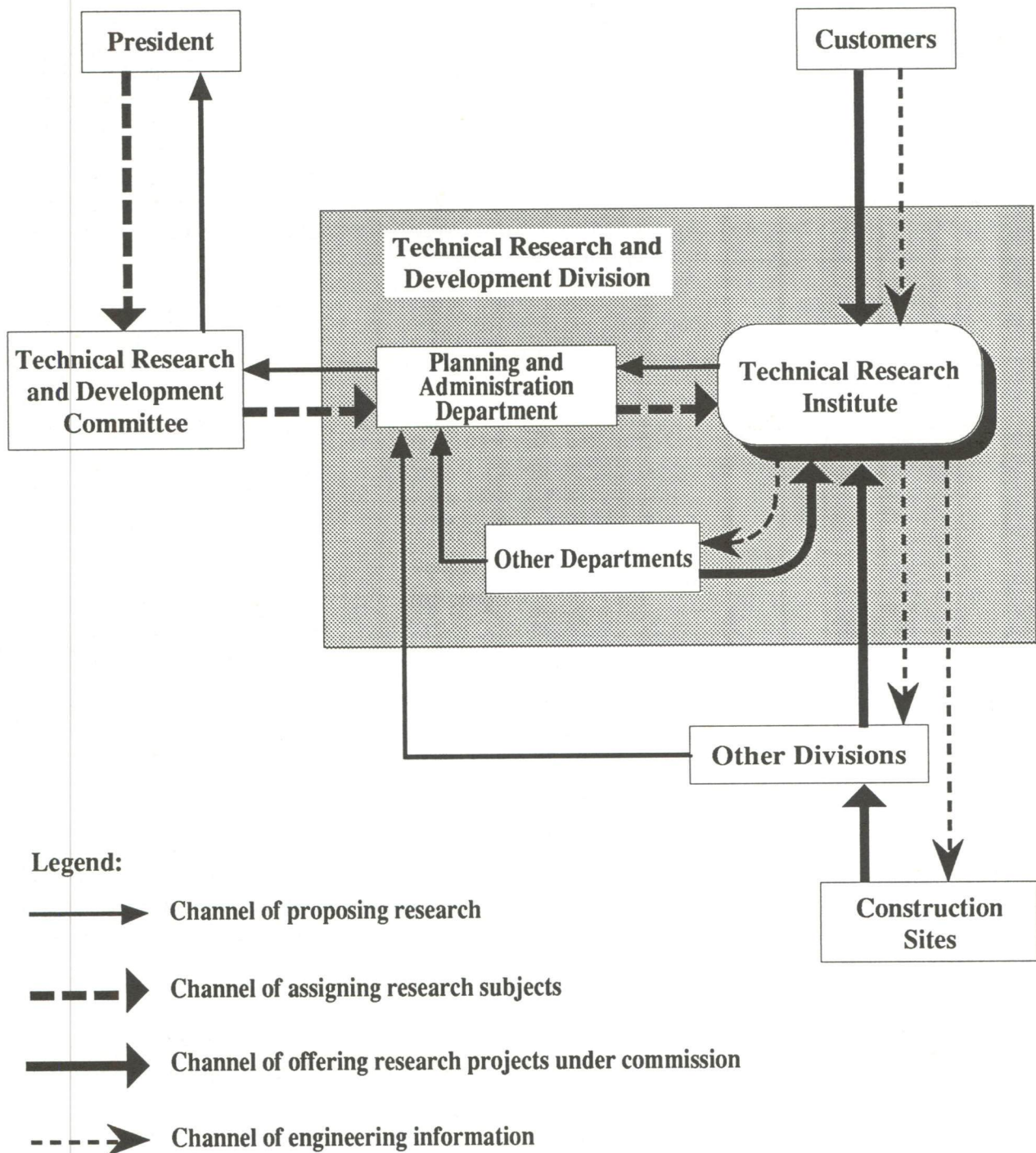


Figure 3.1. Organization of R&D in a Typical Japanese Construction Company

Incentives

There are many incentives that drive industry investments in R&D. To some extent these relate to the favorable publicity that results from technological advances, and this publicity has been recently extended with the videotapes that seem to accompany Japanese speakers wherever they go. It also appears that the possession of an appropriate in-house capability is a major criterion that qualifies a contractor to bid on government projects above a certain magnitude, but it was not clear whether this requirement was explicit or implied, since all of the major contractors have this capability. At times there have also been tax incentives, but these do not appear to have been the driving force. Rather, the main incentives result from the competitive technical edge given to a company by possessing and even patenting or licensing technologies for more productive, economical, or effective construction designs and procedures. New methods and ways of building different kinds of structures can also give an edge in marketing where clients themselves are moving into new areas. The laboratories also serve to develop quantitative data to substantiate new designs to meet Japan's strict building codes and also to document claims and come up with economical solutions to field problems.

More fundamental incentives relate to Japan's geography and social environment. It is a mountainous country with only 20 percent of the land suitable for agriculture. Good building sites are increasingly scarce, so construction technology must adapt to more difficult conditions. Earthquakes, typhoons, and other natural forces place similar demands on construction technology.

The large population living on the available land also places strict social and political restrictions on the builders. Advanced construction methods and procedures have in part been stimulated by the need for extra safety and environmental sensitivity, particularly to reduce the disruption caused by construction in urban areas and in coastal and marine environments. Much of the research that one finds in the laboratories relates to these limitations in one way or another.

Government Research Laboratories

In many ways, the government laboratories are similar to those found in industry, but several of their testing machines are bigger. The Public Works Research Institute (PWRI) and the Building Research Institute (BRI) at Tsukuba are the two largest. They are administered by the Ministry of Construction (MOC). The Ministry of Transportation (MOT) and the Ministry of International Trade and Industry (MITI) also have a role in construction R&D, but their facilities were not on the JTEC tour.

As an overall strategy, MOC specifies eight main components to its R&D system in a March 1990 report titled "Outline of the Various Systems Concerning Construction Technology R&D" (Refs. 3.14, 3.15):

1. Comprehensive technology development projects
2. Cooperative research, governmental and private
3. Cooperative development among local offices
4. Construction technology assessment
5. Assessment and authorization of private construction technology

6. Technology utilization pilot projects
7. Invitations to outside researchers
8. Japan Development Bank financing

Projects in the first category try to focus resources on major nationwide problem areas. There are about two new initiatives per year and they typically last four years and seek involvement of universities, industry, and professional groups. Recent and current examples include

- a. Development of construction technology for ocean space in coastal areas (1986-90) (e.g., see Ref. 3.16)
- b. Development of new wooden housing construction technology (1986-90)
- c. Development of technology for the utilization of underground space (1987-91)
- d. Development of disaster information systems (1987-91)
- e. Development of improved housing for the elderly (1987-91)
- f. Development and application of new materials for construction (1988-92)
- g. Development of superlight and superhigh-rise reinforced concrete building technology (1988-92)
- h. Development of new construction method technology (e.g., prefabrication) (1990-94)

Projects in the second category are more problem-focused and involve cooperative efforts with industry and professional groups. They typically last two to three years. Recent and current examples include

- a. Development of a control system for small bores underground for pipes, cables, etc., to minimize the disruption of surface trenching in built-up areas (1988-90)
- b. Development of technology to apply satellite survey data (e.g., GPS) (1988-90)
- c. Development of structural systems for highway bridges to reduce seismic behavior (1989-91)
- d. Development of substitutes for asbestos in buildings, and improvement of procedures to remove existing asbestos (1989-91)

- e. Development of practical technology for seismic control of buildings (1990-92)
- f. Development of diagnostic system for failures of building facilities (1990-92)

The projects in the third category involve regional offices, tend to be even more developmental and problem-focused, often on problems of local interest, such as improving snow removal or control of shoreline erosion.

Efforts in category 4, construction technology assessment, tend to be internal research evaluations of technology that has been developed in the private sector. Several of the recent topics seem to be focused on better measurement and testing systems, and some are on control systems. Results of the evaluations are made available to the public.

Category 5, assessment of private technology, involves nine approved associations (e.g., Japan Architectural Research Center, Japan Construction Mechanization Association, etc.) to help evaluate new materials, products, or methods proposed by suppliers, manufacturers, or contractors.

Pilot projects (category 6) are under the direct control of MOC to examine the adoptability, efficiency, safety, and economy of new technology. Individual tests are conducted in the field by various regions of the MOC. There were over 150 such tests in the last two years.

The researcher invitation system (category 7) provides a means to bring in over 100 researchers from other government institutes, universities, and private organizations to work in the MOC facilities each year. They participate in the research and testing activities of the MOC research laboratories, and return to their parent organizations with deeper knowledge about their areas of technology, thus fostering effective dissemination.

The Japan Development Bank financing projects (category 8) seem to involve small amounts (budgeted at \$35 million last year) of seed "investments" (presumably to small, undercapitalized groups) and larger amounts of loans (budgeted at \$535 million last year) for up to 50 percent of a new development effort's costs (at 5.4 percent for 25 years in early 1990) to further support the development of promising new construction technologies.

The PWRI and BRI have modern, large-scale facilities dating from their relocation to Tsukuba in the late 1970s, and some of their test facilities are even larger than those of the general contractors. Also, given the larger test equipment in the government labs, researchers can come from industry to run at full scale experiments that might have run at one-half or one-third scale in their company laboratories. However, the government labs seem to have a more difficult time keeping their instrumentation and equipment up-to-date once it has been built.

While their laboratory activities are in many ways similar to those in industry, the public agencies also have a broader role. For example, each year the Ministry of Construction initiates one or two new "comprehensive projects" that last about five years, and it thus has about seven or eight underway at any one time. Current annual government funding is about \$5 million (not including staff salaries), and private industry participants contribute a similar amount. University faculty participate in a consulting or advisory role, sometimes as a project team chairman. These projects can be designed to focus attention on promising new areas of technology, or they might help provide data to improve or standardize a new method or material so that it can become part of the building standards.

The BRI has a technical staff of 118 (of whom 104 are architectural engineers) and an administrative staff of 54. In addition to this, it uses outside contractors to provide the laboratory support (rigging, instrumentation, etc.) and also makes its facilities available to outside researchers who conduct much of the experimental program. The BRI has a 1990 budget of \$15.9 million, about 20 percent of which is for exploratory research (e.g., development of ultrahigh-rise reinforced concrete buildings). Additional information about BRI and its current research activities is given in the trip reports in Appendix A.

PWRI's budget of \$57 million per year is comparable to the research budgets of the larger general contractors, while its staff size (479) is somewhat larger. Like BRI, it also has a considerable amount of cooperation with private organizations, as is the present case for research on high-performance concrete. The trip report (in Appendix A) about PWRI gives more information.

Universities

In general, universities in Japan play a comparatively minor role in construction R&D. On the one hand, government policy suggests that the universities should be the main source of basic research. On the other hand, their facilities are typically older, smaller, and less well staffed, and they seem much more detached from the practical problems facing the contractors and even the government labs. The results of their activities thus seem to have a fairly minor impact in applied fields like construction.

Nevertheless, distinguished academics do often appear to be involved in a consulting or advisory role, and occasionally bite off some of the theoretical aspects of important research efforts. For example, in the Honshu Shikoku Bridge System, universities have been involved in the dynamic analysis of structures, materials fatigue problems, and other important aspects.

A notable exception to this situation has been the WASCOR (Waseda Construction Robotics) effort at Waseda University. The WASCOR operation seems to have been a very successful venture in industry-university collaboration for research, and has gained an international reputation. It appears to have been a catalyst for the Japanese construction companies' ventures into construction robotics. Through its success, the WASCOR effort may possibly be a prototype for closer university-industry interactions in the future in Japan.

Professional Societies and Nonprofit Organizations

Professional societies such as the Japan Society of Civil Engineers (JSCE) and the Architectural Institute of Japan (AIJ) do not directly fund or conduct research (Ref. 3.17). However, they have important roles in providing a forum in which leading professionals from government, industry, and academia can come together in technical and professional committees to discuss research, to come to a consensus on standards and procedures that might be recommended to the government, and to study various problems that relate to construction. In addition to the standing committee activities, AIJ funds special studies, sometimes in response to requests from government agencies. Recent examples include waterfront disaster mitigation, environmental problems related to architecture, and preservation of atomic bomb exposed buildings. AIJ typically commits ¥1.6 million (about \$11,000) to support travel and administrative costs related to such studies, but depends on construction company laboratories for lab-based research or testing that might be needed.

To illustrate the extent of the forum role, the AIJ committees hold some 1600 meetings per year (6 to 8 per day), many if not most using the committee rooms and conference facilities of the AIJ headquarters building. In our visit to AIJ as well as JSCE, it was evident that the geographical compactness of Japan and the fact that a large number of members live in Tokyo or the surrounding Kanto plain make it more feasible to hold regular meetings, even after work in the evening, than is possible for AIA or ASCE in the United States.

Regarding its committees' roles in the development of standards for new materials, construction processes, or even contract administration, AIJ members monitor new developments and, for those that seem significant, they consolidate and exchange relevant information, ask developers for additional information or test results, and come to some consensus as to the appropriateness and benefits of the innovation. The results of this investigation can then be written up as an AIJ standard. Note, however, that from a legal perspective this is more of a recommendation, since the Ministry of Construction and other government bodies ultimately control the building codes for the country as well as the contractual specifications for their own projects.

Through publications and conferences, the professional societies are also important mechanisms for the compilation and dissemination of information, much like their counterparts in other countries. Please see the JSCE and AIJ trip reports in Appendix A for more information.

Also important are various nonprofit organizations and trade associations, particularly for the evaluation and testing of new technologies. An example visited by some members of the JTEC team is the Building Center of Japan (BCJ). BCJ gives fair appraisals of new technology, and reviews the design of any building over 60 meters (197 ft.) high (and also for lower buildings if the designers propose deviations from the current national building code). BCJ is a facilitator for research by government and private companies, and acts as a center for information on construction technology via publications, seminars, etc. Its staff is 70 to 80, about half of whom are technical, mostly architects. It also has 19 standing committees composed of experts from academia, industry, and government, which perform the appraisals of construction projects. BCJ does not receive government support for its annual income of ¥1.6 billion (\$10.7 million), but rather derives its funds from publication sales, monitoring research, appraisal fees, etc. The BCJ trip report in Appendix A provides more information, including how it handles a typical appraisal and how it fits into the overall system in view of the government regulation of the building law.

PROJECTIONS FOR THE FUTURE

There are numerous technical results that have emanated from Japan's construction research. Also important is the relationship of the research institutes to the ongoing operations of their parent companies. For example, the research at the major laboratories is mostly funded from retained earnings. Furthermore, the focus is primarily on researcher-originated projects. While these projects do originate from a proposal and budgeting process that runs on an annual cycle, the typical planning horizon is 5 to 10 years, and current conceptual research extends out at least 60 years for a lunar colony conceived for the year 2050. In other words, the technical laboratories of the major contractors are genuine research organizations, with considerable freedom as well as resources to conduct long-term research. The companies respect their labs as keys to their future growth and survival, economically as well as technically. A few significant examples of the research results to date and their potential will be included in the list that follows:

- 1. CIVIL WORKS.** On the civil engineering side, Ohbayashi has been especially well known for its advanced tunneling technologies, its soil improvement methods, and its deep diaphragm wall construction methods. The large-scale Geotechnical Engineering Laboratory supports this work, and in itself is larger than any comparable facility in the United States. Results include the soft-ground tunnel boring machines that began successfully penetrating the U.S. market in 1979 and the Super Hydrofraise excavators (initially licensed in 1961 and since developed jointly with France's Soletanche company) that continue to give Ohbayashi at least twice as large a share of this market as its next largest competitor (Ref. 3.18). Recent developments in tunneling include participation in a national effort to develop a double-bore tunnel boring machine that substantially reduces excavation quantities and has some mechanical advantages relative to single-bore machines for transit and highway tunnels (Ref. 3.19), and a foam injection method to improve materials stability and transport as well as reduce the environmental problems associated with shield tunneling in very soft soils. The Super Hydrofraise excavators have evolved to include computer-based instrumentation and automation that help assure precise excavation tolerances at trench depths as great as 170 meters (560 feet). As construction worldwide moves to more and more difficult site conditions, proficiency with such advanced technologies will be increasingly important. We might rate Japan's position in these areas as being at least equal with the best in the United States and Europe, and probably moving ahead.
- 2. ACTIVE & PASSIVE CONTROL FOR STRUCTURES.** While there are comparable efforts in the United States to build structures using base-isolation, passive dampers, and active control systems, Japan's research is perfecting these techniques and exploring a number of different design approaches (Ref. 3.8). The Japanese also have good experience from the structures that they have already completed and that have been well instrumented when subject to large earthquakes. These factors would appear to make them well poised to be major players in this new market, and one could expect them to develop an export capability at the component level and probably for the design and construction of seismic-resistant buildings. A large market could arise for these capabilities, not only for buildings in areas prone to earthquakes, but also for other structures such as manufacturing facilities for integrated circuits and other applications where even the vibrations from nearby truck traffic can cause problems that can be eliminated by active or passive control systems. This topic will be discussed in more detail in Chapter 7, "Passive and Active Control (Damping) Systems."
- 3. HIGH-TECH MANUFACTURING BUILDINGS.** While we did not observe any major advantages over other advanced competitors for the construction of superclean rooms (class 1 or better) or bioclean rooms, the Japanese clearly are up there with the leaders, although the market potential will probably remain fairly specialized relative, say, to base-isolated buildings.
- 4. ENERGY CONSERVATION.** With the renewed interest in energy efficiency that was stimulated by the actions of Iraq, it would appear that Japan's contractors, who have kept up research in this area in spite of lower energy prices in the 1980s, will be well poised to take a leading role in the

design and construction of such buildings in the future (Ref. 3.20). With the permanent employment system, the expertise they have accumulated remains in their companies, while comparable U.S. organizations have withered away. Furthermore, the Japanese companies now have more than a decade of operational test data on advanced energy-saving technologies for buildings.

5. LARGE-SCALE FUEL STORAGE. Over ten years ago, one of the panelists saw a well-coordinated program of research at the major construction companies to develop large-scale fuel storage facilities for oil and liquified natural gas. They had to solve many problems related to deep excavation, building concrete structures for use at cryogenic temperatures, soil mechanics under freezing conditions, etc. The results have since been applied in building up Japan's fuel storage capacity to over six months, and this helped insulate it from the price rises that took place in the U.S. almost immediately after the Kuwait event. This research continues—reflecting Japan's typical long-term commitments—and is a good example of a focused client-sponsored research effort (in this case, Japan's gas companies). It has also had spin-offs for the deep foundation diaphragm wall construction that is extensively used for building foundations, subway stations, and even the Akashi Kaikyo bridge anchorage A1 that is described in another of our trip reports. The Japanese appear to have a leading position in such deep excavations.

6. AUTOMATION AND ROBOTICS. For nearly a decade, Japan has made considerable efforts to apply robotics to construction. A major motive is to substantially reduce labor requirements in view of demographic considerations that point to a dwindling supply of skilled craft workers in the years ahead. To date, however, Japanese efforts have been focused on relatively isolated machines for specialized applications, and they have mainly borrowed from other sectors the technologies for sensors, computer software, control systems, etc. Even cumulatively, these isolated robots of the type developed thus far seem to have limited potential for the needed labor savings from a system perspective.

Thus, JTEC panelists were particularly interested to learn about a most ambitious Ohbayashi research effort focused on the nearly full automation of the construction of a high-rise building (variously called ABCF, for automatic building construction floor, or SCF, for super construction factory) (Ref. 3.21). This indeed will require an overall system approach to construction, and a high level of coordination among the various automation elements. As conceived, ABCF or SCF is a platform that jacks itself up above the building and allows the successive floors to be built under it as it goes, kind of like a vertically moving factory production line. It would have tracks and other means to mount, move and manipulate a variety of suspended robots for lifting materials up through the open atrium or elevator shafts of a building under construction, move them to their installed locations, align them precisely, and weld or otherwise fasten them in place. The complete platform would be weather-protected and have some noise and dust barriers so that it could operate 24 hours a day, thus cutting construction time (and thus finance costs) in half.

Although the project has only been underway for three years, Ohbayashi already has one or two buildings planned that may be ready to employ this method within the next two years. This would not be a fully automated implementation at first, but would have the major platform and jack-up components and some robots for welding and/or materials handling. Presumably, Ohbayashi would be working out details for a modular approach to the platform configuration so that the components could easily be reconfigured for buildings of varying geometry (both circular and rectangular are now being studied, but probably with a constant floor plan as the building goes up).

Although Ohbayashi is moving rapidly from concept to implementation, it appears now that it has concentrated mainly on the structural aspects of the building. When asked how they will accommodate the piping, electrical, air ducts, fire lines, and other systems that go into each floor of such buildings, as well as the finish materials, our hosts indicated that they were still thinking about that. Given that the ABCF platform lacks conventional tower cranes or other means to hoist materials up the outside of a building, it seems that if the non-structural systems are not erected concurrently with the beams and columns, these other systems will have impeded access and will thus have to be brought up piece-wise, thus reducing opportunities for prefabrication and other cost-saving methods that seemingly ought to be integrated into the overall automated building system. It remains to be seen in the next few years how Ohbayashi will make these tradeoffs and work out the details to the point that the approach becomes economically competitive. However, in contrast to the isolated and specialized robotics efforts thus far, if this concept does succeed, it has the potential to be a major technological breakthrough with substantial economic implications.

7. **"INTELLIGENT" BUILDINGS.** All panelists who visited some of Japan's prototype intelligent buildings were impressed with Japanese achievements and ambitions in this field. While there has been much talk on this subject in the United States, there does not appear to have been sufficient client demand to stimulate much research and development; thus, the Japanese are gaining a considerable lead. As they demonstrate the practicality and desirability of constructing such automated buildings and homes, it seems likely that they will dominate the market worldwide. This topic will be covered in more detail in Chapter 6, "Building Systems."

SUMMARY

Table 3.3 summarizes the JTEC panel's assessment of the relative status and trend of R&D in Japan as compared to the United States.

Japanese construction companies have well-established and generously funded in-house research and development programs, including well-equipped laboratories, on a level that is almost absent in U.S. construction companies. Partly through the application of their research findings, they have moved ahead of their U.S. counterparts in many areas, including soft-ground tunneling, design and construction of intelligent buildings, deep foundation construction, construction robotics, long-span bridge construction, and in performing urban construction with minimal disruption. In almost every area they are doing more R&D and are thus likely to keep moving ahead more rapidly in the future.

Table 3.3
Relative Status of R&D in Japan and the U.S.

CATEGORY	R&D	
	STATUS	TREND
Construction Contractors	+	
Construction Suppliers	0	
Universities	-	
Government	0	

Coding System			
Japan Compared to the United States			
Status		Trend	
<	Far Behind		Pulling Ahead Strongly
-	Behind		Gaining Ground
0	Even		Holding Constant
+	Ahead		Falling Behind
>	Far Ahead		Losing Quickly

The supplier R&D might be judged as about the same at present, but the past decade's losses in the supplier R&D research capability in the U.S. means that the Japanese are likely to start moving ahead even in areas where they are not ahead now. Later chapters will comment on the steel industries and other supplier types in more detail.

Government laboratories have good capabilities for construction R&D in both countries, and are indicated as both being approximately equal and moving ahead at about the same rate. Indeed, there is good cooperation and exchange of information between Japan's BRI and PWRI and their counterparts in the United States, such as NIST.

Only in universities does it appear that the U.S. has an advantage. Apart from Waseda's WASCOR, the universities seem relatively isolated from the mainstream of industry and government R&D, and there are few if any counterparts to the NSF-funded engineering research centers at Lehigh University (ATLSS) and Carnegie-Mellon (EDRC), or the industry-supported centers such as the Construction Industry Institute at the University of Texas, or the Center for Integrated Facility Engineering at Stanford University.

The bulk of the research in Japan is in industry, however, and this is the major difference in the two countries. The implications are quite important. Since the 1970s, Japanese contractors have been formidable contenders in the international construction market, particularly in Southeast Asia and the Middle East. However, until a Japanese contractor successfully bid low on two San Francisco tunnels in 1979, there was some question about whether they were likely to compete directly in the U.S. market. They have, of course, and the U.S. response has been mixed. Some contractors have worked in joint ventures on U.S. projects, and many have benefitted from Japanese-financed developments. Others, however, have sought legislative protection from Congress and federal agencies, and occasionally have succeeded in banning Japanese contractors from some sectors of the U.S. market. Access of U.S. firms to the Japanese market remains a troubling problem, and even if they entered there is serious question about how well they might do.

Regarding the impact of technology, it seems fairly evident that Japan's rate of progress has been greater than that in the U.S. in many if not most construction fields, and in some Japan is already ahead. The chart in Table 3.3 compares these at only the most summarized level, and much more detail will be given in later chapters. It is not clear what impact this will have on U.S. contractors. Already U.S. firms have purchased and operated Japanese tunneling machines and other types of construction equipment, and it seems likely that they will also be buying Japanese robots and components for intelligent and energy efficient buildings. In this case, the impact will likely be felt by U.S. manufacturers more than by U.S. contractors. Indeed, this has already been the case for manufacturers of steel, elevators, construction machinery, and other goods, and this trend certainly has implications for the trade balance. Offsetting this, however, is Japan's investments in U.S. real estate, without which the past decade could have been a sad one indeed for U.S. building contractors. Certainly there would be a much better future with cooperation rather than conflict between the Japanese and U.S. construction industries.

KEY RESEARCH PERSONNEL AND FACILITIES

The site visits (Appendix A) that formed the basis for this chapter are listed below in four main categories: company research institutes, government research institutes, universities, and professional societies and non-profit organizations. Owing to the large number of people encountered at each site, only the director or other key individual is listed. Each separate trip report lists the full names and titles of the other people who participated in the discussions.

COMPANY RESEARCH INSTITUTES:

- KAJIMA INSTITUTE OF CONSTRUCTION TECHNOLOGY (Kajima Corp.), (Dr. S. Momoshima, Director)
- TSUKUBA INSTITUTE OF CONSTRUCTION TECHNOLOGY (Kumagai Gumi), Tsukuba, Japan (Dr. Sachio Masuzawa, Director and General Manager)
- MISAWA HOMES INSTITUTE OF RESEARCH AND DEVELOPMENT (Misawa Homes Co., Ltd.), 2-4-5 Takaido-Higashi, Suginami-ku, Tokyo 168, Japan (Dr. Naoto Ando, Manager, Timber Engineering, Furniture Development Division)
- NIPPON STEEL R&D LAB #1 (Nippon Steel Corp.), Hiyosi, Japan (Dr. I. Aoki, General Manager)
- OHBAYASHI CORPORATION TECHNICAL RESEARCH INSTITUTE, 640, 4-chome Shimokiyoto, Kiyose-shi, Tokyo 204, Japan (Dr. Toshikazu Takeda, Director, General Manager)
- INSTITUTE OF TECHNOLOGY (Shimizu Corporation), No. 4-17, Etchujima, 3-Chome, Koto-ku, Tokyo 135, Japan (Dr. Toshihiko Ota, Managing Director, General Manager)
- TECHNICAL RESEARCH CENTER (Taisei Corporation), 344-1, Nasemachi, Totsuka-ku, Yokohama, Japan (Dr. Hiroshi Kitamura, President, Technical Research Center)
- TAKENAKA TECHNICAL RESEARCH LABORATORY (Takenaka Corporation), 5-14, 2-Chome, Minamisuna, Koto-ku, a, Japan (Mr. Yoshiyukia, General Manager)

GOVERNMENT RESEARCH INSTITUTES:

- **BUILDING RESEARCH INSTITUTE (BRI)**, Tsukuba, Japan
(Dr. S. Koizumi, Director General)
- **PUBLIC WORKS RESEARCH INSTITUTE (PWRI)**, Tsukuba, Japan
(Dr. Toshio Iwasaki Director General)

UNIVERSITIES:

- **UNIVERSITY OF TOKYO**, Honhgo, Tokyo, Japan (Dr. Fumio Nishino,
Professor of Civil Engr.)
- **WASCOR, SYSTEM SCIENCE INSTITUTE, WASEDA UNIVERSITY**,
3-4-1 Okubo, Shinjuku, Tokyo 169, Japan (Prof. Yukio Hasegawa,
Professor, System Science Institute, and Director of WASCOR)

PROFESSIONAL SOCIETIES AND NONPROFIT ORGANIZATIONS:

- **THE BUILDING CENTER OF JAPAN (BCJ)**, Tokyo, Japan
(Mr. Shoji Kisa, General Manager, International Department)
- **ARCHITECTURAL INSTITUTE OF JAPAN (AIJ)**, Tokyo, Japan (Toshihiko
Yanagisawa, Managing Director)
- **JAPAN SOCIETY OF CIVIL ENGINEERS (JSCE)**, Tokyo, Japan

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CHAPTER 4

CONSTRUCTION MATERIALS

R. N. Wright
G. H. Watson
J. W. Fisher

INTRODUCTION

The JTEC panel's interactions with offices of Japanese government and industry, public and private laboratories, and construction sites have provided substantial information for this chapter on materials for structures, earthworks, and foundations. Topics not covered include materials and components for mechanical systems, exterior enclosure materials, and interior finishes and furnishings. Examples of new techniques and products developed or licensed in Japan, including all the above areas, are given in Reference 4.1. A recent study by the U.S. Air Conditioning and Refrigeration Institute (Ref. 4.2) describes Japanese research and development on alternatives to the refrigerants that contribute to the greenhouse effects and loss of the ozone layer. The panel did not study this important topic.

Construction materials have a critical influence on the performance and cost of constructed facilities. In 1988, Japan's construction volume was \$445 billion (Ref. 4.3) and the amount spent for construction materials was \$100 billion (Ref. 4.1). Improved materials technologies may reduce first cost by substituting lower cost materials for conventional materials, by reducing costs of installation, or by reducing time required for construction. Improved materials may reduce life cycle costs through longer service lives, through reduced maintenance requirements, or through energy conservation. Improved materials may increase life safety and reduce property losses through better resistance to fires, earthquakes, extreme winds, and other environmental hazards. Construction materials are important in international trade as well as for the domestic construction industry. In 1989, the United States had a trade deficit in nonlumber construction materials of \$1.9 billion in comparison to a 1981 trade surplus of \$744 million (Ref. 4.4).

Japanese manufacturing industries and engineering-construction firms are investing heavily in research and development for improvements of construction materials. In contrast, U.S. engineering-construction and construction firms provide little R&D for construction materials, and industry expenditures for construction materials R&D have declined significantly during the 1980s (Ref. 4.5).

Japan's industry and government are collaborating strongly in construction materials R&D. The Ministry of Construction (MOC) alone, has major cooperative projects underway with industry, including new timber construction systems, high-technology materials, high-performance concrete, high-technology construction equipment, base isolation systems for highway bridges, asbestos substitutes for building materials, and materials and systems for active and passive control of building vibrations (Ref. 4.6). While MOC indicates funding for these projects at \$5.45 million annually, these figures include neither the salaries of government researchers nor the private sector investments. The JTEC panel was advised to consider the total level of effort to be about \$22 million annually for these cooperative industry-government studies.

The panel's visits to Japanese universities indicate that Japanese universities are less involved in R&D for development of improved construction materials than their U.S. or European counterparts.

DISCUSSION OF TOPIC

Structural Steel

The panel's perspectives on structural steel are based on visits to the headquarters and R&D Laboratory #1 of Nippon Steel Corporation, which is Japan's largest steel corporation and responsible for about 25 percent of Japan's crude steel production (Ref. 4.7), and visits to construction sites. It was notable in visits to government and engineering-construction company laboratories that Japan depends on its steel corporations for structural steel research, while research on structural concrete is active in the other private and government laboratories. Nippon Steel Central R&D employs about 2000 persons in four laboratories, a level of effort far greater than that of U.S. competitors. The largest U.S. steel corporation has about one-tenth this number of research personnel.

Fire-resistant steel has a yield point of 51 ksi (354 MPa) and tensile strength of 82 ksi (570 MPa) (Ref. 4.8). The yield point rises up to 400 °F (200 °C) and retains more than 67 percent of room temperature yield strength at 1100 °F (600 °C) (Fig. 4.1). The tensile strength declines with elevated temperature as for normal structural alloys. Fracture toughness at low temperatures is as good as normal alloys. Heat-resistant bolts and weld metal also have been developed by Nippon Steel. Heat-resistant steel provides savings in fireproofing expected to more than repay its higher initial cost in many applications. Fire-resistant steel is not yet marketed, but Nippon Steel has erected two demonstration buildings for its own use using this steel.

Nippon Steel has developed and is producing high-strength (50 - 70 ksi [320 - 410 MPa]) steels for buildings, ships, offshore structures and pipes in thickness up to 4 inches (100 mm) (Ref. 4.9). Continuous on-line control (CLC), which has the generic name thermomechanical control process (TMCP), provides at modest additional cost: high weldability (low carbon equivalent) with reduced preheating requirements, and improved resistance to brittle fracture (Fig. 4.2). TCMP has been used to produce low

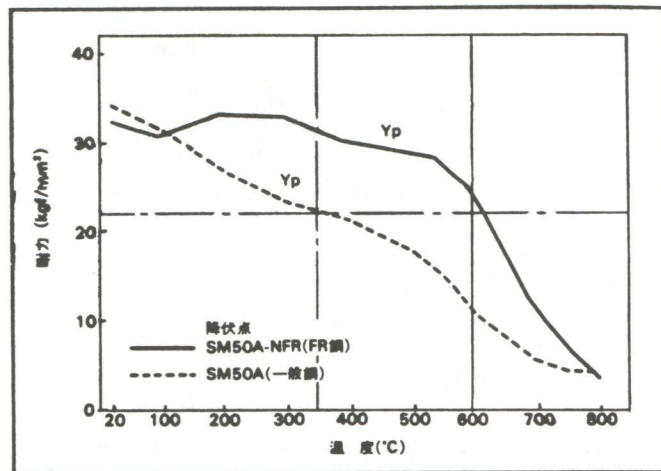


Figure 4.1. Change of Yield Point with Temperature for Fire-Resistant (solid line) and Conventional Steel (dashed line)

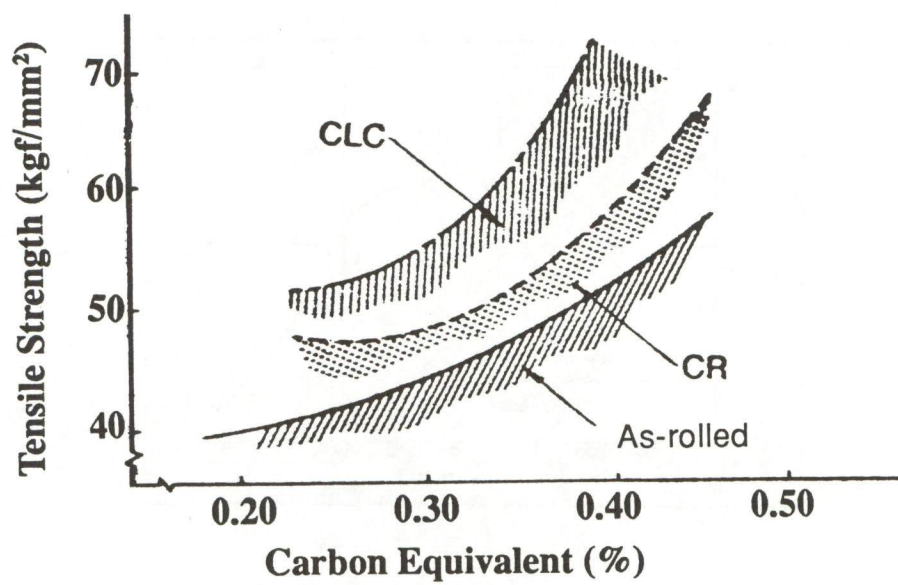


Figure 4.2. Tensile Strength vs Carbon Equivalent for CLC (TCMP) and As-Rolled Conventional Steels

yield ratio (ratio of yield point to tensile strength), and narrow yield point range (variability). The panel observed TMCP steel in use in the Taisei Corporation's New Otani office building under construction in Tokyo. Nippon Steel research shows that low yield ratio improves ductility in earthquakes (Ref. 4.10). Other research also shows that reduction of the coefficient of variation of the yield point in structures designed by the strong-beam-weak-column principle also gives improved structural ductility in earthquakes (Ref. 4.11). Special low-yield-strength steels, as low as 14 ksi (100 MPa), have been developed for seismic isolation and energy absorption applications.

The U.S. Department of Defense began a program in 1990 to develop a U.S. capability to produce TCMP steels for military applications in about five years. At present, U. S. industry can control roll thickness up to one inch (25 mm), but no U.S. manufacturer has the controlled cooling facilities needed to produce TCMP steels.

Nippon Steel has developed and marketed a new series of rolled structural steel beams with depth and flange width constant as flange thickness and web thicknesses are changed to meet strength requirements. Depths of 16 - 36 inches (400 - 900 mm) are provided for a total family of 177 shapes. These are named "hyper beams" (Ref. 4.12). Such a family of shapes simplifies connections. A major market is Japan's system of steel encased in reinforced concrete, which provides restraint of buckling for thin webs and flanges. This is a declining market in Japan (and uncommon in the United States) because of high labor costs in preparing reinforcement and formwork. Hyper beams are rolled by a new method to maintain constant depth, web thickness, and flange width while varying flange thickness for moment resistance. The ability to modify rolling practices may be more important in international trade competitiveness than the hyper beams themselves.

Other Nippon Steel research is developing improved means to coat steels for corrosion resistance and decorative purposes (Ref. 4.13) and to improve corrosion diagnosis systems (Ref. 4.14). Nippon Steel and other Japanese steel manufacturers are far more active in research than U.S. competitors. U.S. steel firms are either licensing advanced technologies from Japan or yielding equity positions to Japanese companies to obtain competitive technologies (Ref. 4.15).

High-Performance Concrete

A major research effort of the Ministry of Construction, in cooperation with private laboratories and universities, deals with "Development of Advanced Reinforced Concrete Buildings Using High-Strength Concrete and Reinforcing" (Ref. 4.16). The program is scheduled from 1988 through 1992 at a total annual funding level of about \$5 million. Its goals are to produce concrete ranging in compressive strength from 5 - 17 ksi (30 - 120 MPa), to produce high-quality reinforcing steel of yield strength 56 - 168 ksi (400 - 1200 MPa), and to develop reinforced concrete components and building systems exploiting these properties.

Research topics for concrete include quality testing of cement, quality testing of aggregate, standards for admixtures, design methods for concrete mixtures, evaluation of workability, evaluation of mechanical properties of concrete, evaluation of compressive strength of concrete in structures, evaluation of long-term properties of concrete, evaluation of durability, development of construction techniques, evaluation of fire resistance, and evaluation of reliability.

Research topics for reinforcing steels and reinforced concrete include production techniques and approved mechanical properties of reinforcing steel, behavior of standard hooks for

lateral reinforcement, effect of lateral confinement on column behavior, effects of axial force and bending on column behavior, modeling stress-strain relations and bond characteristics for concrete and steel, failure criterion of concrete for biaxial compression, deterioration of compression capacity with cracking of concrete, tension reinforcement of cracked concrete, and anchorage and bond characteristics of longitudinal reinforcement.

Research topics on structural performance of reinforced concrete members include deformation capacity of columns, deformation capacity of beams, bond splitting failures of beams, flexural and shear behavior of shear walls, and shear capacity of beams, columns, and interior and exterior beam-to-column joints.

Research topics for structural design include design examples for shear wall, tube and tube-core systems, design methods, design criteria, input ground motions for seismic design, and structural systems for foundations.

The United States presently leads in applications of high-strength concrete, with applications up to 19 ksi (131 MPa) (Ref. 4.17). This advance was accomplished with modest government support for fundamental research in cement and concrete, and cooperative efforts between manufacturers, designers, contractors, private research and testing laboratories, university researchers, and local regulatory officials. However, Japan's focused, well-funded, collaborative industry-government effort is likely to give Japan general leadership in this internationally significant area of construction technology.

Japan's large-scale public works projects such as the Honshu-Shikoku bridges and the Seikan tunnel connecting Honshu and Hokkaido have attracted much attention to improvement of the placement of concrete and its performance in service (Ref. 4.18).

"Self-placeable" concrete that does not need vibration for compaction is suited to complex shapes, heavily reinforced sections, and use of robotics in placement. Studies in fluid mechanics and rheology are improving understanding of the behavior of fresh concrete, and good results have been obtained from uses of superplasticizers and cellulose-based admixtures.

"Biocrete 21" is an example of a "self-placeable" concrete (Ref. 4.19). Its significant properties are summarized as follows: (1) with the help of a superplasticizer it has deformability and segregation resistance to fill every space in the formwork rapidly, even in heavily reinforced areas; (2) due to low water-to-cement ratio, strength and durability are improved, and drying shrinkage and bleeding are reduced; (3) resistance to freezing and thawing is high if appropriate air is entrained; (4) designs can employ complex shapes and construction joints can be avoided since there is no need to provide access for vibrators; and (5) placement time is shortened with no vibration needed, and robotics and automation can be used in placement.

High-durability concrete is being achieved by the use of blast furnace slag, silica fume, and glycol ether and amino alcohol additives. Water-absorbing formwork surfaces are used to improve the density of concrete surfaces. Surface coatings are used to reduce chloride penetration, and epoxy-coated reinforcing bars (developed in the United States) are used to prevent corrosion of reinforcing bars.

An antiwashout segregation-preventing admixture introduced from West Germany in 1979 is used to assist in placing concrete underwater and to improve the bond between placements in inverted construction (layers placed successively below one another). About 654,000 cubic yards (500,000 cubic meters) of this concrete will be used in construction of the Akashi Kaiko Bridge between Honshu (the main island) and Shikoku.

Studies of high-strength, nonmetallic fiber reinforcements are part of a major project of the Ministry of Construction (Ref. 4.6), and were observed at the Building Research Institute, the Public Works Research Institute, and the Kumagai Gumi Tsukuba Institute of Construction Technology. Examples are carbon fibers (70 - 650 ksi [480 - 4500 MPa]), aramid fibers (140 - 430 ksi [960 - 2960 MPa]) and glass fibers (70 - 500 ksi [480 - 3500 MPa]). These fibers do not yield before breaking, and therefore provide strong but brittle components. Useful applications are likely for strong and durable nonstructural concrete elements, such as cladding panels, or for confining reinforcement in reinforced concrete. No concepts have been identified for their use as main reinforcing when structural ductility is required, as it is for any primary, load-carrying member.

High-Performance Composites

Japan has been involved with the development of high-performance composites from the early sixties. Some of the early patents for carbon fiber production were awarded to Japan in 1962 and 1963. This research continues, and today many of the U.S. patents awarded for carbon fiber processing methods are to Japanese companies like Mitsubishi, Asahi Glass, and Fuji. Japan has carbon fiber production capacity comparable to that of the United States.

The U.S. is the major market for high-performance composites. Research on these materials has been largely driven by military concerns but has branched out to aerospace and commercial aircraft use. The United States has nearly half of the major airframe producers in the world, thus the world's large market share. Applications for high-performance composites are spreading out to consumer goods, as evidenced by their use in sports equipment. Automotive uses are slowly expanding in high-strength parts like springs and drive shafts. Toyota has recently patented a composite steering wheel.

It is interesting to note that throughout the '60s, '70s, and most of the '80s, worldwide research has concentrated on fiber development rather than on the polymer matrix. There has been little development in resin materials until recent years. Much research is currently underway in both the United States and Japan on advanced polymer matrix materials, notably thermoplastics rather than the traditionally used thermosets.

Historically, high-performance composites has been a very compartmentalized industry in the U.S. This has hampered research and development. Many U.S. manufacturers are small companies that rely on the resin and fiber manufacturer for their manufacturing and product research. There are indications that this attitude is changing in some areas. Movement is towards fully integrated chemical companies like Hercules and Amoco that can provide fibers, resins, prepreg (fibers preimpregnated with resin for later forming), and in some cases, manufactured articles.

An interesting trend in a somewhat different fashion is being seen with some Japanese steel companies. They are getting involved in composites that can replace steel in some applications. Companies like Sumitomo, Nippon Kokan, and Kawasaki Steel have set up composite (epoxy/fiberglass) tubular manufacturing facilities to build nonmetallic piping for oil field and chemical plant applications - a market they now serve with steel products. No such move has been made by U.S. steel mills.

The entry of the Japanese into the oil field composite market is significant. They can use marketing networks for the new types of materials. The oil field market has been dominated by a handful of small U.S. companies until now. Given the Japanese reputation for applying research to develop better products and manufacturing technology, it is likely that they will soon surpass U.S. manufacturing and product performance technology. The U.S. manufacturers are not applying the resources to respond.

Geotechnical Materials

The direction of geotechnical research in Japan is dictated to a large degree by the country's environment. Earthquakes, typhoons, and very mountainous countryside in conjunction with poor foundation soil conditions result in the major thrust of the research addressing slope stability and foundation improvement techniques.

Most of the research is based on European methods that have been refined and mechanized with a very high degree of success. Major examples of successful improvements include vibro replacement for loose sands and soft soils, the development of the slurry wall system for the construction of concrete underground petrochemical tanks, the use of geotextiles and horizontal drains for slope stability, and foundation preconsolidation with and without wick or sand drains.

The Public Works Research Institute has conducted extensive studies on the uses of geotextiles to stabilize retaining walls and embankments (Ref. 4.20) and has studied uses of expanded polystyrol blocks and beads for lightweight embankments and backfill for pipes (Ref. 4.21). Kumagai Gumi has developed a technique to stabilize bentonite slurries with gelling agents to provide permanent, impermeable walls and diaphragms (Ref. 4.22).

SUMMARY

Japan's government, manufacturing industry, and engineering-construction industry laboratories are giving extensive, sustained, collaborative attention to the improvement of construction materials. Research and development findings elsewhere in the world are monitored carefully and useful results are licensed in Japan. Government research activities are larger than those in U.S. government laboratories. The Japanese manufacturing industry has increased its R&D, while U.S. building materials manufacturers are abandoning product development research in order to cut current expenditures. Japanese engineering-construction firms have large-scale construction materials research efforts that are generally unmatched by U.S. counterpart companies. University professors and researchers are collaborating in these efforts, but at a lesser scale than their U.S. counterparts.

Thus, Japan generally leads or matches the U.S. in implementation of state-of-the-art construction materials technology, and has growing leadership in research, as shown in Table 4.1.

Table 4.1
Relative Status of Construction
Materials R&D in Japan and the U.S.

CATEGORY	R&D		IMPLEMENTATION	
	STATUS	TREND	STATUS	TREND
Structural Steel	+	↗	+	↗
High-Performance Concrete	+	↗	-	↗
High-Performance Composites	+	↗	+	↗
Geotechnical Materials	+	↗	0	↗

Coding System			
Japan Compared to the United States			
Status		Trend	
<	Far Behind	↑	Pulling Ahead Strongly
-	Behind	↗	Gaining Ground
0	Even	→	Holding Constant
+	Ahead	↘	Falling Behind
>	Far Ahead	↓	Losing Quickly

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CHAPTER 5

CONSTRUCTION FIELD OPERATIONS AND AUTOMATED EQUIPMENT

R. W. Nielsen

INTRODUCTION

This chapter will present the panel's observations of Japanese construction firms' field operations and fielded technologies, and will briefly discuss the development of automated equipment by and for the larger construction firms in Japan. Recognizing that one week is far too short a time to visit even a small percentage of the construction projects underway by the major Japanese contractors' firms, this chapter includes information gathered from selected presentations and papers delivered by others: Japanese, U.S., and European.

Panel members visited high-rise buildings and heavy civil projects such as airport and bridge construction on this visit to Japan. There were no visits to electric power production or process facilities under construction. Likewise, the corporate research centers visited were sponsored by firms which emphasized engineering and construction in the high-rise and heavy civil areas. However, the research certainly has applicability to other areas of design and construction.

Throughout this chapter references will be made to six major Japanese construction firms known as the "Big Six." This group consists of Shimizu, Kajima, Taisei, Takenaka, Ohbayashi, and Kumagai Gumi. These six firms have been ranked among the largest construction firms in Japan, with the 1989 contract volumes listed in Table 5.1 (Ref. 5.1). These firms were also the prime contacts in Japan for project site and contractor laboratory visits and have had previous contacts with many of the panel members.

Corporate characteristics of the major Japanese companies are much different than comparable U.S. firms. As will be discussed, more effort is placed on cooperative decision/consensus type of policy making. The concept of continuous improvement is more deeply embedded in these firms than in similar U.S. firms. Likewise, as has been pointed

Table 5.1
Contract Volumes of the
"Big 6" Construction Firms

CONSTRUCTION FIRM	VOLUME (millions, US\$)
Shimizu Corp.	13,151.9
Kajima Corp.	11,940.1
Taisei Corp.	11,502.1
Takanaka Corp.	11,254.0
Ohbayashi Corp.	9,972.3
Kumagai Gumi Co. Ltd.	8,033.9

out in other sections of this report, decisions are based on a longer time frame. Immediate profit is not as big an issue as is the long-term perspective and the effect a decision may have on an established client relationship.

DISCUSSION OF TOPIC

Project Organization

Typically, major players in the Japanese construction industry provide engineering and construction management services. A prime contractor rarely employs his own craft labor; rather, these firms coordinate the work performance and schedule of a number of subcontractors who supply the craftsmen and provide the material required to complete the field construction. However, in contrast to U.S. construction management firms, these prime contractors appear to be more actively involved in the subcontractors' day-to-day activities (Ref. 5.2).

The relationships between prime and subcontractors tend to be long-term in nature and are based upon trust, just as are relationships between prime contractors and many of the owners for whom they provide design and/or construction services. A statement made to members of the panel while visiting the Makuhari Messe (the largest convention center in East Asia, located in the Chiba Prefecture) was that subcontractors have specialty areas, and at times a particular major contractor might be selected because of a long-term relationship that had been established with a particularly skillful sub (See Appendix A, Makuhari Messe visit report). In fact, certain subcontractors may be captive, only performing work with one particular prime contractor.

The construction scene is further differentiated from the approach taken here in the United States by the frequent joint venture arrangements that have been used in Japanese construction for at least the past twenty years (See Appendix A, Makuhari Messe visit report). These relationships are so common that when one host was asked if a particular building was constructed by a joint venture, the answer came back, "Why of course, is there any other way?"

These joint ventures often consist of a number of the Big Six contractors. A visit to the New Tokyo City Hall Building Number 1 in 1989 identified both Shimizu and Taisei as partners in a joint venture that consisted of a total of twelve firms. This joint venture was managing the structural and mechanical construction of one of the three main buildings on the site. While visiting Makuhari Messe, panel members were told that three distinct joint ventures provided the construction management services for the three separate sections of that construction. The Exhibition Hall joint venture consisted of five firms and was headed by Shimizu; the Convention Hall construction was managed by a joint venture team consisting of three firms; and two firms made up the joint venture that managed the construction of the Sports Arena.

Observations made by one member of the panel on this trip and on one previous trip, indicate that craft work hours are scheduled for approximately eight hours per day, Monday through Friday, with frequent Saturday work. Additional overtime is worked when it is necessary to meet schedule. Joint venture employees and management personnel from the subcontractors appeared to work longer hours, just as their counterparts do in the United States. Typically, these personnel remain at the project site until 7 p.m. or later. The average construction worker works 2700 hours per year in Japan, as compared to 2450 hours in the United States and 2100 hours in the U.K. (Ref. 5.3).

In his book *Japan Construction, An American Perspective*, Sidney M. Levy pointed out an instance when construction operations continued on a 24-hour-a-day shift basis because of problems in meeting a scheduled completion date (Ref. 5.4). In this sense, Japanese firms are similar to U.S. firms in commitment to schedule; however, one interesting observation of this work effort was the astonishment expressed by the contractor when asked how compensation was handled for the extra hours. This was apparently not an issue, and the contractor and subcontractors were covering these costs out of their own pockets. Implied was the belief that the owner would ultimately make up the loss on some future project.

Site management organization is similar to that in the United States, with the obvious absence of craft superintendents and the mixture of personnel from different companies who are partners in a joint venture. A typical site organization is shown in Figure 5.1 (Ref. 5.5).

In keeping with the Japanese culture, all members of a project team are involved in decision making (Ref. 5.6). As pointed out by Kakoto, all levels of the organization's management are involved in claims resolution (Ref. 5.1). Not only does this virtually ensure support for the decision, it also provides an opportunity for training that is lacking in many U.S. firms, where policy is more often than not dictated from the top down. It might be said that this approach is possible because all members of the project team are experienced construction personnel. However, information provided by a delegation from Japan's Society of Civil Engineers made up of employees of many of the larger Japanese construction firms confirmed that the first level of field employees is made up of recent college graduates; the second level, of employees with from five to six years of experience; and the third level, of employees with from six to ten years of experience. The project manager typically has at least fifteen years of experience.

Figure 5.2 shows the distribution of typical project management tasks between the home office, branch office, and construction site office (Ref. 5.5). This division of responsibility is similar to what one might expect in the United States, except that the U.S. construction site office assumes most of the responsibilities assigned to a Japanese firm's branch office.

According to the same representatives from the Japan Society of Civil Engineers, quality of construction is a significant issue (Ref. 5.5). An example of the concern expressed by Japanese firms in this area is shown by the quality control requirements established for a recently built sewage tunnel. The contract required the center line of the installed tunnel rings to be within ± 150 mm of the design center line, and the ring diameter to vary no more than ± 40 mm from the design criteria. The contractor established his own criteria of ± 50 mm and ± 25 mm, respectively. Apparently, this type of action is not uncommon in the day-to-day work of major Japanese construction firms.

Two reasons for this emphasis on quality are a desire to obtain excellent client evaluations, and the motivation by both company and individual to give their best performance.

Innovative Work Methods

Just as the Japanese are investigating new materials, so too is research on-going in corporate research facilities to identify and perfect innovative work methods that will reduce craft man-hours in the field or, as the Japanese put it, to "rationalize field work." Examples include efforts to improve slip forming systems; to make more effective use of temporary structures by building them into the final design so that they need not be removed; and the splicing of structural columns together on the ground to minimize the number of crane lifts that must be made and to reduce exposure to personnel who would perform the fit-up and bolting in place. Several contractors are also looking into innovative methods to stabilize soil to

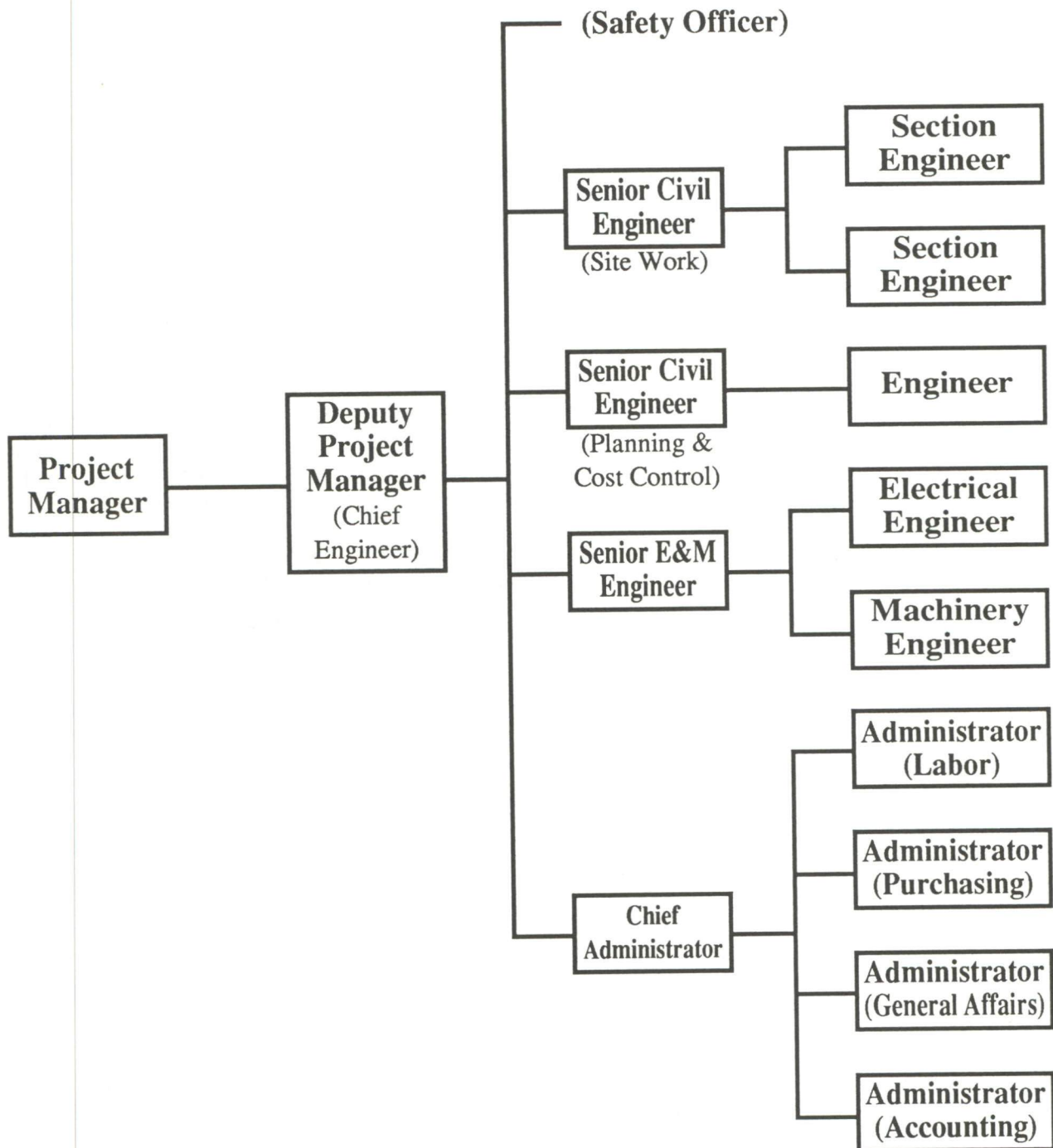


Figure 5.1. Typical Construction Site Organization
(Source: Japan Society of Civil Engineers)

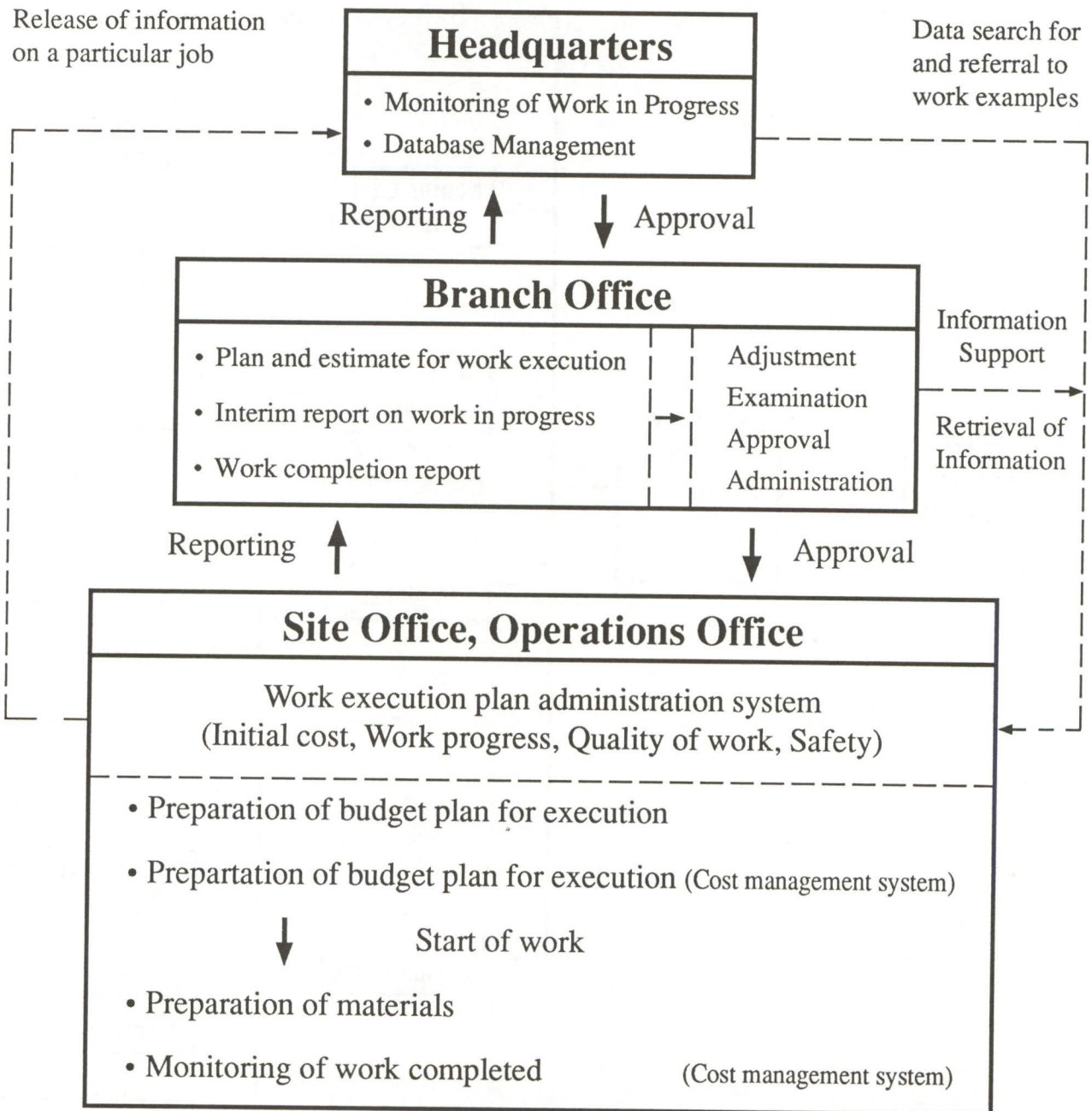


Figure 5.2. Project Management Tasks
(Japan Society of Civil Engineers)

minimize problems with liquefaction and tunnel and trench shoring. Taisei is currently constructing a large centrifuge that will be used to test this type of soil research (See Appendix A, Tasei Research Institute visit report).

In addition, research is being done in the development and use of numerically controlled machines in construction (See Appendix A, Takenaka Technical Research Lab visit report). Possible applications include the bending of process pipe and reinforcing bar for concrete placements.

Technologies that are essential to offshore and deep shaft construction are also being explored. Research in these two areas appears to be motivated by the geographic limitations of the islands that make up Japan. An example is Taisei's recent announcement of a new seabed "open tunneling method," which incorporates the advantages of tunnel boring machines and which purportedly reduces construction schedules from six to four and one-half years and reduces costs by nearly ten percent.

At a number of the panel's project visits, our hosts told us that no innovative methods had been used during construction. These statements were at times made in ignorance of what panel members observed, although no new, earth-shaking methods were in evidence.

What has been observed is the constant effort on the part of the construction site and engineering teams to identify the best approach to solving the problems that are inherent in construction. Issues such as site lay-out, work sequencing and scheduling, safety, quality, client satisfaction, etc., are key issues that preoccupy the thoughts of all personnel. Cost, though important, does not appear to receive the same emphasis as it does in the United States.

Prefabrication and "just in time" material and equipment delivery are two techniques used to minimize problems with material storage at the site and to reduce site man-hours. An example is the use of precast concrete panels in high-rise buildings to form floors and ceilings. After these precast concrete panels are installed, reinforcing bars are inserted, and the concrete is then placed over the panels. Also evident were precast columns and beams. Precast concrete encasement panels are installed around structural columns and precast beams are also used extensively. With limited lay-down space, these items are fabricated off-site, shipped to the project on the day they are needed, and off-loaded from the shipping truck directly to their final position in the structure. An additional example of this is the preinstallation of pipe, HVAC duct, and electrical fixtures in structural steel floor sections prior to erection. Japanese firms are also well known for the design and erection of modularized power plants barged to the site and then off-loaded for quick installation.

Advanced sensing and equipment control systems were used with the clamshell dredge during the seabed excavation for the pier construction of the Akashi Kaikyo bridge. Similarly, at the Honshu cable anchorage A1, the slurry wall excavating machine's sensors were able to control excavation tolerances to within approximately 2 inches when excavating in nearly 250 feet of slurry mud (See Appendix A, Akashi Kaikyo Bridge visit report).

U.S. firms typically develop innovative work methods on a project basis. As the need for an improvement is identified as a result of schedule or cost considerations, project personnel devise and implement new and innovative approaches as solutions. This is in contrast to the Japanese, who appear to take a corporate, and at times, even an industry-wide approach towards the development of techniques which can be patented and used on many projects. Their use of and improvement on techniques and methods developed elsewhere, such as underground tank construction and slurry wall excavation, exemplify their ability to improve upon existing construction operations to meet the geographic needs of Japanese construction.

Safety

As is mentioned elsewhere in this report, the Japanese are concerned with overcoming the image of construction as being unsafe, dirty, and unsophisticated. This poor image appears to be one of the reasons that the best and brightest new engineering graduates are moving into occupations in banking, real estate, and brokerage firms rather than construction. Safety is a significant concern to government and contractor/engineer alike.

The disruptive nature of accidents on a construction site is clearly known to all those who have worked in the industry. Three negative aspects of accidents were identified by members of the Japan Society of Civil Engineers (JSCE) on a recent visit to the United States (Ref. 5.5):

1. Delays in construction schedule
2. A decrease in employee morale
3. Exclusion from contract pre-qualification

The severity of this exclusion from contract prequalification depends upon the particular client, both private and public. It may be a localized exclusion or may be on a nationwide basis and can range from 30 days upward.

Government concern for safety and its willingness to impose sanctions is clearly exemplified by a report made in the March 15, 1990 issue of ENR (Ref. 5.7). On page 23, it was reported that Kumagai Gumi had been prohibited from bidding on all civil engineering public works for a period of up to four months because of an accident at one of its tunneling projects. Kakoto points out that the strongest motivator for safe operation is the government, through its imposition of sanctions in the event of a serious accident.

The project manager of the Makuhari Messe project told panel members that each company has its own safety program, but that individual site managers are able to modify it to meet specific site needs. He told of a government-sponsored construction safety day; of the Makuhari Messe project's efforts to educate workers' families in safety through drawing contests for workers' children and take-home flyers; and of continuous written (posters) and verbal reminders to the work force.

This concern was in evidence, and not just on projects involving Big Six contractors. Throughout the city of Tokyo we saw buildings under construction which were free of unsightly clutter and surrounded by fences at least eight feet high. In addition, where the building structure was being erected, safety barriers were erected at each floor, and the building itself was enclosed by what appeared to be a reinforced plastic fabric. Direct observation confirmed that cleanliness was maintained even in those tasks which are typically very dirty in the United States.

Field Automation

At most of the projects visited, panel members were told that site data collection (e.g., cost, commodity installation, and schedule) was performed manually. The New Otani building construction is one project that is using a computer-based project management system to track daily construction progress. This system was developed internally by Taisei's Computer Services Division.

While visiting the Makuhari Messe site, panel members were told that although its project schedule had been originally developed on a computer, all updates were performed manually. At a visit made to the New Tokyo City Hall in September 1989, one contractor's senior site representative said that he maintained an awareness of productivity and schedule progress by his daily job walks and by the input he received at the scheduling meetings. At that project, computers were not used for project management activities such as cost and schedule monitoring and control.

Major Japanese contractors do use computers away from the design office for detailed drawing preparation. The detail contained in these drawings compares to shop drawings prepared in the United States by structural steel, formwork, or concrete reinforcing bar fabricators. They are used in the fabrication and installation of the commodity. In Japan, these drawings are prepared by the contractor and may be done at the project site, as was the case at Makuhari Messe, or, in some cases, at satellite company offices.

Shimizu's project manager for the Makuhari Convention Center told panel members that on his current project, computers are used to track job site personnel entry and egress from the project using magnetic badges and readers located at each entry point. This technology was also reported used on a Taisei project visited by members of the panel. This is not the norm, and its use appears about equal to its infrequent construction use in the United States. Computers have been used to monitor bridge pier construction (the settlement and position of bridge pier casings on the Yokohama Bay bridge) and to serve as interference detection devices when multiple fixed cranes are used on a site. For the most part, however, computer use in the project environment is limited and not as developed as it is in the United States.

Construction Equipment

Japanese construction firms have done a great deal of research into robotics and semiautomated construction equipment. The purpose has been to improve the field productivity of craftsmen as a hedge against the labor shortages that are beginning to occur in the market. The panel members were told time and time again that younger workers were not entering the work force, and that companies were being left with an aging group of workers. To maintain the industry it is essential to increase what one worker can do while continuing to provide the quality that is expected by Japanese owners and the construction companies themselves. The emphasis on automated equipment is also caused by the desire to improve safety in the industry.

Fielded, productive machines are needed to change the image of the industry and to induce new workers to think of construction as a viable career. These machines are envisioned as improving safety and making the construction worker's career more technical in nature. Automated equipment will allow women workers, who are beginning to enter the market place in greater numbers, to perform this physically demanding work.

There also appears to be a competitive reason for developing automated equipment. To be able to compete with other members of the Big Six, each member must apparently maintain a level equivalent to the others. What is accomplished in technology research is a selling point to be used not only with new clients but also with those clients with whom long-term relationships have developed.

Panel members were told while visiting the Building Center of Japan that research in all areas, including new materials and robotics, is important at all contracting levels. Even very small firms operating only on a prefectural level maintain some form of technology

department, even if it is only one person who looks for new technology that could be applied to the firm's particular business effort.

Equipment that has been developed, at least at the prototype level, includes concrete placing equipment that can deliver concrete for floor slab placement between the structural steel frame work of high-rise buildings. This development has been worked on by several of the major construction firms on an independent basis. Its purpose is to eliminate, as far as possible, the hard labor associated with moving concrete, either by wheel barrows and buggies or by flexible pumping hose, to the point of deposit within a building.

Several firms have also developed a concrete placement boom that can be jacked upwards as a building is enclosed to provide concrete to more exposed areas. One of these booms not only places concrete but can also be locked in place to act as a construction crane for lightweight loads. Except for the crane concept, these concrete placers are very similar to the concrete booms that have been in use in the United States and Europe since at least the early 1970s.

Most of the Big Six contractors have developed equipment to reduce the number of concrete finishers needed to put the final finish on concrete slabs. The equipment has been remote-controlled either by radio or by direct wire tether. This effort has been made because of the difficult nature of the task. To our knowledge, this equipment has not been successful. Indications are that the productivity levels achieved are similar to those achieved by U.S. manufactured "walk behind" power trowels and are an order of magnitude less productive than riding trowels currently manufactured in the United States (Ref. 5.8).

Similarly, a number of Japanese firms have built devices that can be used to remotely test wall panels and wall tiles for adhesion to the wall surface. This equipment speeds up the inspection process and removes the need for expensive scaffolding or suspended inspection platforms as well as removing personnel from hazardous situations.

Painting robots have also been under development by at least two of the Big Six. This equipment is more specialized in nature and works best when designed and applied to a particular structure. Some are used to paint the exterior concrete walls of high-rise buildings, and at least one is used to paint rectangular-shaped support columns. The prime purposes for this equipment are to remove the laborer from a hazardous location and to reduce cost. The painting of exposed concrete walls may seem strange to us, but in Japan it is common to repaint approximately once every five years.

Already mentioned is the structural steel fireproofing material application equipment developed by Shimizu. The third generation of this equipment is currently being used in the field, and with each generation significant improvements have been made. There remain problems with its use, which by extrapolation of comments received by JTEC members, include poor productivity as compared to a human applicator when the structural steel is complex.

Another task that is highly repetitive, that typically occurs in unsafe areas, and that deals with the handling of heavy material, is that of installing reinforcing bars. Several firms have approached automation of this task from a number of different directions. In one case, a traveling crane-like piece of equipment was built that would pick up a number of pieces of reinforcing bar, travel across the mat, and lay the reinforcing bar at the desired location. Another firm has modified a pedestal crane to allow it to pick up the reinforcing bar in its jaws and then hold it in either the vertical or horizontal position while iron workers tie the bar in place.

One firm has approached the problem of placing reinforcing bar for a concrete slab by building a large assembly machine that places the bar in the standard criss-cross fashion and then tack welds the intersections. Once complete, the entire mat is removed from the jig and placed in its final position for concrete. Given the tight U.S. controls that are required to weld reinforcing bar (because of its composition), this is not practical in the United States.

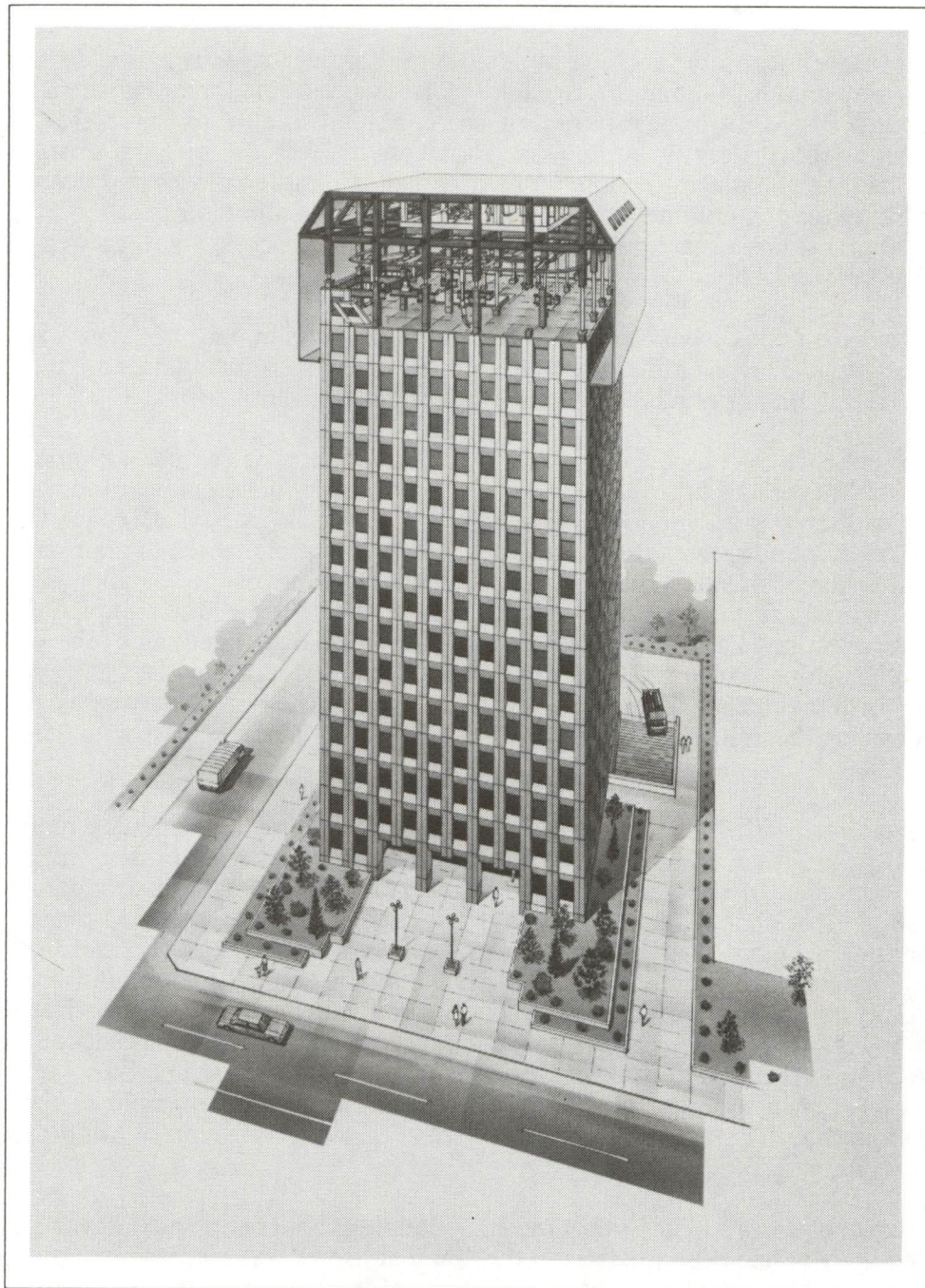
Taisei has developed a machine which builds the reinforcing cages required for concrete beams and columns. It is said that this machine replaces two of the three craftsmen required to construct a twenty-foot-long reinforcing bar cage and is able to complete the cage fabrication in approximately 30 minutes at about one half of the original cost. In this application, the machine places the longitudinal bars on a jig, then places and ties the hoop reinforcing bar to the longitudinal bars automatically. All the operator must do is turn the machine on, align the hoop bars on the machine, and attach the necessary rigging to the cage for removal after the machine has finished (Ref. 5.9).

Advanced concrete forms have been built that minimize the amount of crane movement between placements. However, these appear to be similar to self-raising, jacking type forms that have been used in the United States for the last fifteen to twenty years.

Equipment to improve the process of structural steel erection has also been developed, such as the Shimizu "Mighty Jack." This is a device from which two steel beams are hung by cable and the assembly is lifted into place, and the "Mighty Jack" is then affixed to the top of two columns. The crane is then disconnected and the beams are lowered to their connection locations. After the beams have been installed, the crane removes the "Mighty Jack" from the structure and returns it to pick up two more beams. Another piece of equipment used in structural steel erection is a remote release hook that allows disconnecting of the structural steel load, either column or beam, from the hook without needing to send a craftsman to manually perform the release. The New Otani Intelligent Office Building was using such a remote device for the release of structural columns after placement (see site report in Appendix A).

One of the more fascinating efforts in project construction automation is that currently being pursued by Ohbayashi (Figure 5.3). The intent of Ohbayashi's program is to integrate the operation of a number of different robots in such a way as to allow high-rise construction with only 20 percent of the workers normally required. Those who would make up this construction force would primarily be technicians whose job would be to control the various pieces of equipment. Development and implementation of such a program will necessarily occur over time and will include significant coordination with design engineers. Initially, the system is to include six welding robots, one automatic crane, and three automatically guided vehicles (AGVs). At the present time, a few buildings are planned that may be ready to employ this system in the next few years (Ref. 5.10). Another example of the use of automated equipment in building construction is Taisei's concept of multiple robot construction (Figure 5.4).

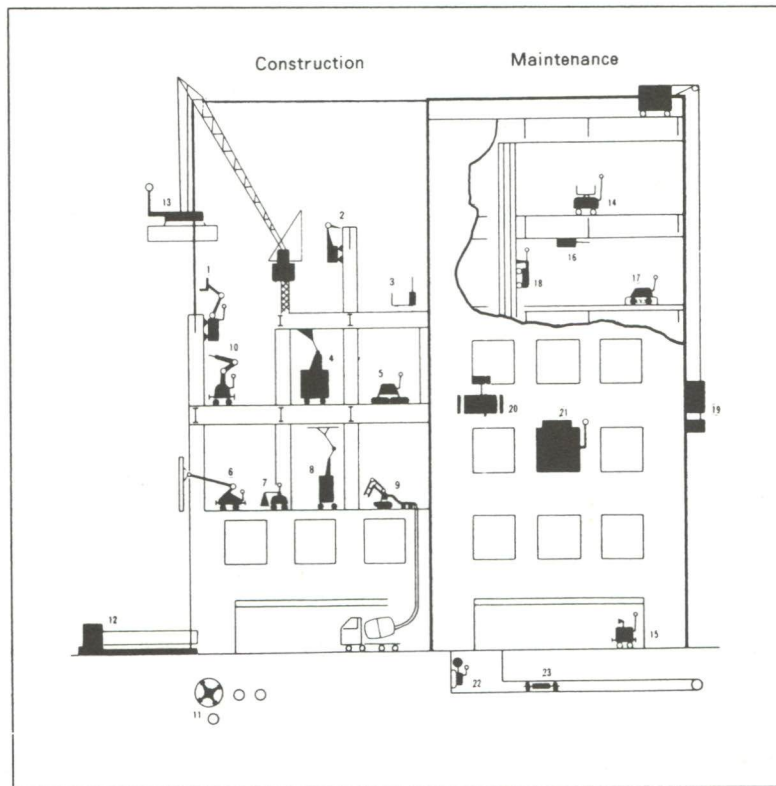
On at least two occasions, panel members visiting buildings under construction were told that automated equipment had been tried at the site, but that its use was discontinued because the equipment was unable to deal with the complexities of the structure. In one case, reference was made to a concrete-finishing machine and in the other to fireproofing material installation. In the case of the concrete-finishing machine, the subcontractor who had been using the machine to finish floors of a high-rise building determined that the concrete surface to be finished was not large enough to justify the expense of moving the machine from floor to floor. The fireproofing equipment had initially been used to apply fireproofing material to structural steel, but it was determined that because of the complex arrangement of the structural steel, use of the machine could not be justified.



**Figure 5.3. Automated Construction of Building
(Ohbayashi Corporation)**

A Team of Robots for Diverse Operations

A conceptual drawing showing a team of robots carrying out diverse operations efficiently and accurately, under the control of a few operators.



- | | |
|---|--|
| 1 Steel frame erecting robot | 13 Position controlling robot |
| 2 Steel frame welding/bolt tightening robot | 14 Package transport robot |
| 3 Material transport robot | 15 Security patrol robot |
| 4 Fireproof spraying robot | 16 Duct cleaning robot |
| 5 Floor finishing robot | 17 Floor cleaning robot |
| 6 Robot to manipulate exterior wall board | 18 Piping system diagnosing robot |
| 7 Floor cleaning robot | 19 Exterior wall maintenance robot
(painting, cleaning) |
| 8 Robot to manipulate wall board | 20 Exterior wall diagnosing robot |
| 9 Concrete placing robot | 21 Window cleaning robot |
| 10 Interior finishing robot
(spraying, painting) | 22 Tank cleaning robot |
| 11 Pipe embedding robot | 23 Pipe inspection robot (gas, sewage) |
| 12 Reinforcement bar erecting robot | |

**Figure 5.4. Automated Construction
(Taisei Corporation)**

Our observations indicate that, for the most part, the prototype automated equipment has not found its way into the field. Reasons such as cost and inadequate productivity have been given for this lack of success. Problems exist with most of the equipment under development. It either cannot handle the complex situations that are encountered in the construction environment, e.g., the beams are too close together, or there are too many obstacles, or the device is much too expensive to construct and control. Even though this lack of field implementation might be considered a failure, that is not the case. These firms continue to refine the products and with each revision, the equipments' capabilities improve, bringing the companies closer to a revolutionary change in the way construction is accomplished.

Research continues in many areas of construction equipment. In addition to Ohbayashi, other Japanese firms are actively exploring ways to integrate construction equipment with information contained in their CAD designs. Their efforts include not only the transfer of information from the computer model to the equipment, but also the use of artificial intelligence to act on that information and the surrounding environment (Ref. 5.11). Taisei's concept of computer-integrated manufacturing in the Japanese construction industry is an example of this (Fig. 5.5). Taisei's plan is to tie the design information contained in a 3-D CAD system and the knowledge of the craftsman who performs the installation together with automated equipment. Its goal is to achieve "STEP-3" (shown in Fig. 5.5) within the next five to ten years.

In summary, the Japanese are endeavoring to build automated equipment for use in many areas of construction. Though not yet successful, their goal is that this type of equipment will ultimately improve the construction environment and increase productivity. Some of the equipment they are working on would not directly find a market in the United States because of design differences (e.g., building painters, exterior wall tile tappers, etc.), but as a result of their efforts they have gained development experience that must certainly put them in an advantageous position.

The keys to successful implementation of automated construction equipment appear to be

1. New materials that are easier to work with
2. Designs more attuned to the equipment (robots) that will be involved in the construction
3. Continued development of automated equipment for construction operations, along with continued efforts to integrate this equipment with the information available in the project design

SUMMARY

The Japanese are knowledgeable and capable contractors. They have been willing to invest significantly in equipment, material, and methods research on a long term-basis. This research, even with limited field implementation, has positioned them well as formidable competitors in the construction industry of the future. In addition, their employees have been exposed to tremendous educational opportunities in construction equipment, materials, and methods that will stand them in good stead in the years ahead. The panel's assessment of the Japanese position relative to U.S. firms in three key areas is shown in

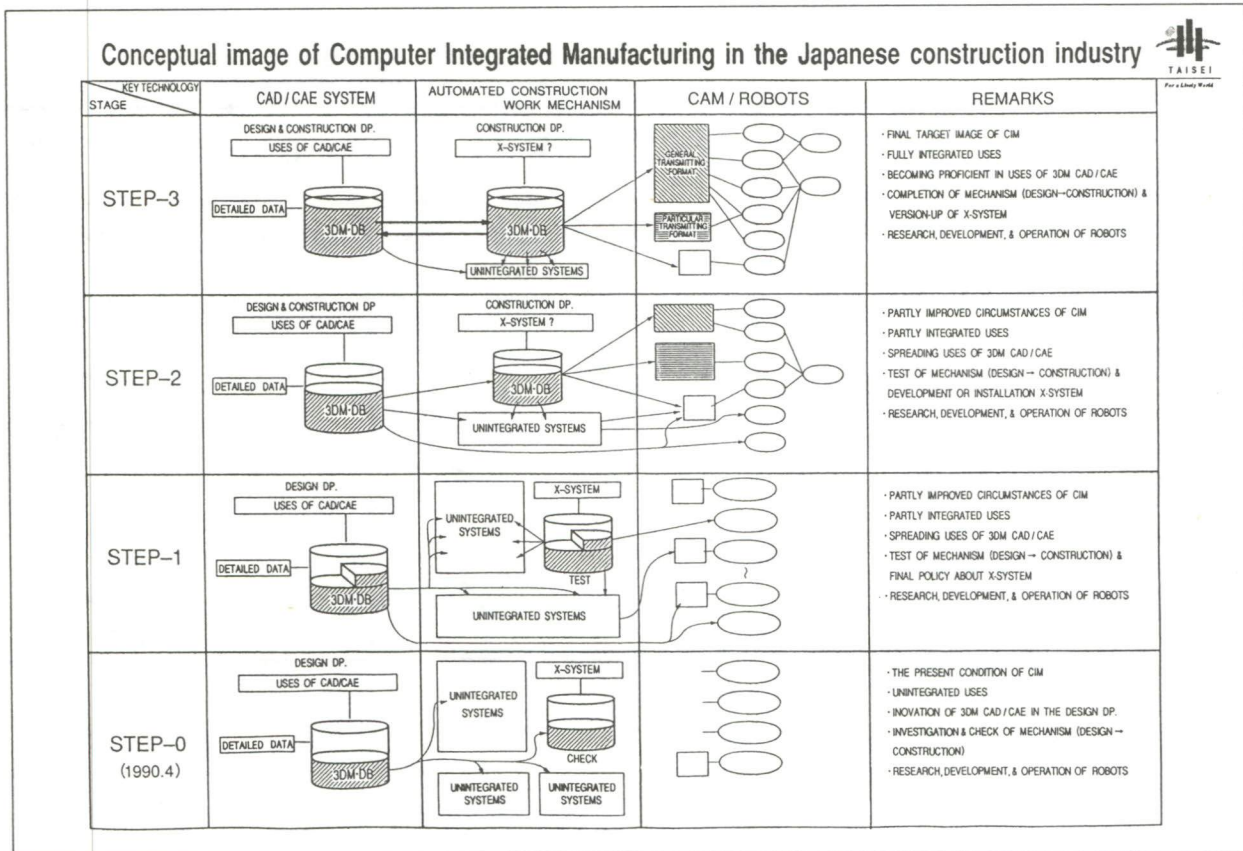


Figure 5.5. Computer Integration in the Construction Industry
(Taisei Corporation)

Table 5.2
Construction Field Operations &
Automated Equipment in Japan
Compared to the United States

ITEM	R&D		IMPLEMENTATION	
	STATUS	TREND	STATUS	TREND
Field Computer Use	-	→	-	→
Construction Methods	+	↗	0	→
Automated Equipment	>	↗	+	→

Coding System			
Japan Compared to the United States			
Status		Trend	
<	Far Behind	↑	Pulling Ahead Strongly
-	Behind	↗	Gaining Ground
0	Even	→	Holding Constant
+	Ahead	↘	Falling Behind
>	Far Ahead	↓	Losing Quickly

Table 5.2 and further discussed in the following paragraphs.

FIELD COMPUTER USE. From an R&D point of view, the Japanese are behind the United States and are likely to remain so. Even though the Japanese are actively developing computer tools to help in management of their projects, the efforts of U.S. contractors in this area should maintain their relative advantage in the future. Japanese firms are also behind U.S. firms in implementation because of the limited number of computerized tools available to field management. There is no reason to believe that this relationship will change in the near future. U.S. firms continue to improve their field competitive position relative to one another through the use of computers for information gathering and assimilation and computer use in field design. To say this is not to imply that Japanese firms are less capable of project management; rather, their contracting system, with less reliance on claims and more concern about long-term relationships with both owners and subcontractors, has not required the development and use of such tools.

CONSTRUCTION METHODS. Japanese construction firms are shown as leading in R&D in this area, with the gap continuing to increase because of the effort which they currently are making in construction method research. Currently, from an implementation perspective, U.S. and Japanese firms are about even, with the trend remaining constant for the next few years. However, if the Japanese continue to invest in R&D, they will likely begin to pull away from U.S. firms.

AUTOMATED EQUIPMENT. It is fairly obvious from the research and development done in this area by Japanese firms that they are far ahead of anything done by U.S. contractors, and there is no indication of effort on the part of U.S. firms to narrow this gap. The Japanese will therefore continue to increase their lead in this area. Even though the Japanese have not fielded great numbers of automated equipment and that which has been tried in the field has not always been a success, they are currently ahead of U.S. firms. It is likely that they will be able to maintain this gap, if not cause it to widen. However, because of the limited number of success stories and the apparent lack of current interest in this area, the panel has chosen to show the trend as remaining constant.

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CHAPTER 6

BUILDING SYSTEMS

D. W. Halpin

INTRODUCTION

Construction research and development in Japan is driven by the lack of and high cost of space. Japan is roughly the same size as the state of Montana, but only 30 percent of its area is suitable for habitation and development. About 130 million people representing the world's seventh largest population concentration are living in this area. Space is at a premium. Therefore, development of the infrastructure involves efficient development and utilization of space. The Japanese seek to find new space by building up, building out, and building down.

Building up is constrained by the fact that Japan is in one of the most active earthquake zones in the world. Building out in the context of offshore construction and the construction of floating facilities is made difficult by typhoons and *tsunami* [tidal waves of unusually large proportions] conditions which are common to the area. Underground construction is used to the maximum degree possible. Lighting, ventilation and relatively poor ground conditions pose major problems in utilizing subsurface areas to solve the space problem. Coping with complex ground conditions has resulted in innovative solutions which place Japan in a leadership position in the construction of subsurface structures. Japanese technology for the underground storage of liquids is among the best in the world.

Recently, the quality of housing and office space has become an issue. Japan has the highest per capita gross national product (GNP) in the world. The Japanese are continually told that they are prosperous. However, as noted in the Mainichi Daily News, 18 July 1990,

...nearly 90 percent of the public believe their country is rich, but only half of them think they are affluent...The housing space available for individuals is 40 percent less than that for the average person living in the U.S., Britain, West Germany, and France. The Japanese have only one-tenth of the park space of the average citizen of these nations...

Office space is at a premium, and the appearance and level of amenities in housing and office space are generally much poorer than those found in other industrialized countries.

Briefings at the Ministry of Construction (MOC) emphasized that one of the key objectives of the MOC in the decade of the '90s is to achieve "good-quality housing and infrastructure that suit the needs of the nation" (Ref. 6.1). Japan is undergoing a boom in office and building (apartment) construction, as shown in Figure 6.1 (Ref. 6.2). Agreements reached by President Bush and Prime Minister Kaifu during the Economic Summit in July 1989 and implemented in the context of the Structural Impediments Initiative (SII) are fueling expanded levels of infrastructure expenditure (Ref. 6.3). Based on these external pressures from the United States, investment in domestic projects is expected to remain strong, with building construction and retrofit being a major component of this domestic investment.

The boom in office building offers an excellent opportunity to improve the amenities of such space. In addition, it provides the opportunity of applying high technology concepts to the construction of buildings so as to improve the working and living environment.

The Japanese see high technology and its use in the design and construction of facilities as a way of solving the space problem and improving the quality of life. Research and development must find ways in which the latest technology can be applied to this problem. Computers, lasers, artificial intelligence, robotics, automation, and advanced materials represent technologies which can be applied.

DISCUSSION OF THE TOPIC

The Building As A Product

As has been typical in seeking solutions to internal or domestic problems, the Japanese have attacked the construction of office and apartment buildings from a new perspective. They have decided to view the building as a system and to seek systems solutions. This allows them to not only address the domestic problem of improving working conditions and living space, but to develop new technology which can be marketed abroad. The concept of the intelligent building is key to this strategy. It is approached as a system which can be developed for marketing as a unit, such as a refinery support system or a mass transit control system. Various products to implement this concept will become spin-offs generating new markets.

As noted by Mr. Kato, General Manager of the Concept Engineering Division at Toshiba, the Main Toshiba Building in Shibaura precinct is an intelligent building and presents a systems solution to improving the working environment of Toshiba employees. It is also a "showroom." It demonstrates how sophisticated building support systems can enhance the work environment and make employees more productive. In this sense, the building is shown to potential customers and generates new business.

The Japanese approach to improving building space is based upon two concepts:

1. Improvement of building amenities
2. Application of electronic/computer systems to enhance the working environment, improve worker communication, and automate building functions

The first thrust recognizes the need of workers and housing residents for a comfortable and stimulating living/working space. Following World War II, qualitative considerations of this type based on psychological aspects of worker productivity and tenant comfort were not a major area of concern. The country was in a rebuilding mode, and space was developed to

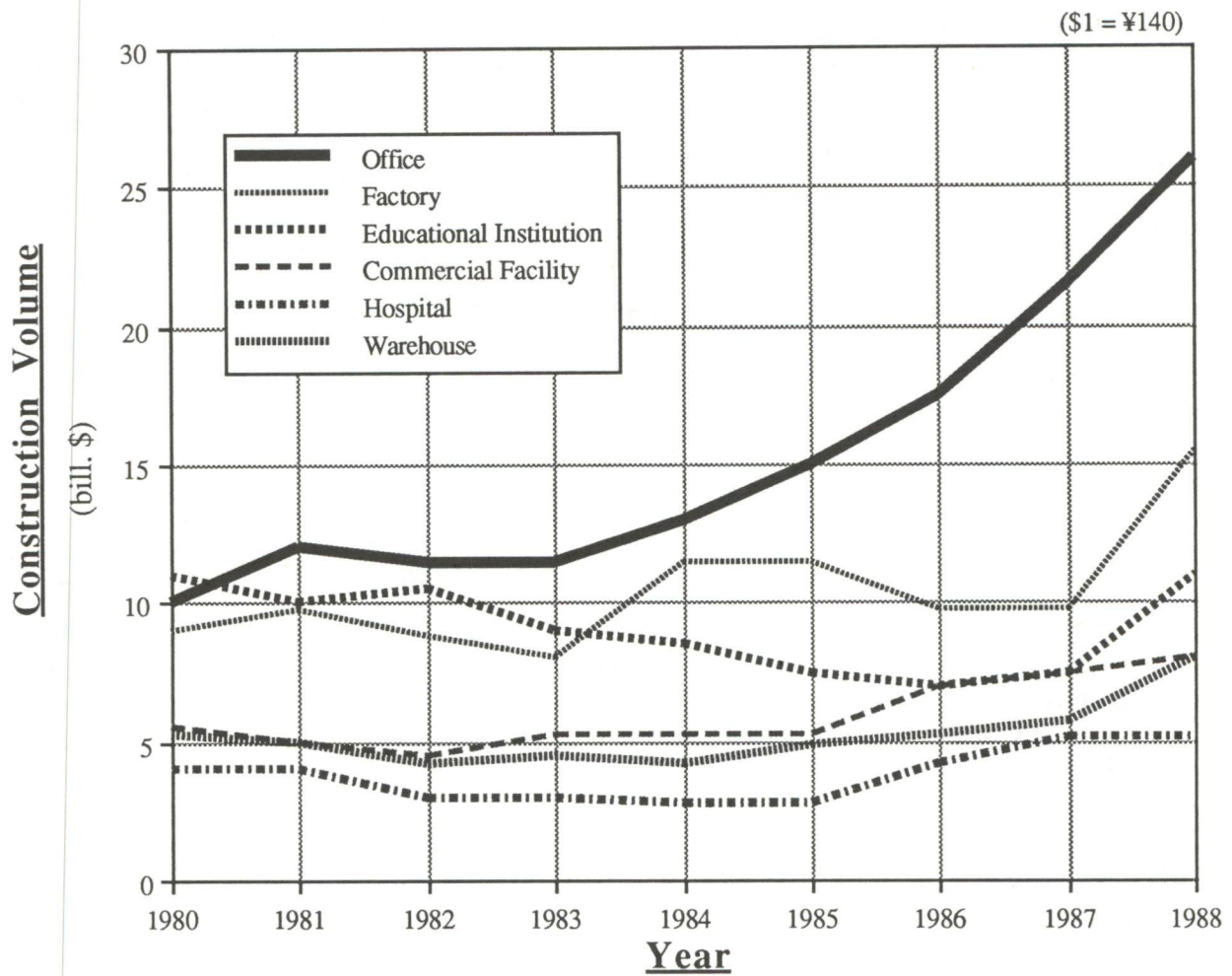


Figure 6.1. Building Construction Market Trends in Japan
(Source: Ministry of Construction, Japan)

be functional. Interiors designed to provide a comfortable and attractive work environment were viewed as somewhat of a luxury. This led to the construction of buildings which are well suited to resist earthquake hazards and capable of supporting daily business activity, but which are Spartan by most Western standards. Visitors from western countries as recently as 1987 have characterized Japanese buildings as "...solid, middle class... (but) ...frankly dull" (Ref. 6.4).

To meet the expectation of the population now entering the work force, qualitative considerations such as building appearance and aesthetics have become more important. The enhancement of the work and living environment so that the employee and resident are happier and more productive is now a pervasive theme in building construction. This concept is captured by the expression, "Amenity." The word amenity was used countless times during briefings held both at building sites and in the modularized housing firms the JTEC panel visited (e.g., Misawa and Sekisui).

The practical application of the systems approach to building design emphasizes four major subareas in intelligent building design as shown, in Figure 6.2:

1. Office service
2. Space planning
3. Building automation
4. Office automation and communication.

Both the idea of "Amenity" and the application of electronics and computer systems to building design are directly related to all four of these topics.

Such items as greenery, atmosphere, athletic facilities, lighting and air conditioning enhance the amenity level of the building. The use of closed-circuit TV, automated temperature and humidity control, as well as electronic file maintenance and video teleconferencing rely upon advanced technologies and computer-based systems.

A study by Kajima Corporation, in conjunction with the design and construction of its office building, developed guidelines for the construction of intelligent buildings. The building features deal mainly with environmental control and enhancement of the work area. Primary focus is on communication, information, and automation. Kajima found that 50 percent of a worker's time is spent on communication. Hence, extensive steps have been taken to facilitate communication activity. In addition, environmental factors to include odor were considered. The building is designed to release various fragrances during the day to enhance the working atmosphere. This attention to one of the senses that would be typically neglected in the United States is indicative of the Japanese approach to detail and the philosophy of "Amenity."

The Intelligent Building

Members of the JTEC panel had the opportunity to visit five intelligent building sites. Three of the buildings were in service, and two were under construction. Buildings that were visited were the

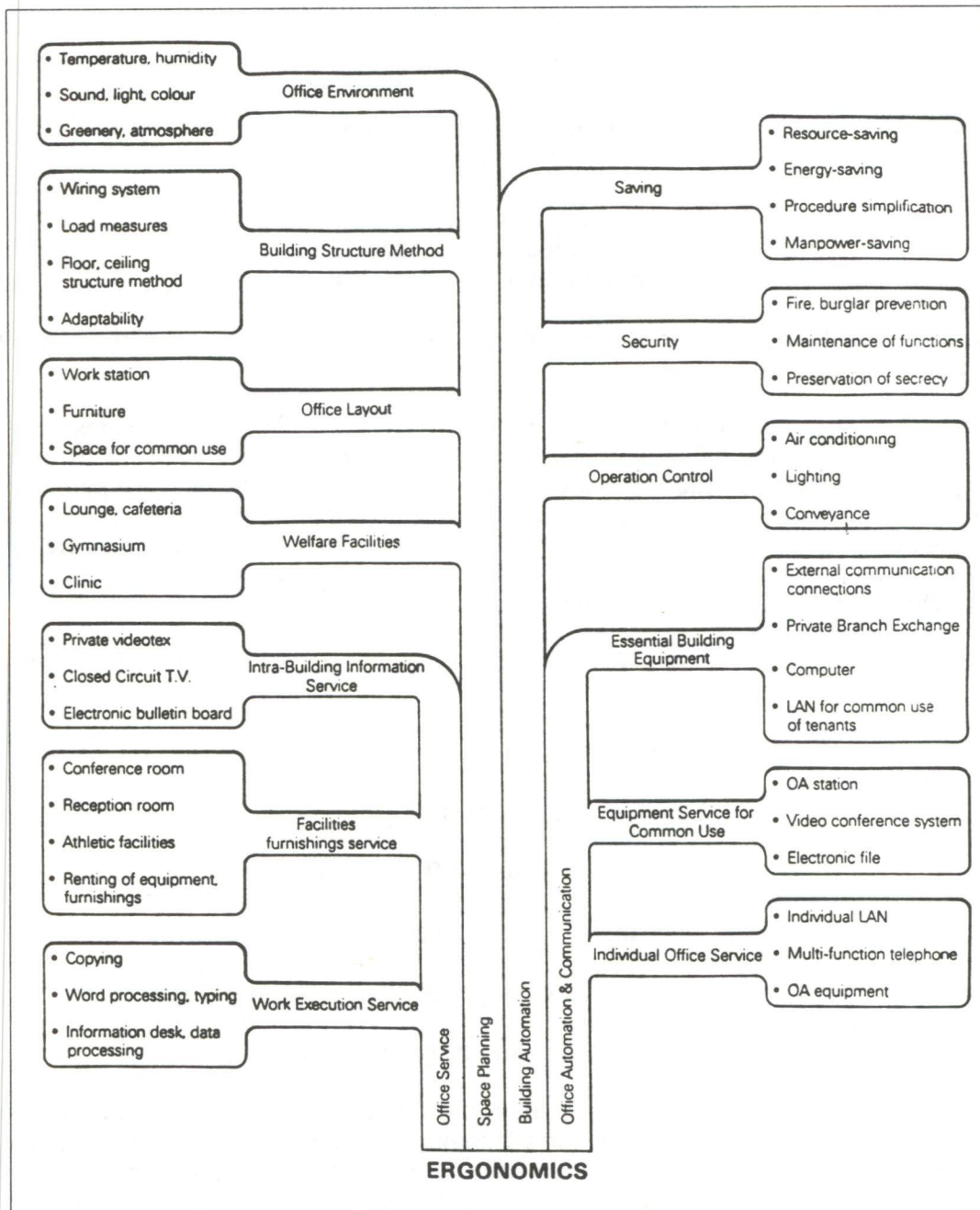


Figure 6.2. Intelligent Office System Research
(Source: Takenaka Corporation)

1. Toshiba Intelligent Building
2. NEC Intelligent Building
3. Kajima Intelligent Building
4. New Shimizu Building Complex (under construction)
5. New Otani Tower (this building will be called the Garden Court Office Building when completed)

All of these buildings utilized various configurations of the intelligent features shown in Figure 6.3.

The Toshiba Main Headquarters Building, completed in 1984, is the oldest of these intelligent buildings. The building was designed by Shimizu Corporation and constructed by a joint venture of Shimizu and Kajima Corporations. The building has a computer support system of Local Area Networks (LANs) connected to minicomputer host machines located on each working floor. The minicomputers on each floor are connected to a mainframe host computer in the basement of the building by a vertical cable and fiber-optic link. This is shown schematically in Figure 6.4. This system supports 2000 work stations.

The concept of Office Automation (referred to as OA in the Japanese literature) is realized in the context of

1. A large "decision room"
2. Supporting teleconferencing facilities
3. High-level executive office systems
4. A business information center
5. Magnetic ID card system
6. Electronic mail and copying system

The "decision room" is a large teleconferencing facility linked to other Toshiba facilities by closed-circuit cable television and satellite telecommunications link. The room itself consists of supporting computers to allow display of data and multimedia presentations on two high definition 100-inch screens. This facility is capable of displaying (in real time) sales and other information from facilities throughout the world to enhance decision-making by the CEO and his advisors.

Selected executive offices are supported by special terminals which make available "a large variety of information simply by pushing two separate keys. The system is programmed with over 300 separate data menus, including sales, profits and other in-house information such as world and domestic economic and business trends, market conditions and so forth." (Ref. 6.5)

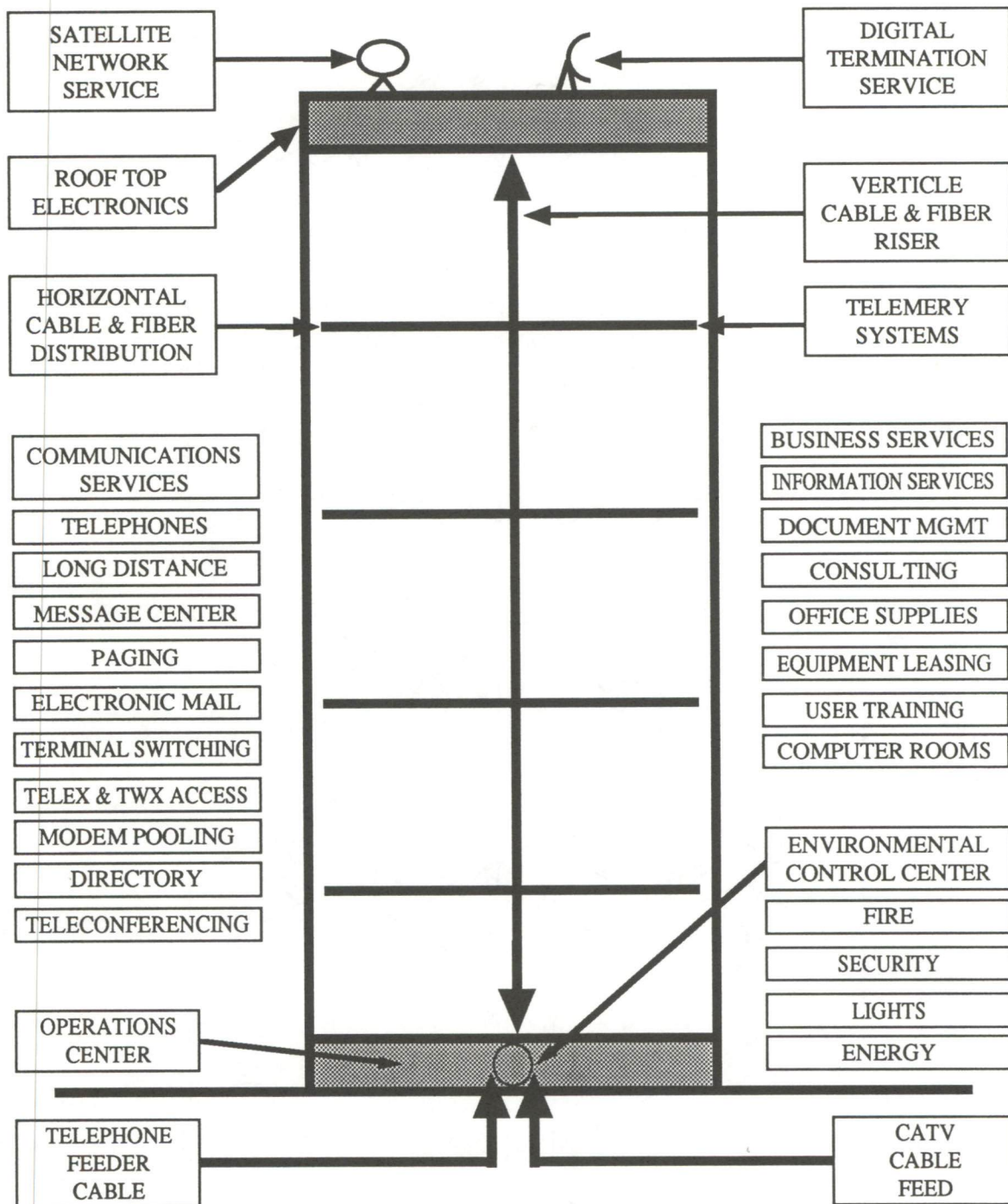


Figure 6.3. Intelligent Building Overview
(Source: Harbinger Group - 6/1/84)

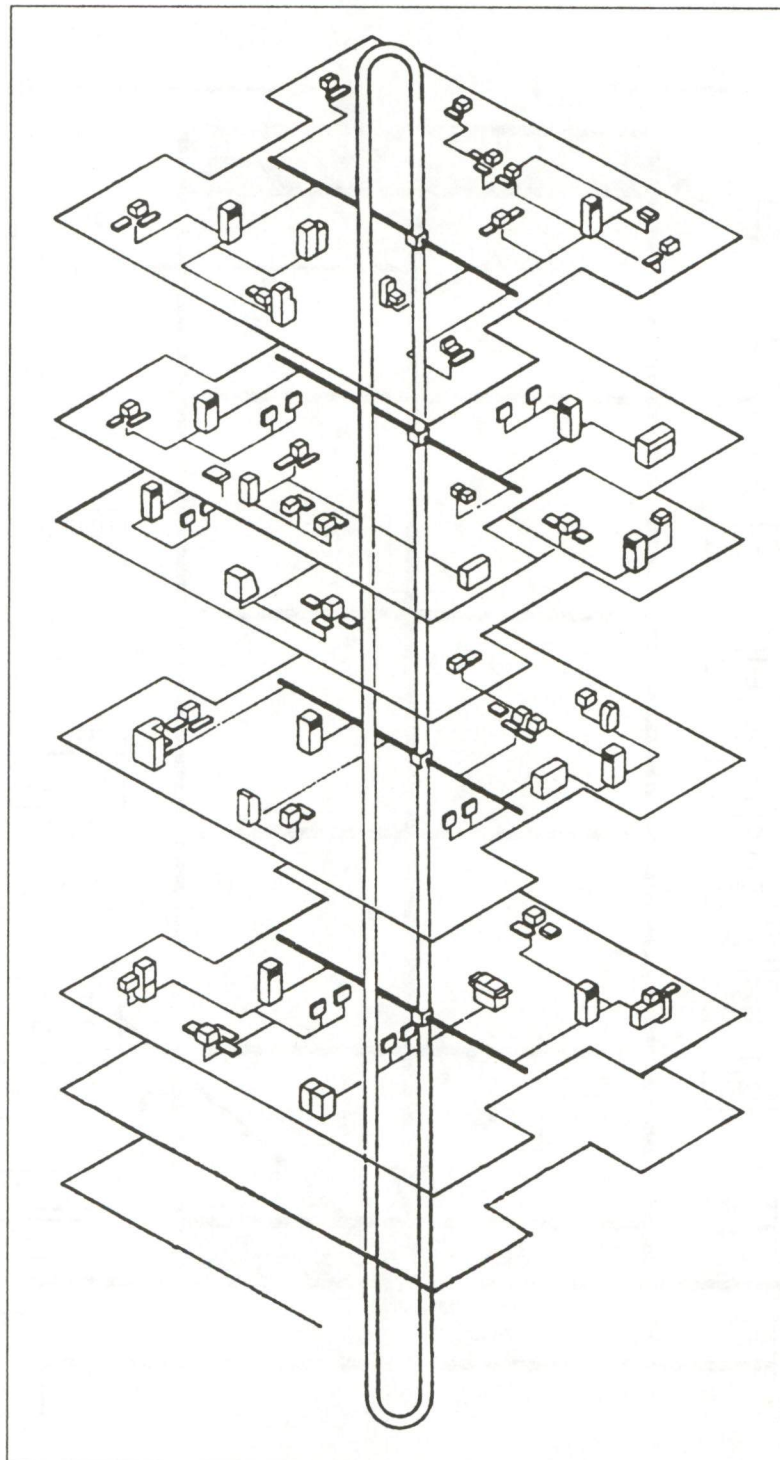


Figure 6.4. Toshiba Building Computer Network Schematic

The business information center includes an automated library which allows for the retrieval of documents electronically. Documents are reduced to an electronic image using the proprietary TOSFILE system. This is an optical filing system utilizing optical laser disk technology. It allows for the storage of 60,000 sheets of data on a 30-centimeter disk. This system can be accessed from a designated terminal on each floor and hardcopy retrieved as required.

A magnetic ID system is used to maintain employee time cards, support security and access functions throughout the building, and to support "cashless" transactions such as purchases at cafeteria and other point-of-sales (POS) terminals within the building. The building also incorporates a sophisticated water-reprocessing system which purifies waste water sufficiently so that it can be reused for nonpotable functions (e.g., toilet flush water, etc.). This system is located in one of the subbasements of the building. The function of this in-building waste water treatment plant is semiautomated and controlled from the central building system's console.

The design of the Toshiba Intelligent Building and the New Shimizu Headquarters Complex is based upon matching tenant needs with required systems. It is assumed that the building owner will be not only leasing space to the tenant, but will be providing a variety of services which will be shared by or at least available to all tenants for a fee. In this context, the operator of the building will be providing both (1) building management services and (2) shared tenant services.

The Shimizu design approach of matching tenant needs to required systems is typical of the approach being taken by other building designers and constructors. Tenant needs include

1. Information communication
2. Round-the-clock functioning
3. Flexibility

Information communication considerations have been discussed above. Round-the-clock functioning addresses the automation of intelligent building systems such as elevator control, heating, ventilating and air-conditioning systems, recycled water systems, lighting and window control systems (including automated control of blinds), and energy efficiency support systems.

The systems which must be designed to address these needs include

1. In-building information
2. Telecommunications system
3. Entrance information system
4. Building control system
5. Security control
6. Wiring system

Automated reception systems allow persons entering the building to electronically query a computer to locate offices, personnel, and shops within the building. This automated reception is typical in many new buildings in the United States. A system observed at one of the new buildings in the Makuhari New Town, however, provides the visitor with hard copy instructions regarding the building and its facilities. A "strip map" showing locations within the building is provided by pressing a button. Figure 6.5 shows an example hard copy.

Shimizu and other intelligent building design firms have developed proprietary systems designed to gain a market position in the emerging intelligent building market. These systems constitute engineering merchandise and represent spin-off products as noted above. Hasagawa defines this type of "engineering merchandise" as follows (Ref. 6.6):

1. Nonconstruction engineering Merchandise
2. Engineering Software Merchandise
3. Other Software Merchandise.

NONCONSTRUCTION ENGINEERING MERCHANDISE. This merchandise group contains treatment systems, air-cleaning systems, and building control systems, all of which can be installed in existing buildings. Air-cleaning systems developed by Shimizu Corporation have already sold 260 units, now used primarily in buildings constructed by other contractors.

ENGINEERING SOFTWARE MERCHANDISE. Engineering merchandise does not always need to involve machinery. It can be engineering knowledge or know-how; for example, site assessment for the planned construction of a supermarket or a factory, and computation of the future balance sheet for a research and development project. Also, demands for environmental assessment are increasing. These engineering software activities have increased as a natural consequence of contractors taking part in a greater percentage of construction projects from the planning stage.

OTHER SOFTWARE MERCHANDISE. The most popular software merchandise is the computer program. There is a growing movement by large general contractors to sell to their smaller counterparts computer programs for design CAD, planning CAD, on-site construction project management, and structural computation.

Typical of this "merchandise" development are proprietary building control systems as noted above. The Shimizu Corporation has developed a system called BECSS (Building Environmental Control System by Shimizu), which is widely used by building owners.

Computer And System Integration

The Japanese approach to shared tenant services is different from that typical in the United States. It is influenced by the permanent nature of the firms occupying the building. In American buildings, the high turnover of tenants places a high priority on flexibility and systems which can be redesigned and readily replaced as the tenant mix changes. In Japan, building space is scarce and building occupants are relatively permanent. Therefore, the design of shared services can be customized to a set of permanent tenants. High flexibility and the need for reconfiguration and replacement is not as great an issue in Japan. For example, the design of building cabling, as well as wall systems, can be fairly fixed since relocation of telephones and computers is normally limited.

Most buildings use terminals tied to host computers. However, very few stand-alone PCs or workstations were observed except at the construction sites. Construction sites use stand-alone work stations for computer-aided design (CAD) activities to support job control



Figure 6.5. Building Reception "Strip Map" Information

functions. Most units observed appeared to be used as terminals to access programs and data bases in a timesharing mode from host mainframe or minicomputers. Although LANs are in evidence, workers use them to access central data files. The interactive use of LANs, where several team members work together to share data developed within personal databases (e.g., such as a design team working interactively within a CAD environment), was not observed. Development of personal databases appeared to be limited.

The Japanese are encountering system integration problems similar to those experienced in the United States in interfacing building support systems. The concept of shared tenant services is also new and is requiring the Japanese to look at building rental from a new perspective. As noted by Rubin (Ref. 6.7):

In Japan...the operation and rental of the speculative buildings were similar to the 'shared tenant service' intelligent buildings in the U.S. It has been difficult to interest tenants in the full range of services offered...

The integration of energy management, security, communication and office automation systems in Japan has been just as difficult as in the U.S...

Further, he notes that little standardization of hardware is present since manufacturers use differing data transfer protocols and umbrella organizations have not yet formalized interface standards.

It would appear, however, that major construction and vendor firms are working to overcome this problem. Firms with a vested interest in overcoming the barriers to system integration include major construction firms as well as large hardware and electrical firms such as Hitachi, Mitsubishi, Toshiba, NEC, and NTT. As manufacturers of building equipment such as elevators, telephone and computer systems, and ventilation and lighting equipment, the large vertically integrated firms see solution of the interfacing problem as a necessary breakthrough required to establish market share in the intelligent building market.

Cutting Edge Building Systems Technologies

A review of the research publications of the Big Six construction firms reveals that efforts to establish controlling technological positions in the building construction sector is driving research in a wide variety of building systems.

1. **BUILDING ELECTROMAGNETIC PROTECTION SYSTEM.** By sheltering a building from outside electromagnetic noise, it is possible to transmit information inside without using cabling. An additional benefit is the enhancement of transmission security. (See Fig. 6.6)
2. **FREE-ADDRESS OFFICE SYSTEM.** In a free-address office, workers share chairs and desks to raise efficiency. Walls contain storage space, and each employee's materials are placed in a movable cabinet. Workers, usually sales representatives, spend about half of their time at their desks. By using the free-address system, certain advantages can be achieved:
 - a. For a staff of 100, 50 work stations can be used.

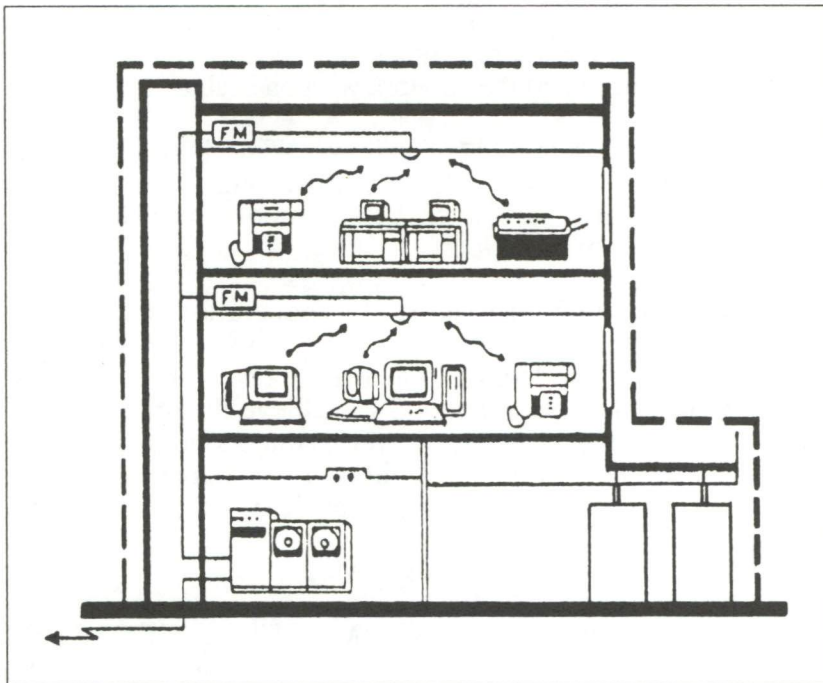


Figure 6.6. Schematic of Building Electromagnetic Protection System

- b. A reduction in crowding occurs due to shared use of support resources.
 - c. Support resources (e.g., work stations, etc.) can be larger and of better quality. Better quality leads to improved "Amenity"
- 3. **ASEISMIC FLOOR SYSTEMS.** This system is used in special areas where sensitive equipment such as computers and telecommunication devices are located. It is also being used for the floors of fire prevention centers and art museums.
- 4. **HOME AUTOMATION.** This system provides residents with all necessary building information and allows fire prevention and building security to be managed more efficiently. Using Local Area Networks, each home is connected to the network with one cable.
- 5. **SOLID WASTE DISPOSAL SYSTEM.** This is a waste collection system for condominiums. Each family puts its trash in special containers, which are then carried to an automatic disposal unit that serves the residents of each floor.
- 6. **CLEAN ROOM AUTOMATION.** In cooperation with a conveying equipment maker, a system has been developed for automated conveyance of semiconductors to and from a clean room environment. The system uses a floating method to achieve dust-free conveyance. This system is being promoted in the semiconductor industry. It is expected that this new technology will be a springboard to obtaining full turnkey orders from semiconductor companies in the future.
- 7. **FLEXIBLE FLOOR WIRING SYSTEMS.**
- 8. **CRYSTALLIZED LIQUID ICE THERMAL STORAGE SYSTEM.** This system uses inexpensive off-peak electricity rates to make ice that is then melted and used for cooling during the day. Because the ice crystals are like sherbet, the heat-transfer efficiency is increased significantly, making possible the compactness of the thermal apparatus.
- 9. **GRAY WATER SYSTEMS.** This system processes the water from kitchen sinks, bathrooms, laundry rooms, cleaning, and so forth. The quality of the water is improved, and the treated water recycled for use in flushing toilets and washing cars (i.e., nonpotable use) (Fig. 6.7).
- 10. **AUTOMATIC BLIND SYSTEM FOR SUNLIGHT AND LIGHT CONTROL.** This system controls indoor light by automatically opening and closing blinds and by turning lights on and off. The heat load caused by sun shining through windows is reduced, and lower-cost air conditioning is made possible (See Fig. 6.8).
- 11. **TELECONFERENCING FACILITIES.**
- 12. **SPECIAL BUILDING MATERIALS FOR SINGLE AND MULTIFAMILY HOUSING.**

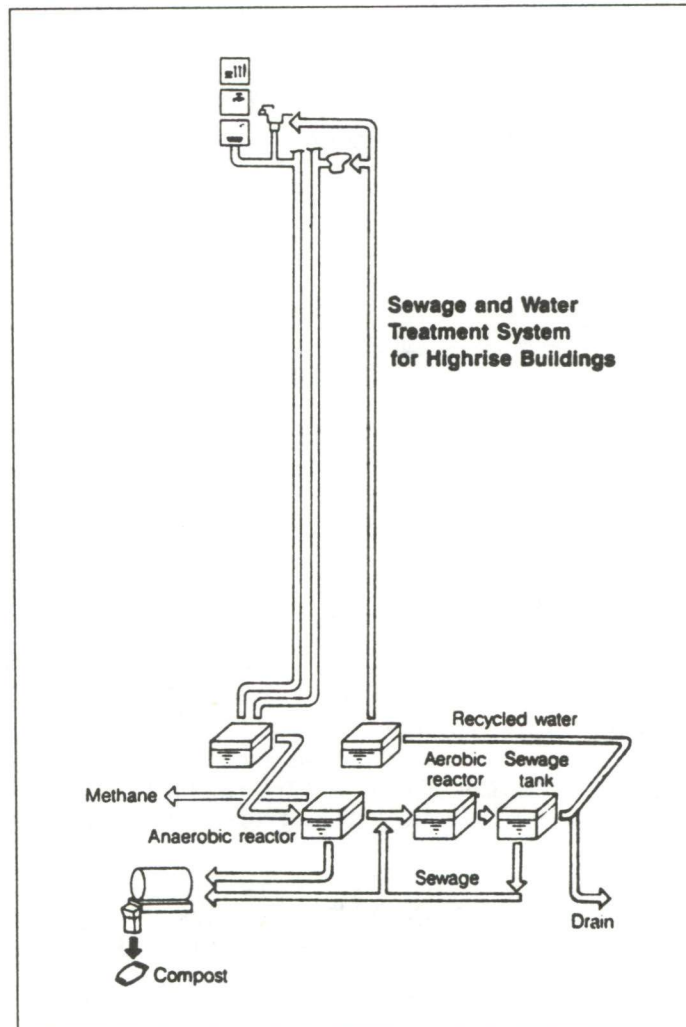


Figure 6.7. Schematic of Gray Water Recycling System

Energy Conservation System

Due to its lack of natural energy resources, alternate energy sources and energy conservation systems are a major area of research and development in Japan. The Super Energy Conservation Building at the Ohbayashi Corporation Technical Research Institute utilizes 98 energy conservation measures to reduce the life cycle cost of the building by approximately 50 percent. The cost of the building to include construction cost, operating cost, maintenance cost, and mechanical replacement and repair costs, based on a 65-year service life, is shown in Figure 6.9. The 98 energy saving features are tied to eight specific technological areas:

1. Double skin construction
2. Flat-slab construction
3. Solar collector system
4. Solar cell
5. Machine room design
6. Thermal storage tank
7. Energy conservation lighting system
8. Underground solar energy storage

The south-facing wall utilizes a double glass wall to create a greenhouse or passive solar zone. When cooling the building, natural draft is utilized for reducing cooling load. When heating the building, the solar heating within this zone is used directly to heat the building.

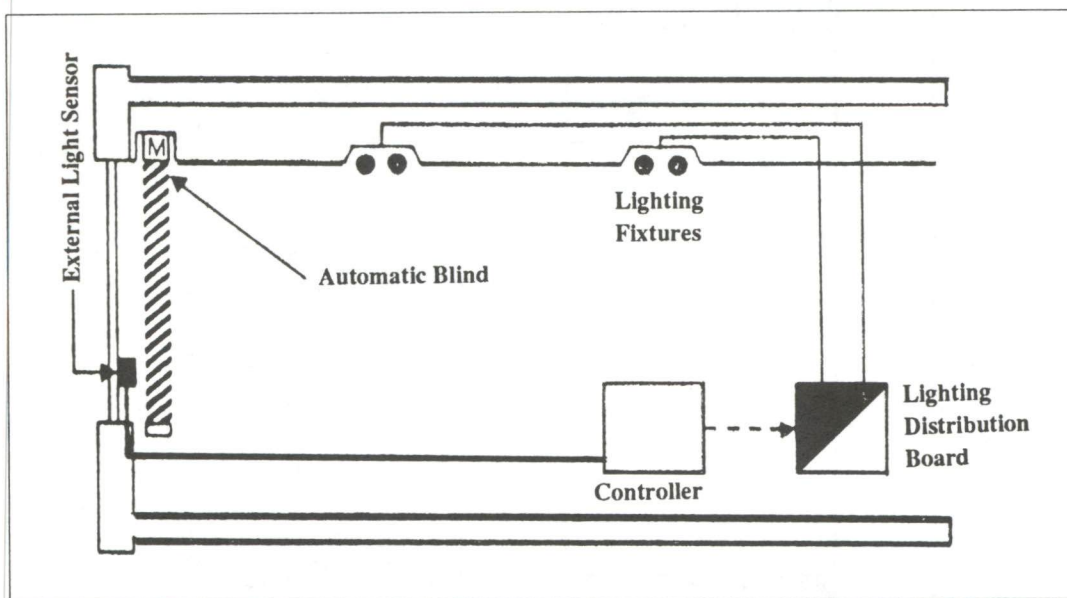
Flat slab construction allows the reduction of floor-to-ceiling distances and reduces the overall volume of the building. This reduction in floor height is achieved using a ductless air supply system.

The machine room is located on the top of the building. It utilizes such features as (1) thermal wheel exchanger, (2) non-leaky damper, (3) a large temperature differential system, (4) air exhaust using natural draft cooling, and (5) high-efficiency motors.

The lighting system uses automation to minimize the lighting load. Certain features allow for automatic turnoff of emergency exit signs and automatic dimming control based on the amount of daylight available.

In autumn, collected excess solar energy is stored in the earth through underground pipes for utilization in winter. This heat reservoir reduces the winter heating requirements.

Based on its unique design, the Ohbayashi Super Energy Conservation Building received the 1984 ASHRAE Energy Award given by the American Society of Heating, Refrigerating and Air-Conditioning Engineers.



**Figure 6.8. Automatic Blind System
(Side Elevation)**

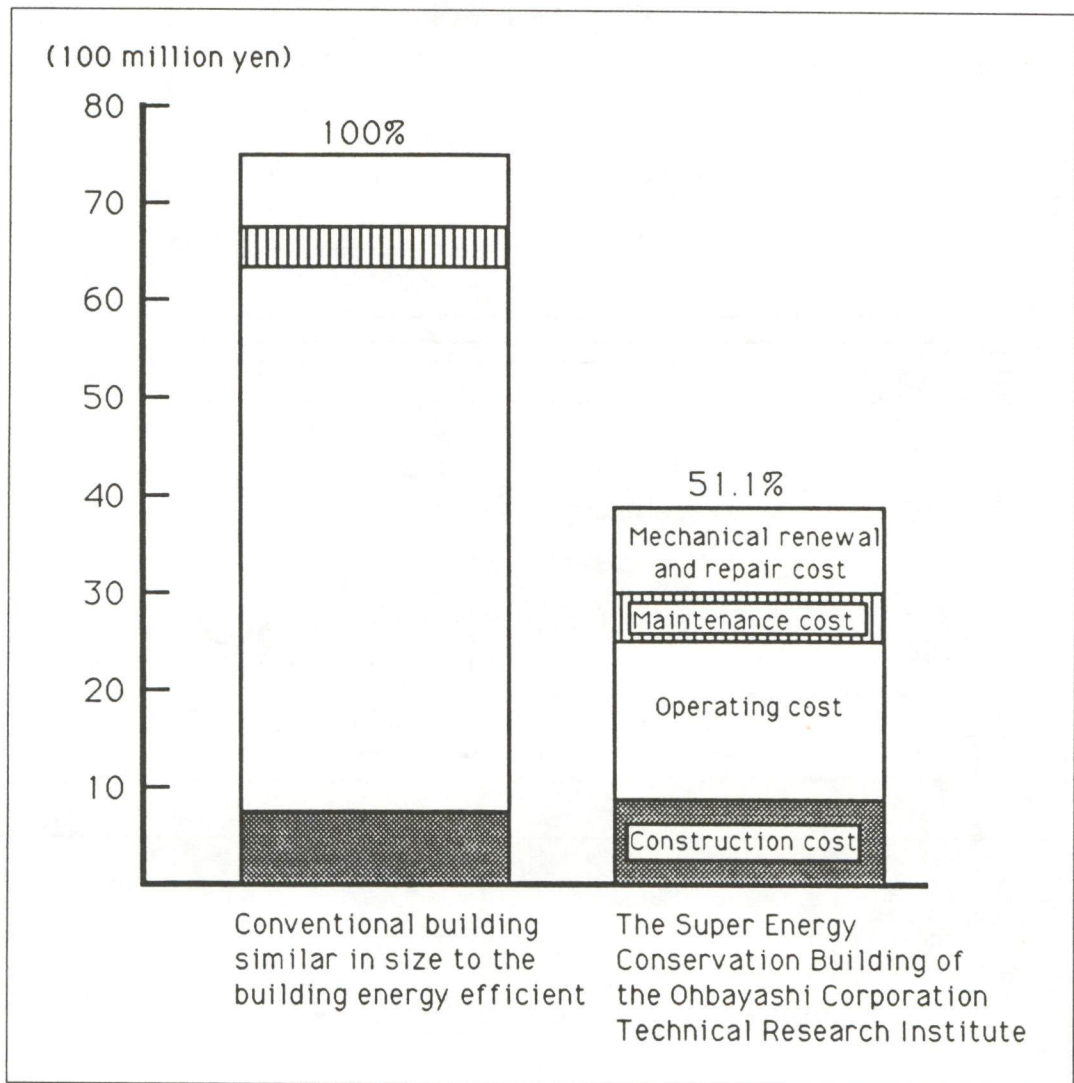


Figure 6.9. Life Cycle Cost Comparison

(Source: Ohbayashi Corp. Technical Research Institute)

Futuristic Building Technologies

New and innovative methods are being pursued by the Japanese in their efforts to "build up." Although these concepts are in the prototype stage, the major construction firms appear dedicated to perfecting and exploiting new technologies in the high-rise building area.

One of these techniques described to the JTEC panel is the Ohbayashi Automated Building Construction (ABC) System. This approach utilizes a super building platform which moves upward with the completion of each floor. The super building platform or construction floor is enclosed, and the work of constructing the building frame is carried out by robotic devices. A picture of the system is shown in Figure 5.3. This method will be tested in concept on a prototypical building within the near future. The ABC system is typical of the Japanese approach to advancing the state of the art by "a process of fusing diverse technologies into a creative whole" (Ref. 6.8).

The major construction firms are also designing "superhigh-rise" buildings which will be significantly taller than anything built to date. Overcoming the problems of wind and earthquake loading as well as vertical transportation also requires an innovative "fusion of technologies." Kajima's 800-meter high-rise building concept is typical of this development. As stated in its literature (Ref 6.9),

The Kajima plan calls for constructing a 200-story building composed of twelve 50-story cylindrical units, each 50 meters in diameter and providing approximately 2,000 square meters per floor....Sky lobbies located above each 50-story unit serve as terminals for high-speed shuttle elevators from the entrance lobby as well as transfer points to local elevators operating within each building unit...

Kajima has incorporated [into the building]...its latest earth-quake and wind controlling building technology, which not only ensures structural integrity during an earthquake or typhoon, but minimizes building vibrations to assure a pleasant, virtually vibration-free living environment.

Takenaka Corporation is also designing a superhigh-rise building structure which will be a city within a city. The project is called Sky City 1000. It consists of "a conical artificial city with a diameter at the top of 160 meters and a diameter at the bottom level of 400 meters, covering a total of 800 hectares" (Ref. 6.10). The structure will be over 1000 meters in height.

Since the building will be too heavy (at 6 million tons) to be supported by conventional column and beam construction, a new structural system called "conic shell structure" has been developed. "Composite panels constructed of extremely strong carbon fiber and material 40-50% lighter than reinforced concrete shall be utilized in construction" (Ref. 6.10). It is estimated that the structure will have a cost of approximately \$500 per square foot and require 14 years to construct.

These efforts at planning and building supertall structures and automating the building process are indicative of the Japanese commitment to "building up" to gain more living space. Solving the problems of designing and constructing such futuristic structures is driving research that will inevitably lead to breakthroughs in building construction technologies.

SUMMARY

The quality of the buildings and support systems observed equals that of new buildings being constructed in the United States. The need for new building space is fueling large expenditures in this sector. This, in turn, is leading to a concerted effort to perfect the concept of the intelligent building.

In the Japanese market...plans are being made to construct intelligent buildings and 'smart' commercial zones furnished with INS (Information Network Systems), cable television, office automation equipment, and other sophisticated information systems. In addition, Japanese contractors are optimistic about plans mapped out by local governments in Japan to build high-tech cities that will house research and development facilities and educational institutes in each prefecture (Ref. 6.6).

Innovative systems are being developed to integrate the concepts of amenity, automation, and ergonomics to improve the quality of living and working space.

These systems, however, are adaptations or syntheses of existing technology. With a few exceptions, existing technologies are being altered to meet the needs of the Japanese building construction industry. In this sense, the Japanese seem to be following a basic strategy of adapt, improve, and resell. A general assessment of the status and trend of R&D and implementation of some areas within the building systems area is given in Table 6.1.

Figures quoted to the panel during site visits would indicate that the per-square-foot construction cost in both the building and housing markets greatly exceeds that typical in the United States. The cost of the New Shimizu Headquarters complex will exceed \$300 per square foot. Square foot cost of the prefabricated housing observed at Misawa Homes exceeds \$160 per square foot. The quality of these facilities were comparable to those being built in the United States, but the Japanese costs are considerably higher.

The use of automation is being applied to provide buildings with a low level of intelligence. New buildings utilize magnetic card access systems, extensive LAN systems to enhance communications, teleconferencing capabilities, and automated building control systems to achieve a new standard in building amenity. However, these concepts have also been applied widely in buildings throughout the United States.

As noted by Rubin, facility management is gaining recognition as a profession in Japan, as in the United States (Ref. 6.7). A New Office Promotion Association was established in 1987 under the auspices of the Ministry for International Trade and Industry (MITI). It had 40 sponsoring organizations and 247 corporate members as of April 1990. The Japan Facility Management Association has existed for three years and has 120 organizational and 125 professional members.

The Japanese fascination with advanced technology and its application to problem solving in the construction industry was in evidence at the new buildings visited by the JTEC team. However, with the exception of energy conservation and clean room technologies, no particularly new or innovative building systems research was observed. It would appear at this time that the United States still has a leading position in building systems research pertaining to conventional office building construction. In the housing area, a larger percent of the Japanese industry is utilizing modularized construction techniques (approximately 11-12 percent), and customized materials such as precast autoclaved lightweight ceramics and

Table 6.1
Building Systems in Japan
and the United States

ITEM	R&D		IMPLEMENTATION	
	STATUS	TREND	STATUS	TREND
Building Automation (Intelligent Features)	-	↗	0	→
New Housing Materials	0	↗	+	→
Energy Efficient Buildings	0	↗	+	→
Building Amenities	-	↗	-	↗
Clean Rooms	>	↗	+	↗

Coding System Japan Compared to the United States			
Status		Trend	
<	Far Behind	↑	Pulling Ahead Strongly
-	Behind	↗	Gaining Ground
0	Even	→	Holding Constant
+	Ahead	↘	Falling Behind
>	Far Ahead	↓	Losing Quickly

concrete (PALC) are more common. Home automation, safety, and materials to include modularized panel construction are areas of R&D. Research in energy-efficient housing units was not observed.

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CHAPTER 7

TYPES AND DESIGN OF STRUCTURAL SYSTEMS

J. W. Fisher

INTRODUCTION

The JTEC panel's visits focused on bridge and building structures. Building structures included prefabricated housing; office, apartments, and factory buildings; and high-rise building construction. Information was also obtained on structural systems for use in underground structures such as tunnels and storage caverns.

The panel observed no "new" structural systems in the various types of structures that it examined and reviewed. In general, the traditional beam-column type of building structure was observed for the various construction materials used in building construction. Connections of steel components were welded or bolted.

Since Japan is located within an active seismic area, the type of structural system is largely determined by the required earthquake resistance of structures (Ref. 7.1). Hence, seismic resistant structures are used throughout the country for buildings and bridges (Ref. 7.2).

Japan has about 43,000 bridges with span lengths ≥ 15 m on the national highways, expressways, and prefectural roads. About 43 percent are steel, 54 percent are reinforced and prestressed concrete, and 3 percent are other materials (Ref. 7.16).

System building concepts have been extensively introduced into prefabricated housing and buildings. This has allowed a modular approach suitable for factory automation, which makes extensive use of computer-aided design and production. Mass production of standardized parts and components reduces costs as well as the number of components (Ref. 7.4; See also Misawa Homes trip report, Appendix A).

Extensive use of computers is apparent in all construction-related activities for the design and analysis of structural systems (Ref. 7.5). CAD/CAE systems appear to be used more extensively on routine projects in Japan than in the United States. Finite element systems are

used extensively, on par with the United States. It does not appear that Japan is doing a lot of research in underlying computational mechanics, nor in advancing the theory of finite elements. Typically, the Japanese have watched the research and development of NASTRAN, ANSYS, GTStrudl, etc. They have very effectively made commercial use of these developments by utilizing these packages with workstations and other computer hardware. The United States (particularly academic institutions) seems more interested in formalizing the design process and developing computer-based concepts and tools to approach the overall design process.

Similarly, in knowledge-based system applications (Artificial Intelligence or AI), there was evidence of application of AI shells from abroad to capitalize on the in-house knowledge of specialists. However, there was little evidence of research and development work in knowledge representation and processing theory that relates to structural and civil engineering applications.

Work on integrated systems such as information flow systems between processes and phases (i.e., planning, design, fabrication, erection and operation), seems to rely heavily on software tools from abroad. Nevertheless, the Japanese are acquiring these tools and carrying out a significant effort on integration of the office environment (see Chapter 6). Simulation of a design and the effects of the environment using computer tools and other kinds of media are common at all of the major contractors.

DISCUSSION OF THE TOPIC

Steel Structural Systems

The 1988 material distribution, as represented by floor area, for structural framing in building construction is listed in Table 7.1 (Ref. 7.3). In terms of overall floor area, steel is the most widely used material, although timber is a close second.

Availability of materials and seismic design requirements have led to extensive use of the rigid frame construction process in Japan (Ref. 7.6). This type of structural system was in evidence at many of the building construction sites. Figure 7.1 shows an example of the rigid steel frame structure near the elevator core of the New Otani Intelligent Office Building. The prefabricated elements with beam extensions made extensive use of shop-welded joints in combination with field-welded and bolted connections. The three-story columns were erected in this structure with the aid of a remote release clamp (Figure 7.2) which allows construction workers to detach the rigging from the steel column assembly and beam elements in a safe and easy way.

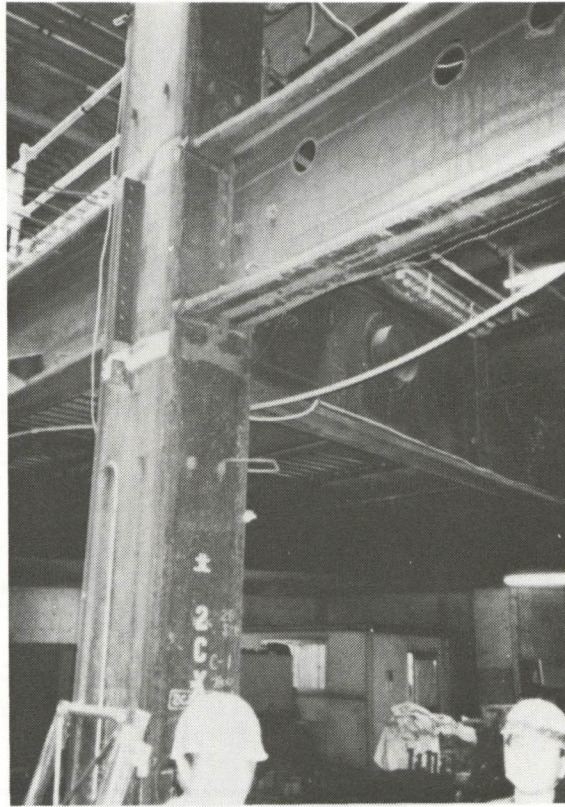
Extensive use of built-up box columns were noted on many steel frame structures, as illustrated in Figure 7.1(a). This scheme appeared to standardize the connections needed in the two planar frames of the structure. Concrete-filled box columns are common.

The layered construction method of completing three floors at a time from the bottom up makes extensive use of the column-beam steel frame and a steel-formed deck or prefabricated concrete slab to serve as the formwork for the cast-in-place concrete floors. This composite system is similar to systems used in the United States. The layered construction of the steel structure permits inside construction with improved safety.

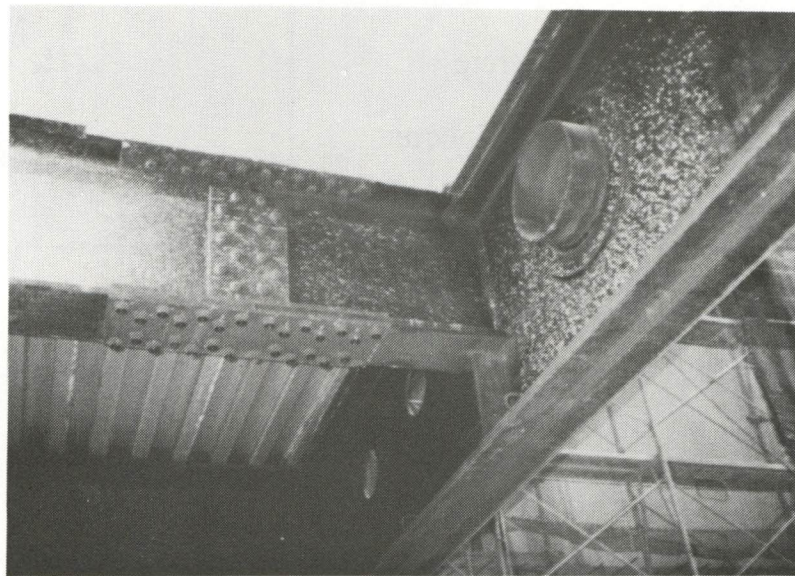
Significant focus on system type housing and buildings has developed for steel structural systems. A major effort toward standardized structural members suitable for factory fabrication and automation has resulted. This incorporates modular systems with interchangeable members and connections that allow for mass production of standard parts at

Table 7.1
Material Distribution for Structural Framing in 1988

MATERIAL	DISTRIBUTION
Steel	36%
Timber	32%
Reinforced Concrete	21%
Steel/Reinforced Concrete (Encased)	11%



(a) View of Steel with Combined Welded and Bolted Connections



(b) View of Beam Stub to Girder Detail

Figure 7.1. Typical Steel Construction Details at New Otani Tower with TMCP Steel

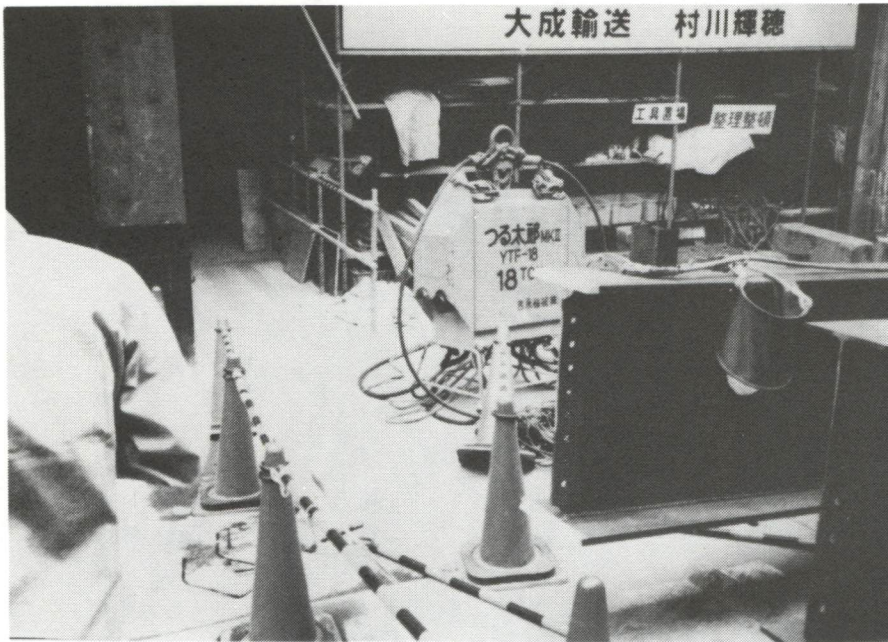


Figure 7.2. View of "Intelligent Tool" to Permit Release of Cables Used to Install Columns and Girders in Steel Frame (Note Details of Beam End for Welded Joint)

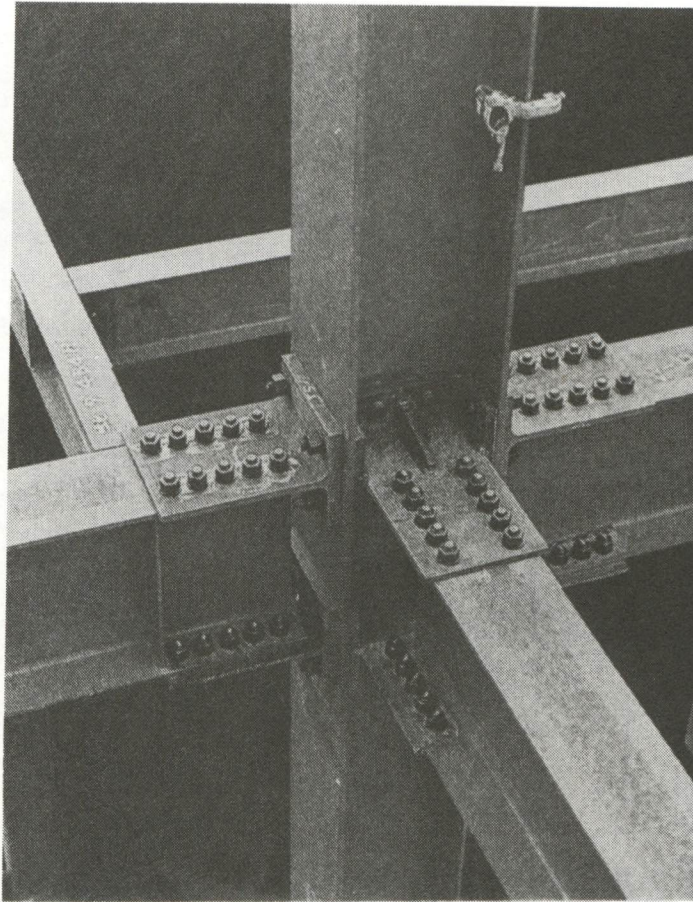


Figure 7.3. System Building Field-Bolted Rigid Frame Connections (Ref. 7.4)

special plants providing accurate dimensions and quality. Figure 7.3 shows a factory processed steel frame and bolted connections to provide an earthquake-resistant rigid frame. The members and connections are easily handled on-site, resulting in greater safety and faster installation. The number of components (pieces and bolts) has been reduced by 60 percent compared to the normal steel frame structure. A new type of hot-rolled wide flange beam with fixed section depth and different flange thickness in a series enhances tolerances, optimizes steel weight, and promotes standard connections (Ref. 7.7).

The development of special steels has been one of the major factors promoting the use of steel in structural systems in Japan. This includes the rolled wide flange shapes with specified depth between the flanges cited earlier and, more importantly, the development of the new structural steels reviewed in Chapter 4.

The TMCP (thermomechanical control process) steel materials are being utilized to fabricate steel frames, as shown in Figure 7.1. Numerous construction sites appeared to be making use of this material because of its ease in fabrication (see Chapter 4). This results in a substantial decrease in fabrication cost that more than offsets the cost of the material. This point was cited by Dr. Tokunaga at the Washington, D.C. JTEC Workshop when he noted use of the material had made Japanese shipbuilders once more competitive with lower labor cost construction in Korea (Refs. 7.8, 7.9). These materials are now available for structural applications up to a 100-mm thickness with 55 - 65 ksi (380 - 450 MPa) yield strengths. Furthermore, these steels have an improved yield-to-tensile-strength ratio (≤ 0.8) which enhances their structural performance, as illustrated in Figure 7.4. The characteristics of these steels improve their performance under adverse loads (i.e., earthquake) as well as enhance the strength and ductility of the frame. Both plate and rolled shapes are becoming available to users.

At the present time, the United States does not have the capability of producing these types of materials for any of the structural markets (shipbuilding, buildings, bridges, offshore structures, etc.). It seems clear their characteristics are a way to provide reliable construction more competitively than the structural steels commonly used in the United States.

Other special steels for structures are also being developed and marketed in Japan. The fire-resistant steel cited in Chapter 4 permits steel frame buildings with a significant improvement in fire protection (Ref. 7.7). Figure 7.5 shows an external steel structure that would not require any additional fire protection since the temperature rise caused by radiation would not be detrimental. Experimental work at industry and government fire laboratories have confirmed the applicability of this structural steel (Ref. 7.11). The application of this material has demonstrated that it shortens the construction schedule, eliminates spraying of insulation, and increases floor space.

Japan's Ministry of Construction (MOC) is cited as having initiated a comprehensive technology development program on the practical application of high-strength steels, which has promoted the development of standards and design procedures (Ref. 7.10). It is clear that this effort is productive.

Work was also indicated as being carried out on a "new" joint not dependent on bolts or welds. The goal is to provide improved construction and automation. No details of this work was provided.

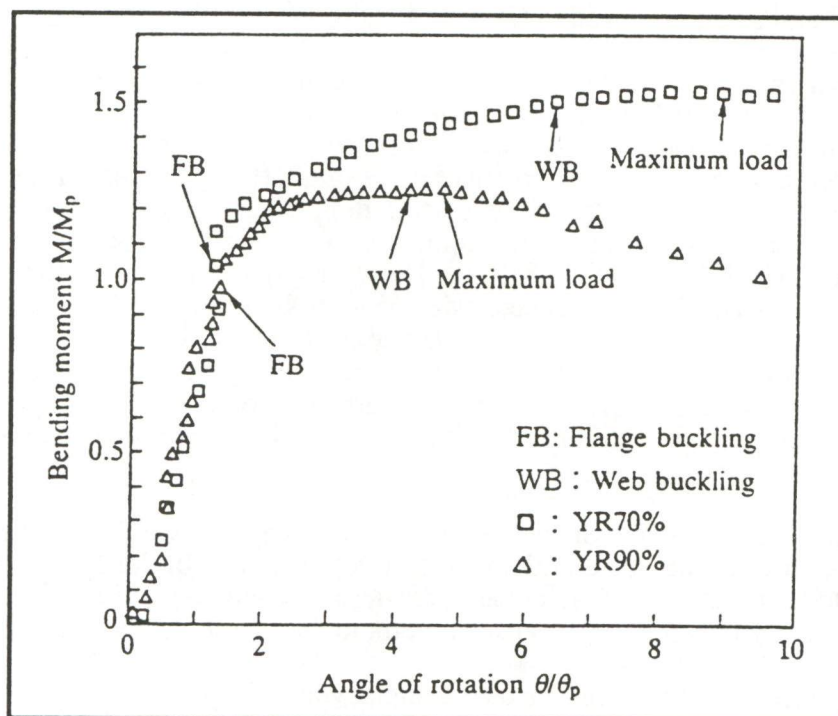


Figure 7.4. Bending Test Comparison of a Low Yield Ratio (YR= 70%) and Conventional Yield Ratio (YR= 90%) with $\sigma_y = 85$ ksi (Ref. 7.11)

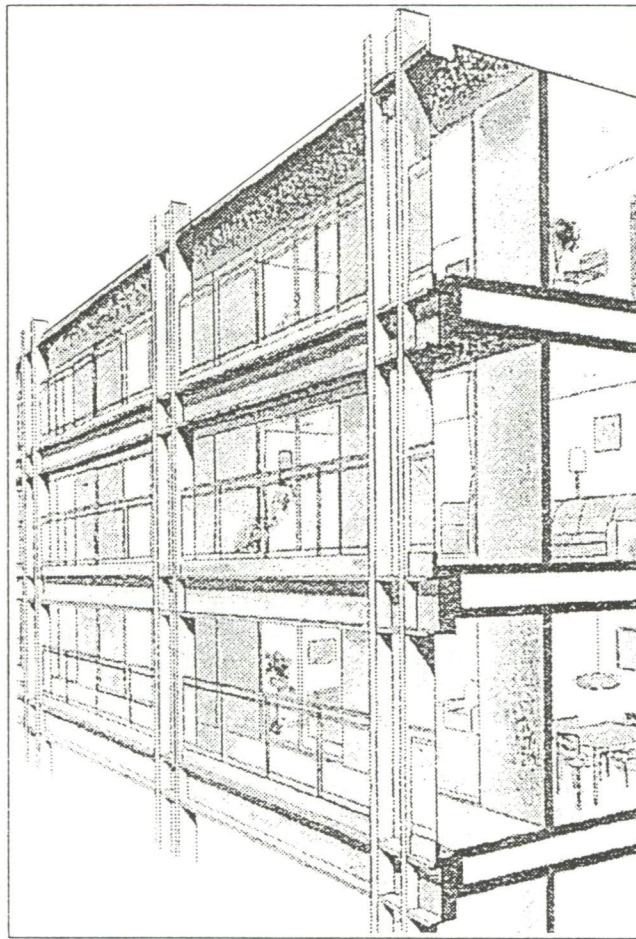


Figure 7.5. External Steel Skeleton not Requiring Additional Fire Protection (Ref. 7.12)

Reinforced/Prestressed Concrete Structural Systems

As noted in the introduction, Sato has indicated that reinforced/prestressed concrete represent about 21 percent of the constructed floor area in building construction (Refs. 7.3, 7.6). Extensive use of prefabricated concrete elements was evident in several of the building projects visited by the JTEC team. This included the New Otani Intelligent Office Building and the Ohkawabata Housing (River City 21) project. Figure 7.6 shows erection of precast concrete beam elements in a high-rise condominium unit at River City 21. Prefabricated girders were also used in below-ground stories of the New Otani Tower, and prefabricated concrete elements appear to be used extensively in underground construction.

The commonly used concrete strength for the concrete frame members is at present 4 - 5 ksi (28 - 34 MPa). Work on high-strength concrete for high-rise construction is currently under study by Ministry of Construction laboratories as well as the construction company institutes (Refs. 7.12, 7.13). Chapter 4 has reviewed the materials work underway on both steel and concrete in an attempt to develop new structural systems. Reference 7.13 details major studies planned on structural elements as well as methods to analyze and design concrete structures.

Figure 7.7 shows a reinforced concrete cage and steel stubs for connecting beam elements (Ref. 7.12). Major efforts appear to be underway on developing prefabricated concrete elements utilizing new materials.

Concrete bridges in Japan's coastal areas have experienced deterioration attributed to chloride ion penetration of the concrete (Refs. 7.14, 7.15). This has resulted in studies to develop repair procedures and guidelines (Ref. 7.14). This experience with deterioration has also resulted in experimentation to develop technology for improving the durability of concrete (Ref. 7.15). This resulted in studies on application of carbon-fiber-reinforced plastics (CFRP) for the tendons of prestressed concrete members (see Chapter 4). Studies beginning in 1985 resulted in construction of a prestressed concrete bridge with I-shaped girders reinforced with CFRP tendons and with epoxy-coated reinforcement bars for stirrups. This structure was completed in 1988 and remains under observation.

Another application of carbon-fiber-reinforced concrete (CFRC) has been the development of CFRC curtain wall components as a replacement for conventional precast concrete (Ref. 7.16). Figure 7.8 compares the Kajima-developed CFRC unit to a conventional precast unit.

Other Structural Systems

Steel-Reinforced Concrete

The extensive use of concrete-encased steel members has resulted in the identification of this type of construction as steel-reinforced concrete structures. Sato has indicated that 11 percent of building floor area is constructed utilizing this structural system (Refs. 7.3, 7.6). In the United States, encased concrete composite systems have not been in general use for several decades.

The new type of rolled wide flange introduced in 1989 (Ref. 7.7) is aimed at this type of construction. Figure 7.9 provides a comparison of the new and conventional wide flange beam sections. The uniform depth simplifies design work as well as fabrication efficiency of the steel skeleton and the form work necessary for encasing the steel beams. The composite behavior of the encased members permits use of thinner webs than those of conventional

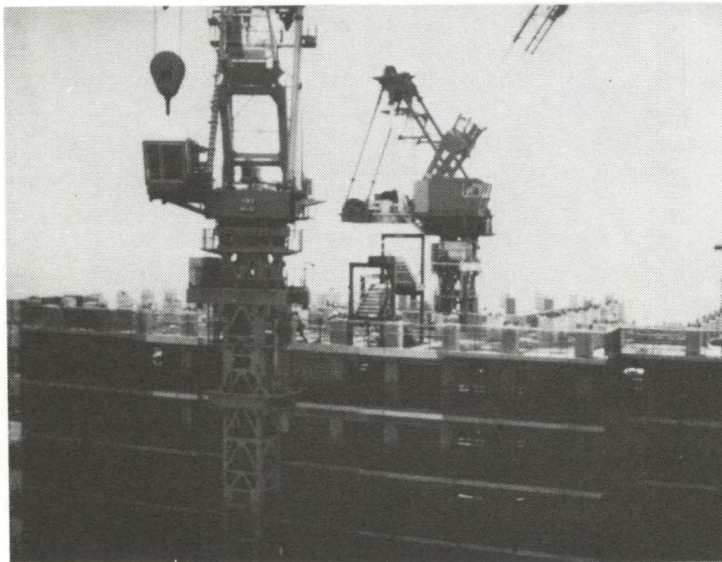


Figure 7.6. Precast Columns, Beams, and Slab at River City 21 Complex

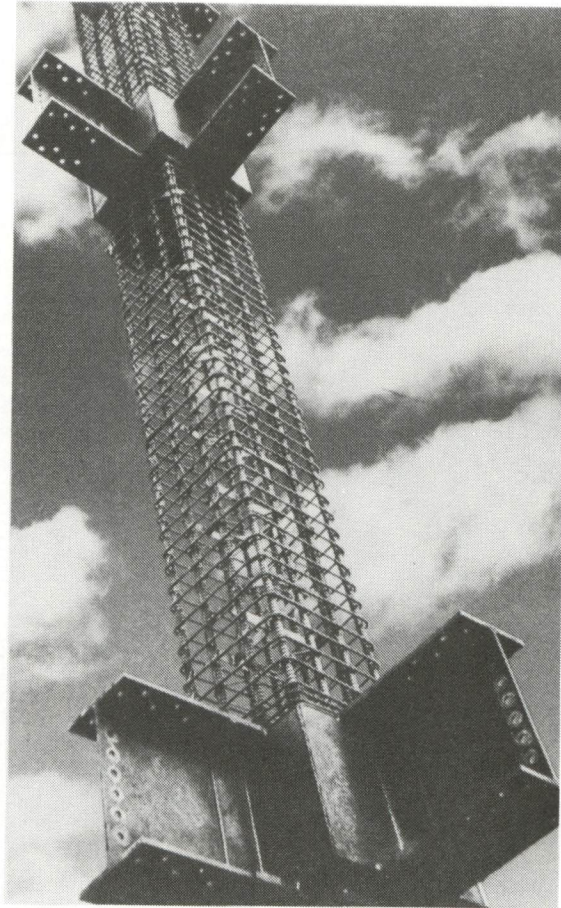


Figure 7.7. Reinforcement Cage for Cast-In-Place Concrete Column and Steel Stub Connection System for Girder Elements (Ref. 7.13)

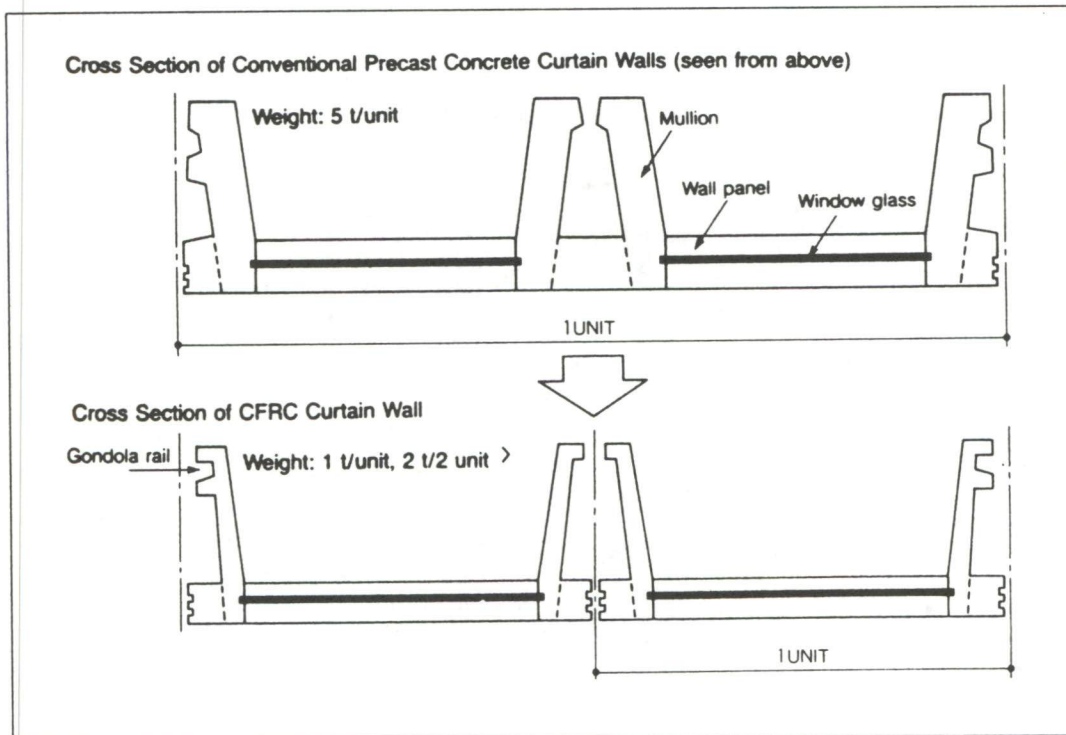


Figure 7.8. Sections of Kajima CFRC Curtain Wall Compared to Conventional Precast Concrete

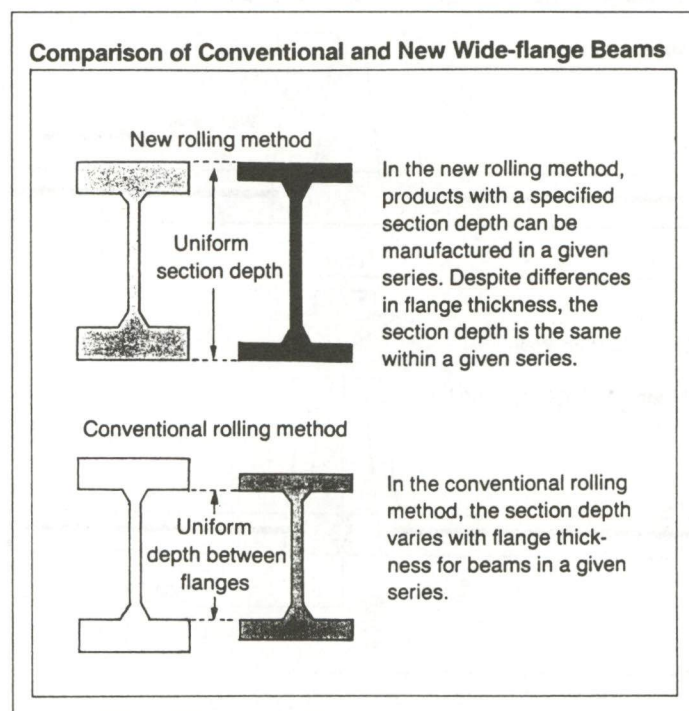


Figure 7.9. Comparison of New and Conventional Wide-Flange Beams (Ref. 7.8)

wide flange shapes, since the concrete encasement prevents instability of the thinner steel webs or flanges.

This type of construction is apparently attractive in Japan for high-rise construction with longer spans. It provides a steel frame to support the form work for the concrete placement. In addition, it supports the bottom-up construction sequence currently used in Japan.

Other Mixed Systems

Other structural systems commonly used in the United States are also being used in Japan. The composite steel beam with formed steel deck and concrete floor slab is increasingly used (Ref. 7.6). The formed metal deck can be seen in Figure 7.1 (Ref. 7.1). Precast floor panels are also used to form the concrete slab. This is also used with cast-in-place concrete topping to provide adequate earthquake resistance.

However, mixed structural systems, combining a concrete core with steel girders and outside columns, are not as prevalent in Japan as in the United States. It is likely that this is due in part to the seismic design requirements imposed throughout the country. There have been a few trial applications of mixed systems, but they are seldom used.

Composite concrete-filled steel box columns are more commonly used than tubular round columns. This does provide easier connection fabrication.

The current Ministry of Construction focus on developing ultrahigh-rise, reinforced concrete buildings, and new construction technology can be expected to bring to focus to this area.

Other mixed systems that were observed under development were new timber construction techniques. This is an area of study by the Building Research Institute (BRI). Activity was also apparent at company research institutes. An example is the 460 ft. (140 m)-diameter laminated wood dome-steel cable system developed by Kajima for an indoor multiple use sports facility. This structure will be completed in 1990. Figure 7.10 shows a model of the structural frame and cable assembly.

Kajima has developed a computer-driven system that takes the CAD output and cuts the model material, which greatly enhances model building. Soon this capability should be extended to fabrication of structural components.

Passive and Active Control (Damping) Systems

Japan's exposure to earthquakes and wind have resulted in significant research and development by industry and government into systems to control the dynamic response of buildings and bridges (Refs. 7.2, 7.17). Both active and passive damper systems are being developed for controlling the response of structures to earthquakes and wind. Base isolation systems are also being extensively studied and built to prevent ground motion energy from entering the structure.

Passive dampers to control motion have been used in the United States for both bridges and high-rise buildings. Examples include the tuned mass dampers which are installed on the Bronx-Whitestone Bridge main span, and Citicorp Building in New York City (Ref. 7.17). However, it is clear that Japanese construction companies and government laboratories have significantly more work underway on active damping systems for bridge and buildings (Ref. 7.17). Both U.S. and Japanese engineers have reservations about the use of active

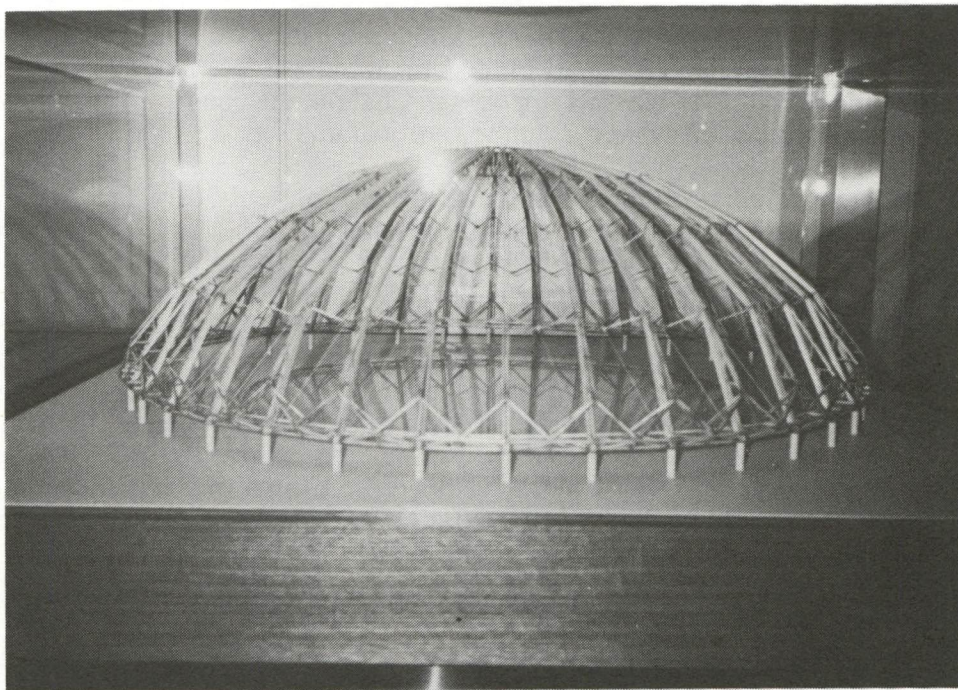


Figure 7.10. Wood-Cable Structural System Model

dampers because of the uncertain reliability of the power sources needed for computer control (Ref. 7.17).

A leading advocate of the active control system has been T. Kōbōri, Professor Emeritus of Kyoto University and now Executive Vice President of Kajima Corporation. As a result, Kajima has played a major role in development of a "dynamic intelligent building" for seismic and wind control. This has resulted in extensive laboratory development and confirmation with shaking table experiments as well as the recent construction of a narrow eleven-story office building (13 x 43 ft. and 108 ft. high) (4 m x 13 m x 33 m), as illustrated in Figure 7.11 (Refs. 7.6, 7.17, 7.18).

This structure has motion sensors in the basement, the sixth and the eleventh floors, as shown schematically in Figure 7.12. It also has active mass dampers on the eleventh floor which are activated by the computer control system. The structure has been subjected to a strong wind and the response was observed with the active mass driver (AMD) system off and engaged. This demonstrated the effectiveness of the AMD system (Ref. 7.6). In addition, in a moderate earthquake which occurred in October 1989, the AMD system also reduced the structure's response by about 50 percent (Refs. 7.17, 7.18).

Another means of reducing damage from earthquakes is to use shock absorbers called base-isolation systems between the building and the ground. These systems are also being used in California (Ref. 7.19). Most of the major Japanese construction institutes have developed their own systems and have built experimental structures as well as a few prototype structures with these devices (Refs. 7.17, 7.21). Figure 7.13 shows a schematic of a typical system as developed by Kajima Corporation (Ref. 7.20). It is recognized that base isolation systems are not effective for structures taller than ten to fifteen stories or for wind-related control.

The base-isolation system has also been utilized on a few bridges in the United States and Japan. In fact, cooperative studies are being carried out to combine passive and active control for the seismic resistance of bridge structures (Ref. 7.2). Figure 7.14 shows a schematic of an idealized hybrid control system for use on bridge structures (Ref. 7.2). This program was initiated in 1990. Guidelines for designing base-isolated highway bridges were drafted in 1989 and a joint research program with the Public Works Research Institute and industry is continuing the R&D program as well as incorporating the system into experimental bridges (Ref. 7.2). For longer span bridges, tuned mass dampers are not likely to be effective enough. Active damping systems appear to be a mechanism for controlling both seismic and aeroelastic response of this type of structure.

Another type of passive damper has been developed by Kajima Corporation and used on the Kajima Headquarters Building No. 2 in Tokyo (Ref. 7.21). This structure utilizes a bell damper made of steel, as illustrated in Figure 7.15, to help absorb earthquake energy between the two structures. Other passive dampers are Shimizu's roof-mounted sloshing dampers (Ref. 7.17).

Retrofit Systems for Existing Structures

Work on retrofitting existing bridge and building structures for earthquake resistance and corrosion damage (Refs. 7.22, 7.23) seems about the same in the United States and Japan.

An example of a reinforced multistory building can be seen in Figure 7.16. Here an external steel frame has been added to increase the resistance and minimize relative deformation of the lower floors of the structure.

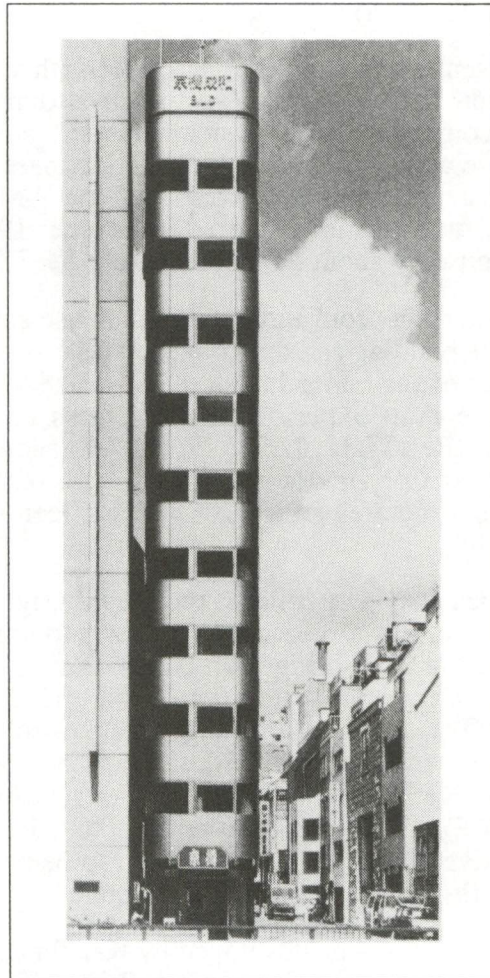
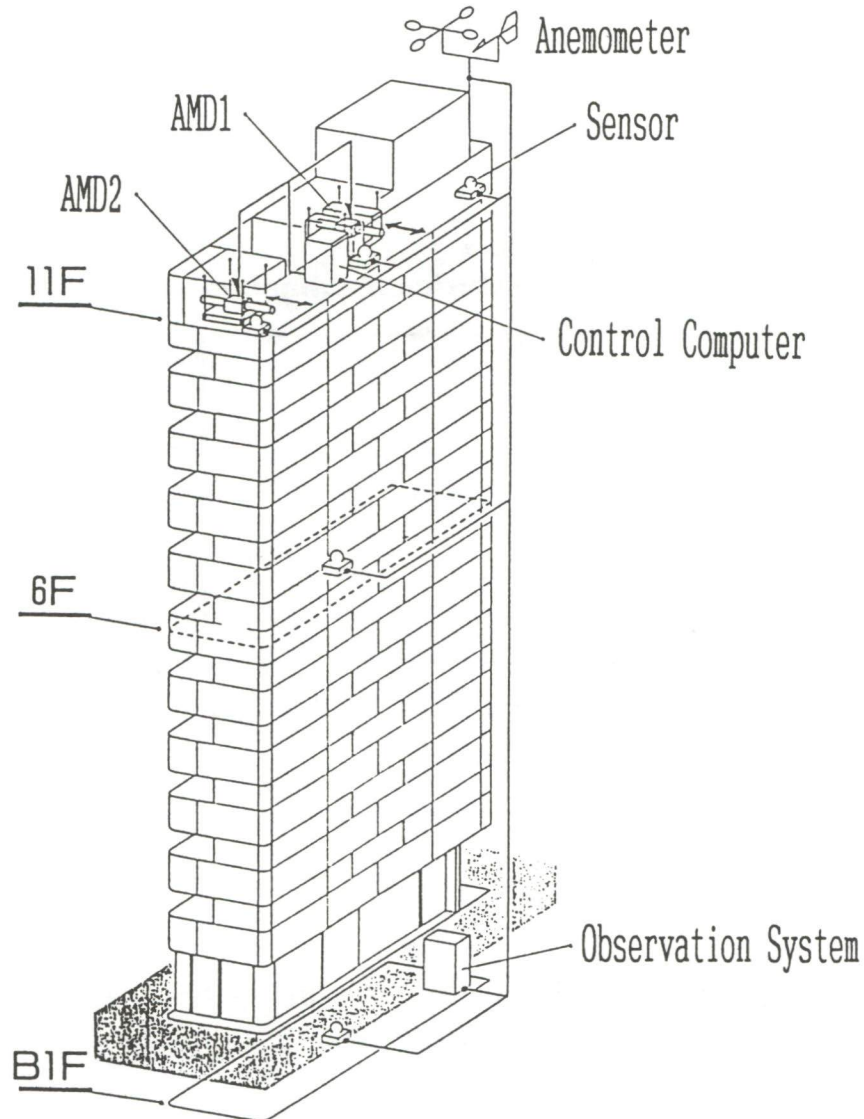


Figure 7.11. Kyobashi Seiwa Building in Tokyo with Active Mass Dampers

Realization of Active Mass
Driver (AMD) System in 1989
(Kyobashi Seiwa Building in Tokyo)



AMD System of
Kyobashi Seiwa Building

Figure 7.12. Schematic of Active Mass Damper System in Kyobashi Seiwa Building

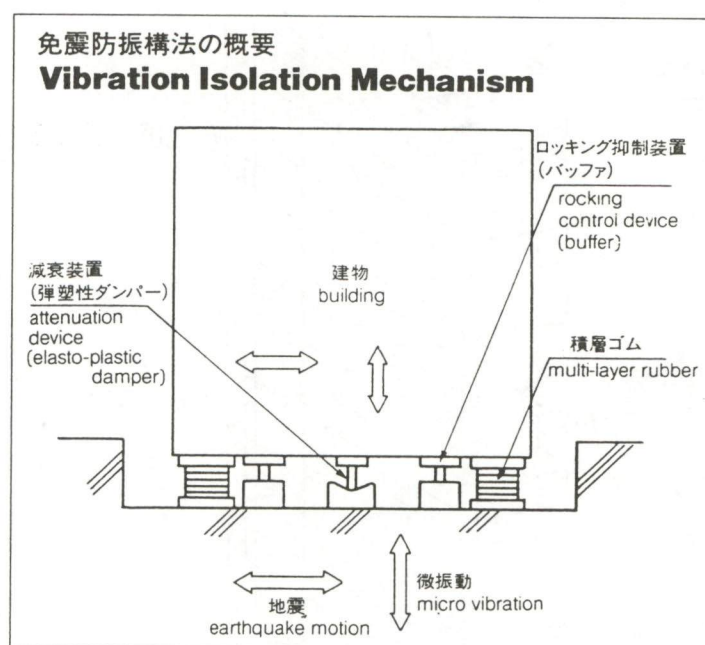


Figure 7.13. Schematic of Base-Isolation System at Kajima Research Institute

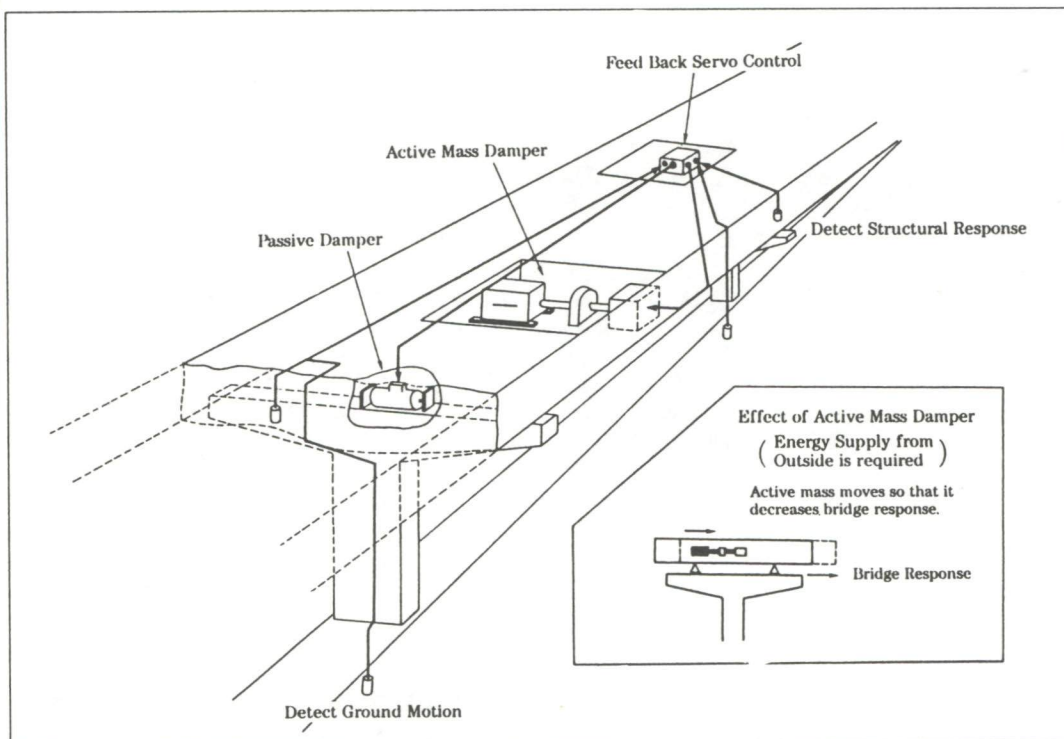


Figure 7.14. Hybrid Control of Bridge Structures (Ref. 7.2)

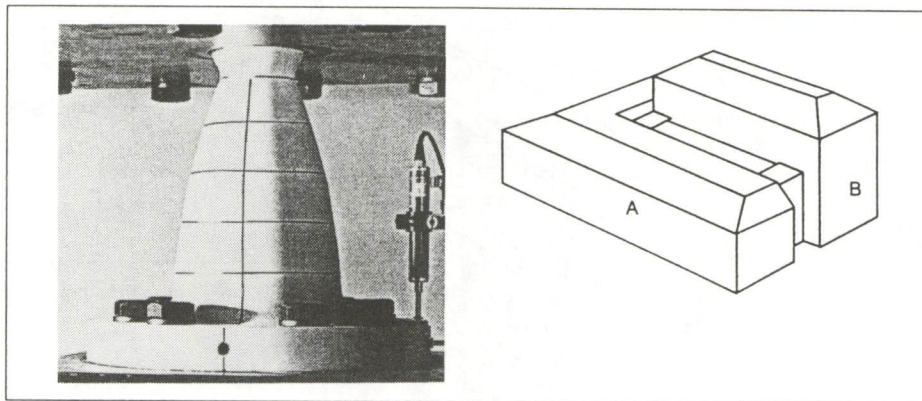


Figure 7.15. Bell Dampers Used to Connect the Atrium Areas Between 5-Story Building A and 9-Story Building B (Ref. 7.21)



Figure 7.16. Externally Reinforced Structural Steel Frame for Small Building

Deterioration of concrete and steel bridges in coastal regions is a serious problem in Japan. This has resulted in studies and development of guidelines for repairing concrete bridges (Refs. 7.16, 7.24).

Japanese investigation of the causes and development of means of repair for deterioration of steel bridges from repeated loads (fatigue) seems to have lagged behind that in the United States, probably because the U.S. interstate system with its large volumes of truck traffic were a reality before similar expressways were constructed in Japan (Refs. 7.25, 7.26).

Subsurface Structures

The utilization of underground space is more important in Japan because of the shortage of available land areas in urban areas (Refs. 7.27, 7.28). Since the 1970s, major R&D efforts have been undertaken to optimize the New Austrian Tunneling Method (NATM), develop automation and robotization of tunnel-boring machines (TBM), and automate the control of earth pressure of the face for the sealed type of shield machines.

These technology developments have also resulted in cast-in-place methods of constructing slurry walls for surface-down construction of deep underground construction with automatic control systems (Refs. 7.27, 7.29). The visit to Akashi Kaikyo Bridge site (see site visit report, Appendix A) provided an opportunity to see the large slurry wall being constructed at a depth of 246 ft. (75 m).

The TBM systems have been automated so that the drill-and-blast method can be carried out quickly and safely with an automated jumbo drill and automated shotcreting machines. The Automated Drill Jumbo has increased accuracy of the parallel line drilling, which makes the automatic operation of the shotcreting machine easier and increases the stability of the rock wall.

The use of shield machines for soft ground construction with pressurized slurry and earth-pressure balancing shields, although pioneered in Europe, have been mainly developed in Japan. Major studies are being carried out by many of the research institutes on the automatic control and robotization of the shield machines (Ref. 7.27). This is enhancing the possibility of a fully automated shield tunneling system. An example is the Shimizu system shown in Figure 7.17. Precast concrete tunnel liner segments can be conveyed from the stockyard on the surface to an erector in the rear of the shield machine. The earth-pressure balance machine was utilized in the San Francisco area in 1979 when this Japanese technology was introduced into the United States by a Japanese contractor.

More recently, multiface (MF) shield machines are being used in Japan to construct double circle cross-sections. Japanese R&D is focusing on other schemes of the Double-O-Tube (DOT) tunneling machine. The Kyobashi Tunnel was completed using the MF shield method (Ref. 7.28). The DOT shield machine uses the earth-pressure balance type construction. Automation of the shield tunneling operation depends extensively on computer utilization controlling automatic surveying with a laser transit and gyrocompass; direction control uses the surveying results in automatic selection of thrust jacks and control of water pressure at the face by controlling the speed of pumps on the slurry shields.

Studies are also underway on using artificial intelligence and fuzzy theory to integrate separate automation technologies so that factory automation technologies and local area networks can be developed into a fully automatic machine. Hence, tunneling and other underground construction has resulted in significant advances in precast concrete components and structures. There is no comparable R&D effort in the United States.

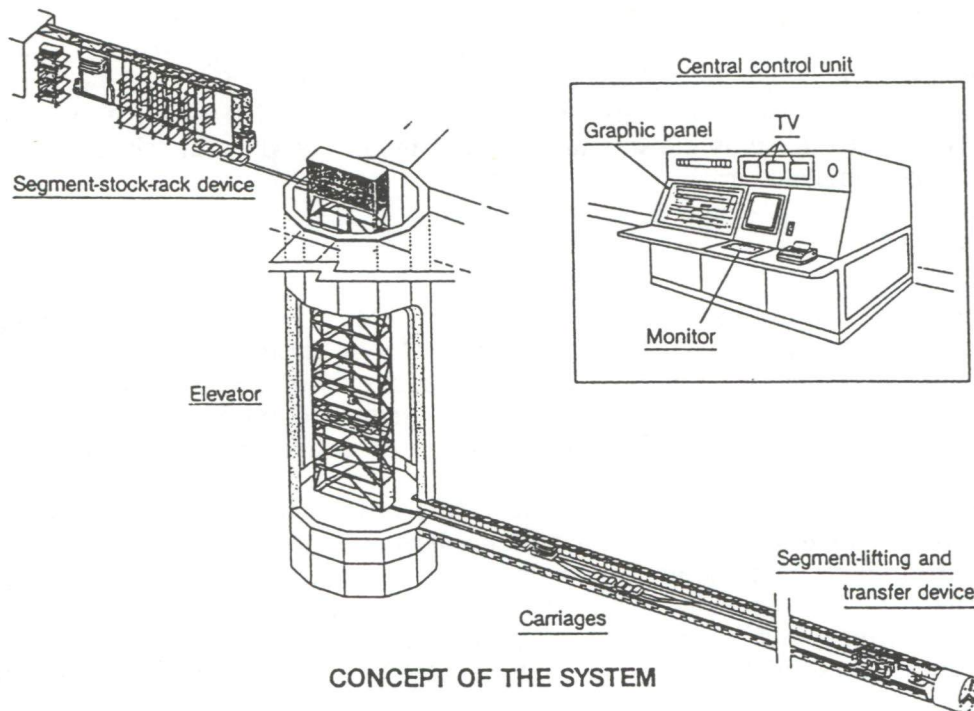
AUTOMATIZATION & ROBOTIZATION IN SHIELD TUNNELLING WORKS

AUTOMATIC SEGMENT CARRYING SYSTEM

This system allows the segments to be conveyed from the stock yard on the ground to the erector in the rear of the shield tunneling machine without manual operation.

The system consists of the following components;

- (1) Battery-operated carriages which are automatically controlled by "Central control Unit".
- (2) Automatic segment-stock-rack device
- (3) Automatic Elevator
- (4) Segment-lifting and transfer device
- (5) Central control unit and optical communication system



OTHER AUTOMATIC SYSTEMS

- <1> Automatic surveying and direction control system of shield tunnelling machine
- <2> Automatic multiple segment erecting system
- <3> Automatic cross setting and erecting system of steel bars for secondary lining reinforced concrete.

Figure 7.17. Shimizu Automatic Shield Tunnelling System

New foundation systems for buildings are being studied such as soil-cement pile systems and soil-cement underground wall systems as a means of preventing liquefaction and unequal subsidence due to seismic events.

Special Structural Experimental Facilities

As noted in Chapter 3, the structural experimental facilities are extensive at the technical research institutes. They feature large universal testing machines (1,000 - 2,000 kip, or 4,448 - 8,996 kN), large reaction floors (50 ft. x 150 ft., or 15 m x 45 m), reaction walls (25 - 40 ft. high, or 8 - 12 m), and shaking tables (13 - 16 ft. square, or 4 - 5 m). The research institute facilities are augmented by larger test facilities at BRI (82 ft. or 25 m reaction wall and shaking table) and at PWRI (shaking tables and wind tunnels). The shaking tables have both horizontal and vertical movement and have assisted in the development of antivibration technology.

The BRI and PWRI facilities are often used to scale-up test specimens so that full-size prototype studies can be carried out. This permits systematic development of knowledge on structural systems before they are put into construction practice. An example is the assessment of the pseudo-dynamic experimental study carried out on a six-story steel building frame at BRI (Ref. 7.30).

This dedication to systematic development of knowledge can be seen in the construction of a new low-speed wind tunnel at PWRI for the Akashi Kaikyo Bridge study. Although two large low-speed tunnels exist at PWRI, an 8.2 x 13.1 x 33 ft. (2.5 x 4 x 10 m) and a 3.3 x 6.6 x 9.8 ft. (1 x 2 x 3 m) test section, a new 33 x 131 x 33 ft. (10 x 40 x 10 m) test section is being constructed to study the structural system and its aerodynamic characteristics. This facility will be completed in 1991.

SUMMARY

Japan's government and engineering construction industry laboratories and engineering capability are systematically developing technology for the design and construction of a wide range of structural systems. Table 7.2 provides a summary of the status and trends of Japan compared with the United States in the development and implementation of structural systems and related factors. It covers each of the major sections dealt with in this chapter.

Extensive use is being made of CAD/CAM (CAE) systems in the design, manufacture and construction of structural systems. Although the Japanese may not be doing a lot of research in theory of finite element methods, knowledge representation, and database and processing theory, they have purchased and maintain state-of-the-art machines and software. Likewise, they are acquiring tools for integration of the office environment. Hence, although the United States is ahead in the R&D effort in the CAD/CAM (CAE) areas, implementation is at least equal to the United States, and the trend indicates Japan may be gaining.

The use of CAD/CAM has resulted in significant system building concepts for housing and low-rise construction for apartment, office, and factory structures. This in turn has promoted factory automation and the use of robots and intelligent tools in an experimental fashion, not only in the laboratory but in trial field applications. No similar effort exists in the United States.

In steel structural systems, the development and availability of special steels has resulted in significant R&D and implementation of these materials in structures. Many of these steels cannot be produced in the United States. There is strong evidence that such steels make steel

Table 7.2
JAPAN / U.S.
STRUCTURAL SYSTEMS

Categories	R&D		Implementation	
	Status	Trend	Status	Trend
CAD/CAM (CAE)				
F.E. Analysis	-	→	O	→
Design	-	→	O	↗
Construction	-	→	-	↗
DATA BASES				
KBS	-	→	-	→
Integrated Systems	-	→	-	→
SYSTEM BUILDINGS				
Housing	+	↗	+	↗
Apartments, Office, Factory	+	↗	+	↗
AUTOMATION (FACTORY)	+	→	+	→
ROBOTICS/INTELLIGENT TOOLS	>	↗	+	→
STEEL STRUCTURES				
Special Steels	+	↗	+	↗
High Rise	O	→	O	→
Bridges	+	→	O	↗
CONCRETE STRUCTURES				
Precast	O	↗	O	→
High Strength	-	↗	-	→
High Rise	-	↗	-	→
Bridges	+	→	O	↗
SUBSURFACE				
Precast Tunnel Liners	+	↗	O	→
Precast in Slurry Trenches	+	↗	+	↗

Table 7.2
(CONTINUED)

Categories	R&D		Implementation	
	Status	Trend	Status	Trend
MIXED SYSTEMS				
Wood & Cable	+	↗	+	→
Steel/Concrete	-	↗	-	↗
EARTHQUAKE & WIND				
Active Damping	+	↗	+	↗
Passive Damping	O	↗	O	→
Base Isolation	+	↗	+	↗
MONITORING				
Earthquake (Active Damping)	+	↗	+	↗
Performance	-	→	O	→
REPAIR & RETROFIT				
Bridges	-	→	-	↗
Buildings	O	↗	O	↗

Coding System Japan Compared to the United States			
Status		Trend	
<	Far Behind	↑	Pulling Ahead Strongly
-	Behind	↗	Gaining Ground
o	Even	→	Holding Constant
+	Ahead	↘	Falling Behind
>	Far Ahead	↓	Losing Quickly

structural systems more competitive. High-rise construction seems on par with that in the United States, whereas bridge design and construction has resulted in a significant R&D effort directed to the construction of the world's largest bridges.

Concrete structural systems are on a par with the United States for precast concrete elements. However, in high-strength concrete and high-rise construction, the Japanese are at present behind. A major effort has commenced on high-strength concrete, as noted in Chapter 4. In bridge construction, R&D, and the application of new materials, the Japanese are ahead.

In other structural systems, the extensive use of encased steel members is a practice not commonly used in the United States today. Furthermore, the use of composite steel concrete systems seems to have lagged the U.S. However, extensive work is underway as is increased implementation of the systems in structures. A recent Ministry of Construction initiative has focused on large wood structures and wood/cable mixed systems. No comparable effort exists in the United States.

Research and development efforts and trial implementation of active control damping systems for earthquake and wind far exceeds the U.S. effort. Several structures have been built that utilize an active control system to limit the dynamic response of buildings and bridges. In addition, major experimental studies and applications are underway on base-isolated structures.

Repair and retrofit studies and implementation on existing bridge and building structures seems to lag the U.S. efforts in some areas, particularly where we have experienced distress earlier.

In utilization of the underground space, the Japanese have led the development of shield machines for soft ground tunneling with pressurized slurry and earth-pressure balancing shields. There have also been extensive studies and application of precast slurry walls in deep foundations. Overall, the Japanese have an impressive R&D effort underway related to structural systems.

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APPENDICES

APPENDIX A

VISIT REPORTS

The JTEC panelists' tour of the Japanese construction industry lasted one week, from the 16th to the 20th of July 1990. The panelists visited and gathered information from eight different types of sources:

- Government organizations
- Government research facilities
- Private research facilities
- Housing manufacturers
- Intelligent buildings
- Construction projects
- Universities
- Professional societies.

The agencies visited are listed by their respective categories on the following page. A visit report was written for each agency visited. Each report lists the date, time, and participants (panel members and agency) of each meeting and presents a narrative of activities, significant findings, and/or a scope of discussion.

SEQUENCE

GOVERNMENT ORGANIZATIONS

Ministry of Construction (MOC)
The Ministry of International Trade and Industry (MITI)
The Building Center of Japan

GOVERNMENT RESEARCH FACILITIES

Building Research Institute at Tsukuba
Public Works Research Institute

PRIVATE RESEARCH FACILITIES

Taisei Technical Research Center
Takenaka Technical Research Lab
Ohbayashi Corporation Technical Research Institute
Tsukuba Institute of Construction Technology, Kumagai Gumi
Nippon Steel Corporation Headquarters
Nippon Steel R&D Lab #1 at Hiyosi
Institute of Technology, Shimizu Corporation
Kajima Institute of Construction Technology

HOUSING MANUFACTURERS

Misawa Homes Co., Ltd.
Sekisui House, Ltd.

INTELLIGENT BUILDINGS

Kajima Intelligent Building
The Toshiba Building
The NEC Building
The New Shimizu Headquarters
New Otani Intelligent Office Building, Taisei Corporation

CONSTRUCTION PROJECTS

Ohkawabata Housing - River City 21
Akashi Kaikyo Bridge
Makuhari New City
Kansai International Airport
Trans-Tokyo Bay Highway Project

UNIVERSITIES

Waseda University
Tokyo University

PROFESSIONAL SOCIETIES

Japan Society of Civil Engineers
Architectural Institute of Japan

MINISTRY OF CONSTRUCTION (MOC)

Date and Time: Monday, July 16, 1990, 9:30 a.m. to Noon

Participants: JTEC Panel

Ministry of Construction:

Mr. Hirosuke Tamada, Deputy Director General
General Affairs Department

Mr. Tadayuki Tazaki, Deputy Director
Technical Investigation Section, Minister's Secretariat

Mr. Yoshihito Takeuchi, Deputy Director
International Affairs Division

NARRATIVE OF ACTIVITIES

Mr. Tamada welcomed the JTEC Panel and gave a general overview of Japan's construction community. Japanese construction is 70 trillion yen (about \$500 billion) annually, 30 percent public projects.

R&D is important. Public and private sectors cooperate. Japan has a serious shortage of construction workers. Special efforts are made to improve productivity.

Mr. Tazaki provided the main presentation. He discussed three types of projects described in a brochure presented to the JTEC team. Note that the Ministry has far larger research activities underway in its laboratories. Also, note that these funds include neither researchers' salaries nor private sector activities. The real level of effort is approximately four times greater.

1. Comprehensive Research Projects for Construction Technology

There have been 21 projects in 20 years. Most projects are 5 years in duration. Eight are currently active with total annual current government funding of \$5 million. Private participants contribute an approximately equal amount. Universities contribute expertise. Universities' faculty participate as consultants on research project teams, often the faculty member chairs the project team.

Universities are not funded to do the research because the Ministry wishes to manage the work to reach goals. In general, university research facilities do not match those of industry or government.

The Ministry uses a committee to select new research projects. Funds are available to start one or two per year. Most projects appear to be development rather than fundamentally new technologies.

2. Joint Industry-Government Projects - \$.56 Million Annually

These are projects that are initiated by industry. The Ministry funding is small, of the order of \$100 thousand per project per year. It might help in providing data for the evaluation system described below.

3. Evaluation System for Construction Technology - \$86 thousand Annually.

The certificate of approval by MOC recognizes the technology and allows its use on government projects, but doesn't remove all liability. This resembles the EC agreement system with a variety of assessment organizations for various technical areas. The government pays the cost of the committee, but the developer of the technology pays the costs of developing the data for the assessment.

DISCUSSION

ACCEPTANCE OF INNOVATIONS AND RESPONSIBILITY FOR FAILURES

How are new materials accepted into construction? A Ministry-sponsored committee assesses research results for acceptance in use. Civil engineering structures are government owned and government can accept new materials using the evaluation process described above. The Government takes full responsibility for a designated prototype project. The Building Law (building code) applies to private building construction and is developed by the Ministry. The Ministry can accept new materials or processes not covered by the Building Law. How are failures of innovations treated in private construction? The U.S. fire retardant treated plywood problem was described; no Japanese counterpart was offered.

When problems are encountered in performance of constructed facilities, the problems are referred to the Ministry's laboratories.

ARCHAEOLOGICAL EXPLORATION OF SITES

This can require up to five years in Japan before construction can proceed. The process has not yet been facilitated by advanced technology. This might be an area for R&D to advance construction productivity.

RESEARCH AND DEVELOPMENT

Japanese research is .5 percent of construction volume and most is privately funded. Major construction companies put more than one percent in R&D. Government does not provide tax incentives for research. Is there really no strong government incentive? Companies need high technology to attract major private clients or to meet the requirements to qualify for public works projects.

SIGNIFICANT FINDINGS AND IMPRESSIONS

1. It would be valuable to translate the "Outline of the System Involved in Construction R&D" to document the Japanese system for research and acceptance of innovations for construction, and to translate the responses prepared by the Ministry to the topics submitted by JTEC prior to the meeting.

2. Japan has a strong program of construction R&D, about 0.5 percent of construction volume considering only research by general contractors and not that by government of manufacturing industry (only the latter do significant research in the U.S.). General contractors, manufacturers, and government laboratories are the principal researchers in Japan. University faculty advise government and private sector research, but universities are less active in applied construction research than their U.S. counterparts.
3. The incentive for research by private general contractors is to be considered qualified to perform public works construction. Tax incentives are not significant.
4. Japan has an effective program for acceptance of innovations in construction practice that involves third party assessment and approval by the Ministry of Construction.

THE MINISTRY OF INTERNATIONAL TRADE AND INDUSTRY
(MITI)

Date and Time: Monday, July 16, 1990, 1:30 p.m. to 5:30 p.m.

Participants: JTEC - All Panelists and Observers

MITI

1. Housing Industry Division
Yoshinori Suzuki, Director (Law)
Tadashi Kambayashi, Deputy Director
(Nuclear Engineering)
Koji Inoue, Deputy Director (Law)
Naohide Tsurukawa, Automation (Mining Engineer)
2. Ceramics and Construction Materials Division
Masayasu Hosumi, Deputy Director (Economics)
Fumihiko Matsukawa - Partial Involvement

Interpreter: Ms. Kurosawa (furnished by JTEC)

SCOPE OF DISCUSSION

1. General welcome and greeting by Director Suzuki. Strong welcome and expression of interest in cooperating with the panel's objectives.
2. Explanation of JTEC purpose and panel interests.
3. Distribution of handout prepared for visit with three principal parts, relating to Housing Industry Division only.
 - a. Background of housing concerns and drivers for the current MITI efforts. The efforts are based on an interim report by Professor Eitaro Tsiyimara of Keio University and emphasize two aspects:
 - Housing must be improved;
 - With rising land prices and changing needs of citizens, housing must define a new role.
 - b. An outline of a Technology Development Project for New Industrialized Houses. The project covers a seven-year period, from 1989 to 1996, has an estimated cost of ¥10 billion, and an R&D body including 35 companies (list of companies to be furnished to Cecil Uyehara). The project has four R&D themes:
 - (1) A simulation system to allow prospective owners flexibility in specifying housing design needs

- (2) The development of materials and automation to alleviate skilled worker shortage problems
- (3) The development of interior materials and housing equipment
- (4) Energy utilization

The project is in its first phase of feasibility studies and is beginning its R&D phase.

c. A review of recent MITI projects in housing including three major projects:

- (1) The House 55 Project from 1976 to 1979, focusing on supply of low-cost, functional industrialized housing. The project was a joint effort between MITI and MOC and had a total budget of ¥1.5 billion.
- (2) A New Housing Development Project, from 1980 to 1985, to improve the quality of single-unit houses. The project was funded by MITI with an R&D cost of ¥2.3 billion.
- (3) A 21st Century Apartment Project for technology and engineering development from 1984 to 1990. The R&D effort was funded jointly by MITI and private companies with a total cost of ¥5.2 billion.

SIGNIFICANT FINDINGS FROM DISCUSSIONS

1. Industrialized construction represents about 16 percent of the Japanese housing market.
2. MOC has control of building codes. The MITI efforts are more technical in nature.

MITI co-funds with industry research to improve building codes, e.g. to allow habitable basements in dwellings. Yet, these take some time to affect the building code of MOC. MITI encourages voluntary actions by industry in place of building regulations, like the U.S. example of a voluntary standard to control flammability of furniture.

3. For R&D, MITI identifies needed projects; a MITI Council then determines if problems can be resolved through technology; MITI then develops a budget and determines if the R&D can best be done through private groups or through the MITI Research Institute.
4. Some of the R&D efforts are not successful.
5. MITI role is more with manufacturing side of housing; MOC is concerned with field operations.
6. MITI is in charge of suppliers of all construction materials except wood, which comes under the Department of Agriculture. MOC relates to the users of materials.
7. Japanese best efforts to address worker shortages are through pre-assembly and field automation.
8. MITI has a Product Sciences Research Institute at Tsukuba.
9. MITI questions for panel related to:

- a. Radon and asbestos problems in U.S.;
- b. U.S. approach to skilled worker shortages;
- c. U.S. approach to industry consortia;
- d. U.S. interest in cooperation and information exchange with Japan.

THE BUILDING CENTER OF JAPAN (BCJ)

Date and Time: Wednesday, July 18, 1990, 1:00 p.m. to 5:00 p.m.

Participants: JTEC - Ken Chong, Bob Hanson, Reed Nielsen

The Building Center of Japan:

Masayoshi Yoshida, Director, Department of
Technical Appraisal
Shoji Kisa, General Manager, International Department

Translation Service: Mariko Kobayashi

NARRATIVE OF ACTIVITIES

Mr. Kisa reviewed the mission of the Building Center of Japan (BCJ), which is to give fair appraisal of new technology and to review the design of any construction in Japan that is 60 meters high or higher. If a structure is less than 60 meters high and there are no deviations from the building law, then the only review performed is by the local building official. The Center also provides a vehicle for research for government and private companies and acts as the center of information of construction technology, holding seminars to disseminate such information.

The Center has a staff of 70 to 80 with about half being technically oriented, the majority being architects. In addition, there are 19 standing committees made up of experts from academia, industry, and government, whose purpose is to perform appraisals of Japanese construction projects. The Center's annual income of approximately 1.6 billion yen (U.S. \$10.7 million at 150 yen per dollar) comes from publication sales, research, and the fee received for the performance of a technical appraisal. Funding is not received directly from the government.

Mr. Yoshida said that Japan has only one building law. It applies to the entire country and includes all facets of building construction including safety, hygiene, fire safety, etc. It also includes regulations such as building height and set-back, as well as limitations on the total floor area-to-land space occupied by the structure. Supporting this law are ordinances and minister notifications, which consist of engineering standards and methods of design that are allowed.

The Building law also addresses the performance standards of equipment like HVAC equipment.

Article 38 of the Law was referred to often and states the following:

The provisions of this Chapter or those of orders or ordinances based thereon shall not apply to buildings using special building materials or methods of Construction unanticipated thereunder, if the Minister of Construction deems that the said building materials or methods of construction are equal or superior to those specified in the said provisions.

Approval for any deviation comes from the Ministry of Construction. The BCJ provides a review and recommendation of the new methods or materials to the MOC for its use.

An example of how this would occur was discussed. The contractor who had a project with a structure of 60 meters or higher would first go to the MOC to determine applicability of Article 38. After confirmation, the contractor would be sent to the BCJ to obtain an application for technical review. Depending upon the type of innovation, test data might be required to verify integrity of the method or material. A presentation would be given to the appropriate review committee, including any pertinent test data. The review committee, which may consist of up to 20 members, would query the contractor as to the details. If the full committee accepted the presentation, then a subcommittee would be assigned the actual review.

This subcommittee would have an average of 3, one-half-day meetings, during which the presenter would provide additional information concerning the innovations and answer questions posed by the subcommittee. This process takes approximately two months, after which the subcommittee prepares a formal report to the entire committee. The presentation of the subcommittee's report to the whole committee is not attended by the contractor. The cost for this type of a review is paid for by the submitting contractor and is in the neighborhood of 1.7 million yen (U.S. \$9500). Last year, there were approximately 2000 of these applications, of which 100 were for high-rise buildings.

According to our hosts, the BCJ does not normally involve itself in issues dealing with construction methods (i.e., the particular approach used by the contractor to place concrete, lift loads, etc.). However, it is involved in issues such as heavy wall welding, the erection and assembly methods of prefabricated/modular residential units, and the construction methods used in building reinforced concrete structures higher than 20 stories because of the complex nature of this type of construction and the critical need for quality control.

Mr. Yoshida commented on the precast floor/ceiling system that we saw at the Ohkawabata Project earlier in the day, a system that apparently has wide use in Japan. The contractor first sets the precast panels in place, and then places a thin concrete slab over them to form the floor.

In contrast to the relatively short time it takes to obtain a review under Article 38, any change in the construction law may take a long time because it is necessary to go through the Ministry of Construction, the ordinance Cabinet, and the DET. Currently, the law is being rewritten, with completion scheduled for September 1990. Copies of an English translation may be obtained from Mr. Kisa. The last edition cost approximately 20,000 yen.

The BCJ contracts R&D work out to the MOC designated laboratories. These laboratories are usually part of or sponsored by foundations. To obtain this certification, labs must have demonstrated expertise in the particular area, the lab must have the necessary equipment, and must also have shown stability. These designated laboratories do not necessarily include the research facilities of the major Japanese contractors. The Building Research Institute is one of these designated laboratories.

The Building Center of Japan is not active in the inspection of already completed buildings. This is the responsibility of the Ministry of Construction and the various prefectures. Manuals for inspection and repair are prepared by the Ministry of Construction for use by city and prefecture inspectors. Inspections are scheduled every one to three years, depending upon use. Residential apartments are inspected every three years and department stores every year.

QUESTIONS ANSWERED BY MR. YOSHIDA AND MR. KISA

The responsibility for new ideas, methods, or technologies remain with the proposer. The contractor/architect/designer is liable for performance.

BCJ has received some applications for the use of structural plastics in construction. These have been limited to such things as shades and pool covers. Our hosts had no knowledge of their use as building structural members. Fiber-reinforced plastics have been used in tanks for sewage treatment plants.

There have been some uses of aramid fibers for concrete reinforcement; however, for the most part, fiber reinforced concrete is not used because of cost.

QUESTIONS ASKED BY MR. YOSHIDA AND MR. KISA

Mr. Hanson and Mr. Chong discussed the process for code changes used by the ICBO and there was a brief discussion of the organization and process followed by the City of San Francisco to inspect high rise buildings after the October 17, 1989, earthquake.

SIGNIFICANT FINDINGS AND IMPRESSIONS

Part of the emphasis on implementation of new technologies is the need to make more efficient use of construction laborers. One of the ways this can be accomplished is through increased use of prefabricated components and more automation.

Japan is facing the same problem that the United States is being confronted with; that is, in terms of college graduates going to work for firms other than architect/engineering firms. Apparently, many of Japan's graduate architects and engineers go to work for competing industries, such as banks, developers, and insurance companies. Reasons given include such things as, better pay and benefits and the perception that construction is a dirty and risky (interpreted to mean unsafe) profession. Technical graduates receive better pay when they work in nontechnical fields. Government leaders recognize this trend, and there may be an effort to increase pay for those who work in construction.

Construction firms are motivated to be involved in R&D for many different reasons. The Center is not aware of any real tax benefits for involvement in R&D. One of the most compelling reasons may be the desire each company has to differentiate itself from its competitors. Working in R&D apparently gives a firm an improved image and improves its competitive position. This effort is not just seen in the larger companies, but also at the prefecture level where smaller contractors are also looking for a competitive edge. The top twenty or so major contractors have their own research labs. The mid-size national contractors have a joint research facility. Even smaller firms may have technical development departments or sections whose assignment is to look for ideas that can be applied to improve the firm's competitive edge.

THE BUILDING RESEARCH INSTITUTE (BRI)
(at Tsukuba)

Date and Time: Thursday, July 19, 1990, 9:00 a.m. to Noon

Participants: JTEC - K. P. Chong, J. W. Fisher

Building Research Institute:

S. Koizumi, Director General
Dr. M. Hirose, Deputy Director General
Dr. Y. Mimura, Director
Research Planning and Information
T. Murota, Director
Structural Engineering Department
T. Nireki, Head, Materials Division
Dr. H. Suzuki, Associate Director, Fire Research
Y. Hirano, Chief, Planning and Investigation Division
Dr. S. Yusa, Director
International Research Cooperation

NARRATIVE OF ACTIVITIES

1. The BRI has 118 research staff of which 104 are architectural engineers, organized into 6 departments and the International Institute of Seismology and Earthquake Engineering (ITSEE). The administrative staff numbers 54. It does not have much laboratory support staff and relies on outside contractors to provide support with rigging, instrumentation, etc. Its total 1990 budget is \$15.9 million.
2. About 20 percent of BRI's research budget is exploratory and directed toward two major projects identified as (1) development of ultra high rise reinforced concrete buildings, and (2) development of new construction technology. The longest period for a project is five years. BRI has a major problem in keeping its equipment and facility updated because of budgetary constraints.
3. Surprisingly, the research program in structures is strongly tilted towards concrete systems. Of 19 engineers in structures, 4 are related to steel and 5 toward reinforced concrete. However, there are 5 additional engineers in other departments. The steel industry is relied on by both contractors and government to provide steel-related R&D.
4. A great deal of R&D is focused on seismic performance and resistance of various types of structures. This includes modeling seismic resistance to provide criteria for high-rise construction, factory-built structures (including the U.S.-Japan program on precast concrete, PRESS), passive and active structural control, connections for large structural steel sections, and concrete reinforcing systems and materials. A cooperative study with industry is starting on active control systems to develop design criteria for structural safety.

5. It was noted that private sector labs carry out most of their experiments on $1/5$ to $1/3$ scale models. The BRI facilities are used for full-scale prototype experiments. Industry provides the staff to execute the experiments. Our hosts indicated that they know of no work in Japan with a focus on intelligent structures for damage assessment.
6. There is use of steel-reinforced concrete structures where structural shapes are encased in concrete. This permits steel to support form work. Nippon Steel has developed the Hyperbeam with thinner flanges and webs with a focus on this market segment (20 percent). It does not use mixed construction in a significant way where concrete elements are connected to steel elements. Models for the force transmissions are not considered adequate. Some pilot studies have been carried out. There is not much activity focused on "new" types of structural systems. Steel box columns filled with concrete are more common than tubular columns. Precast concrete floor elements are frequently used with a cast-in-place concrete slab acting compositely.
7. There appears to be the same problem with communication between maintenance and service behavior and those responsible for design that exists in the U.S. They have no stated service life requirements, but it is being talked about, with not much R&D effort.
8. A major study on high-performance concrete was initiated in 1988. At present, 3.9-5 ksi is used as high-strength concrete, by JAS Specification. MOC is studying the range of 9-17.4 ksi. Two areas are being examined, the concrete strength (silica fume, admixtures, aggregates, etc.), and strength of reinforcing steel bars (58-174 ksi). Some projects have been approved by MOC using concrete in the 5-7.5 ksi range.

There is concern with the durability of concrete and a desire to extend service life to about 100 years. This is resulting in studies on carbon fibers (70-650 ksi), aramid fibers (140-430 ksi) and glass fibers (70-500 ksi). In addition, industry is examining corrosion resistant reinforcement steel.
9. Work on steel connections has focused on the metallurgical properties and fabrication practice of welded joints. A single-pass, 3-electrode submerged arc weld is being evaluated for plate thickness applications up to 70 mm. Also under examination is the thermomechanical controlled process (TMCP) for steels. These materials are easy to weld with low carbon equivalent (Still need preheat for many thicknesses) $y \leq 70 \text{ kg/mm}^2$.
10. New foundation systems being examined include a soil-cement pile system and a soil-cement continuous underground wall system. These are believed to be means of controlling liquefaction and/or unequal subsidence.
11. Fire research is directed toward development of design systems for fire safety. This includes overall fire safety; fire prevention on outbreak and growth of fire; fire protection of building structures; smoke control and escape planning, and examination and improvement of fire safety for existing structures. Presently, special designs are approved by MOC; and the issue of liability is not clear. They are evaluating computer graphic models (PC-based), but these are not yet available to designers. After the 1985 Science Expo, it used a building to carry out tests on fire-smoke distribution and have extensive experimental fire research facilities. Industry makes use of facilities to evaluate products and structural components.

THE PUBLIC WORKS RESEARCH INSTITUTE (PWRI)

Date and Time: Thursday, July 19, 1990, 1:00 p.m. to 4:30 p.m.

Participants: JTEC - Ken Chong, John Fisher,
Robert Hanson, Richard Wright

Public Works Research Institute (PWRI):
Dr. Toshio Iwasaki, Director General
Dr. Yasushi Sasaki, Director
Earthquake Disaster Prevention Department
Dr. Kazuhiko Kawashima, Head
Earthquake Engineering Division
Mr. Shigetoshi Kobayashi, Head
Concrete Division
Mr. Minoru Fujiwara, Head
Bridge Division
Dr. Katsuyuki Kutara, Head
Soil Mechanics Division
Dr. Kiyoshi Katawaki, Head
Chemistry Division
Mr. Hirotaka Kawano, Coordinator
International Research Cooperation
Mr. Shinsoku Kyosai, Research Coordinator
for Wastewater Treatment
Mr. Takeo Nakajima, Head
Traffic Environment Division
Mr. Asaichi Miyakawa, Head
System Division

SUMMARY OF DISCUSSIONS

PWRI has annual funding of \$57 million, including salaries and other expenses, and a staff of 479 including 20 Ph.Ds. Note that MOC reports of research funding do not include salaries of government researchers nor the private sector activities. The level of effort, thus, is approximately four times that described by MOC. Patent right conflicts have occurred in cooperative research activities with the private sector.

PWRI and the Building Research Institute (BRI) are the lead government laboratories for research on high-performance concrete for construction. Private companies participate with their own research and provide specimens and data to PWRI and BRI. The level of effort for the government laboratories is \$3 million in 5 years, in addition to researchers' salaries. New materials science and applications to buildings and public works are studied. Attention is given to low-heat portland cement for large structures and fiber reinforcement for toughness of high-strength concrete.

Carbon fibers and aramid fibers are studied for prestressed concrete. These are considered to have potential for corrosive environments. Bond, corrosion resistance, stability in concrete, resistance to fire, and economy are assessed. Sensors are developed to measure stresses in

fibers and relaxation of prestressing. Fibers have no inelastic range. How can structural ductility be attained?

Geomaterials under study include geotextiles used for slope stability and expanded polystyrene used in embankments and fills to reduce settlements and enhance slope stability through reduced dead load.

Corrosion protection research includes cathodic protection and fluorine and silicone high-performance coatings; metallic spray painting is not studied. A life cycle performance approach is used for recommended practices.

Earthquake research for public works structures is formulating ductility provisions for design and for passive and active control systems. Draft design guidelines for base isolation for bridges were issued in 1989. Research on active control includes tuned mass dampers and active mass dampers, and variable stiffness tendons for cable stayed bridges. Considering how vital transportation facilities are in earthquakes, PWRI is considering criteria for "absolute safety," which is ability to resist the maximum credible earthquake.

PWRI is cooperating with thirty private sector companies in biotechnology research to improve sewage treatment processes. Environmental quality and conservation of land and energy are objectives. The government encourages commercial buildings to provide gray water recycling, and much recycling is conducted by industry. A new process for filtering raw sewage and recovering energy from the filtrate reduces treatment requirements and increases energy recovery. Biosensors and genetic engineering for treatment bacteria are research topics. The Long-term U.S.-Japan Annual Conferences on Sewage Treatment Technologies provide good links for U.S. and Japanese research and practice.

Efforts are underway for sewer tunneling to avoid the disruptions of open cuts for piping. Much research is needed to sense and deal with interferences. Based on available records, Tokyo has mapped its buried utilities and recorded these in a computer-based information system.

Major efforts are underway to reduce air and noise pollution from highways. About one third of measurements exceed environmental criteria. PWRI is conducting wind tunnel and acoustic studies and considering designs for noise barriers.

PWRI prepares standard designs for public works structures that are used by national, prefectural, and local governments. Thirty-one volumes exist and are updated as design criteria are changed. Volumes are sold by MOC's Technology Research Center for National Land Development.

PWRI is developing the Disaster Information System sponsored by the MOC. It involves helicopters for imaging disaster effects, a data mapping system to display results at emergency management headquarters, and a data analysis system with simulations to define effects of damages. An initial version is expected to be operational in 1991.

SIGNIFICANT FINDINGS AND IMPRESSIONS

1. PWRI is effective in research and well integrated with construction and research programs of the private sector and government ministries. Long-term cooperation in the Panel on Wind and Seismic Effects of the U.S.-Japan Program on Natural Resources

has led to effective interactions between the U.S. and Japanese civil engineering laboratories.

2. Development of high-performance concrete is a significant, cooperative effort between Japanese government and private laboratories. Good ideas are needed to achieve ductility in concretes reinforced with brittle fibers.
3. Japan is giving significant attention to lifeline earthquake engineering to reduce losses in severe earthquakes. The U.S. is considering an enhanced program and would benefit from close collaboration with Japanese laboratories.
4. Japan is giving strong, fundamental attention to techniques for sewage treatment. The need is worldwide. Research appears well linked between the U.S. and Japan. Is the U.S. industry preparing to develop and market improved sewage treatment processes and equipment?
5. Japan has recognized its need for a modern disaster information system. No corresponding activity is underway in the U.S., but U.S. needs are similar.

TAISEI TECHNOLOGY RESEARCH CENTER
TOTSUKA, KANAGAWA PREFECTURE

Date and Time: Tuesday, July 17, 1990, 9:30 a.m. to 5:00 p.m.

Participants: JTEC - George Watson, Reed Nielsen, Cecil Uyehara

Taisei:

Dr. Hiroshi Kitamura, General Manager
Mr. Eiichi Goto, Deputy General Manager
Mr. Masanori Nakamura
Mr. Kazuhisa Takeda
Mr. Shinya Higuchi
Dr. Toru Sueoka
Dr. Kenji Kuroha
Dr. Yasunori Matsuoka
Mr. Yutaka Tsuruta
Mr. Hirokazu Hashimoto
Dr. Soichi Kawamura
Mr. Kazuhiro Enomoto
Mr. Hiroyuki Narihara
Mr. Masato Majima

Translator: Reiko Kurosawa

NARRATIVE OF ACTIVITIES

The panel members were welcomed by Mr. Takeda and told that the morning session would consist of presentations by specialists from Taisei on some of those panel questions to which Taisei was able to respond. Later in the day, the group would be formally introduced to Taisei's Technology Research Center by tour and video and be given answers to those questions dealing with R&D funding of the Institute. Mr. Goto, the Institute's Deputy General Manager, also extended his welcome to the panel members.

Dr. Kenji Kuroha said that the Center is involved in quality control of concrete. Taisei performs quality control checks for salt, air, and slump prior to placement of concrete and is investigating methods of determining concrete strength without having to wait until the concrete has set and cured. This concrete strength research is based on the determination of a particular batch of concrete's water/cement ratio.

The method Taisei uses takes about five minutes to determine this ratio in fresh concrete. This effort to develop methods of determining cement content has been performed over the past ten years, while the water volume research has been performed over the last five years. The testing innovation has been used on a few significant projects, but is not normally done at this time. When using the water/cement ratio to determine concrete strength, the firm still requires concrete cylinder breaks, in addition to the other tests that it historically performs.

High-strength concrete is becoming a more common building material for high-rise buildings in Japan. Because of seismic concerns, Japanese buildings must be earthquake-resistant. In the past, this concern caused contractors to believe buildings had to be built of steel. However, because steel structures are expensive, a new approach is to use steel and concrete

in combination. The Japanese construction law requires concrete with a breaking strength of at least 500 kg per square centimeter (approximately 7000 psi).

As a result, Taisei has done research into concrete production and its use in high-rise buildings. This research is necessary to convince the Ministry of Construction and the Building Center of Japan of the safety of the concrete design. Taisei presented a paper on this subject at the 1990 concrete symposium at Berkeley.

Taisei has been able to realize concrete specified design strength of 600 kg per square centimeter (8500 psi). Concrete with higher strength is still in basic research. Dr. Kuroha has visited the United States to learn about our technology and provided several reports that documented his research. His assessment is that the U.S. spends less time determining the actual strength of the concrete used in the structure and in improving the concrete production consistency than does Japan. Instead, the U.S. increases the cement content of the mix to compensate for strength variations, which increases the strength, but also increases the curing temperature.

He said there is a current national project ongoing on concrete reinforcement, in addition to the basic concrete research being done by the large construction companies.

Dr. Kuroha was asked to explain the process by which Japanese building codes were changed. His response was that typically there are no changes, rather requests are made for a deviation from the code to use a new technology. If it is justified, then it is permitted. For structures taller than 60 meters, the design and any innovations are approved by the Ministry of Construction on a building-by-building basis. This review is performed by the Building Center of Japan.

Dr. Yasunori Matsuoka discussed Biocrete-21 in response to the panel's question on high-performance concrete. This concrete uses a biopolymer as a viscosity agent, which reduces the need to use vibrators for placement, minimizes segregation, and improves the durability of the concrete. Because the mix is so fluid, there is a reduction in the need to use vibrators, which makes the mix ideal for automated concrete placement equipment. Basic research has just been completed and Taisei is in the process of identifying applications. Dr. Matsuoka anticipates that this mix would be used for architectural, caisson bridge placements, or where access is otherwise limited or the placement is congested. Taisei is using this mix on the foundation of the centrifugal testing laboratory that it is building at the Technology Research Center.

This concrete mix has such a high slump that field measurement of the mix is made by the diameter of the spread of the concrete after removal of the slump test cone. This diameter can range from 20-70 cm. Compressing strength achieved thus far is near 450 kg/cm (6400 psi) at 28 days.

Mr. Yutaka Tsuruta discussed Japan's research in roofing materials. Each year a total of over one hundred million square meters of roofing are installed. Unlike the United States, Japan has been using butyl rubber roofing for some time. Currently, its use accounts for 25 percent of this yearly installed total. In 1989, about 35 percent of installed roofs were liquid applied polyurethane membrane. The remaining 40 percent is built-up asphalt roofing--a traditional technology. Several years ago, new torch-applied asphalt technology was imported from Italy. Next spring, the Japan Industrial Standards (JIS) will issue a quality standard for the use of a modified bitumen built-up roofing using a burner. The Architectural Institute of Japan (AIJ) has issued a tentative application guide to allow its use for the next two years.

Mr. Tsuruta said that contrary to what he found when visiting the United States in 1970, 80 percent of Japanese firms use two-part sealants. This is the preference because of improved quality and durability of the two-part over one-part sealants. Silicone sealants make up the major part of the market. Silicone-modified polyethyl is increasing in use. Polysulfide systems were used in the past, but because of durability problems, their use has decreased. Although silicone sealant technology was originally developed by General Electric and Dow Corning, licensees are currently manufacturing the product in Japan.

Currently, Japanese curtain walls are 60 percent precast concrete. This is because wind loading requirements in Japan are 600 kg/m (125 psf) for negative loading, and 450 kg/m (95 psf) for positive loadings for buildings up to 200 meters in height. For a 300-meter building, these requirements are respectively 800 (165 psf) and 550 (115 psf). He anticipates an increase in the use of metals. Proposals that combine glass and silicone for curtain walls are being considered at the present time.

Mr. Hirokazu Hashimoto began his presentation on protective coatings by asking what we meant by hazardous coatings. We explained that we would like to learn what Japan has done to eliminate hazardous materials from coatings. As his work has been in corrosion prevention, he said he would discuss the research Taisei has done in coatings to protect steels and concrete. For concrete, it uses three layered acrylic resin emulsion based coatings. It has done this because of the tendency for concrete to crack, and it wants a durable coating that will withstand these stresses. The total thickness is one millimeter and requires repair after approximately ten years. It is applied by rollers and spraying. At the moment, this has not been a pollution issue. It has been used for the last 15 years.

He said that Taisei has not done any research on protective coating for reinforcement bar, but it is working on structural steel coating with epoxy resins. Japan has just introduced cathodic protection technology. This is very recent, and it does not have any results. Urethane resins and fluorine resins are used for most of this coating because the acrylic resins are not as durable. Most coating research is done by manufacturers, so when there are specific needs, Taisei makes a request of the manufacturers. The resultant product is then tested for suitability by Taisei.

Dr. Soichi Kawamura, who works in Taisei's Seismic Engineering Group, addressed seismic research issues. He provided copies of a paper that describes Japan's seismic design method.

He explained that research is being done by both the Ministry of Construction and private companies into the energy demand by earthquakes on buildings. Taisei currently performs research on a limited basis in a number of areas: earthquake observation, high frame wall (HFW) structures (Taisei is currently performing load tests on a 15-story building jointly with the government), and earthquake response issues. There are two types of government-related research programs:

- A. A new research project sponsored by the Ministry of Construction where industry and government share the work
- B. Research done by a contractor that is necessary to obtain Ministry permission to use an innovative technology that is considered outside the building law. This requires a special review by the Building Center of Japan (BCJ). In this, the idea and the research results supporting the submittal are presented to the BCJ for review. The BCJ (a nonprofit institution) gives a recommendation to the Ministry of Construction, which issues a decision to proceed or not.

He has rarely experienced a consignment type of project where the government pays the cost. In (A), sometimes government pays, and sometimes each participant pays its own costs. In (B), the contractor has to pay the cost of review by the BCJ.

Seismic resistance requirements for prefab housing and "normal" buildings are basically the same. This is important because more and more prefabricated structures are being built in Japan.

The base isolation technology developed by Taisei is a sliding system called the "TASS" system. A portion of Taisei's Research Center is supported on this isolator which not only uses a sliding concept, but also the flexibility of rubber to protect the structure in a seismic event. Taisei is the only Japanese company using a sliding system. Other companies are using rubber, high damping rubber, and/or lead core elastomeric bearings.

Over the past 4 years, 40 permits allowing the use of base isolation systems have been issued by the Ministry of Construction. Currently, there are 10 buildings in Japan that use some form of base isolation. Taisei has built 3. There is only one active seismic isolation system currently in use in Japan.

When asked what follow-up measurement is done to evaluate the ten systems currently installed, he said that measurement instruments are installed at the locations to determine effectiveness. Taisei measures two buildings, one with base isolation, the other without, to compare the effectiveness of the isolation system.

Through the AIJ and BCJ, contractors are able to compare the data compiled on the various systems. Taisei is currently performing tests to compare several types of base isolation systems: sliding, high damping rubber, and natural rubber with bearings.

While having lunch, the panel was told that tax benefits were not the major reasons Japanese contractors perform research. It appears that the effort to make their construction more efficient, their overall building costs more competitive, and to maintain and improve client relations are more important reasons for R&D. Taisei also attempts to rotate personnel through the research and development facility.

Approximately one-half of the personnel are more or less permanent, while the others rotate in from other divisions of the firm.

After lunch we were shown a video on Biocrete-21. The cost of the mix relative to normal concrete is approximately double. Taisei's approach to this concrete research is from a value added point of view. Our hosts said that the radiation shielding capability of this concrete is the same as normal concrete. It was developed jointly with the Takeda Chemical Industries, Ltd.

Mr. Kazuhiro Enomoto is responsible for the Center's computer division and supports the computers used there by helping computer users and maintaining the computer network. Computers were first introduced at the Institute in 1969, although Taisei had been using computers since 1961. The Institute began with a Mazatron computer, and in 1984 received a VAX 11/750. It, along with personal computers, was used for data processing. Currently Taisei's main research center computer is a VAX 8550. Last December, it installed a super mini-computer called CONVEX. In 1986, the Center began using a LAN, and in 1988, Taisei began the construction of a company-wide network.

This companywide LAN, called the INS network, consists of both analog and digital systems. It includes a TV conferencing system in addition to engineering work stations.

The digital network is completed, and the analog network installation was scheduled to begin in 1990. The companywide system does not extend to construction projects. There are six people supporting the system. Decisions concerning computer purchases are made by the Information Service (IS) department. Personal use equipment is requested by the end user, and if the request conforms to company policy and individual needs, IS proceeds with the purchase.

Mr. Hiroyuki Narihara handed out information on structural steel connection details. He said that Taisei attempts to incorporate piping, HVAC, and other items as attachments to the structural steel systems for installation jointly with the steel. Taisei also splices columns together on the ground to minimize the number of crane lifts.

Laminar tearing is avoided by using proper materials. Taisei minimizes tearing by following standards that limit sulfur content. Currently the sulfur content of typical structural steel shapes is less than 0.01 percent. Weld cracking is minimized by adequate quality control of welds, by performing base metal preheating, and by reducing the hydrogen content in the welding rod. Structural fatigue in buildings due to seismic activity is not being addressed because of the limited effect seismic events have on structural fatigue. For each project, tests are run to verify that the fracture will not occur.

Current research is underway to better understand the steel normally used by Japanese constructors. Work is also being done in Japan to gain a better understanding of 80 kg/mm (approximately 114 ksi) materials. There is work ongoing by various other manufacturers on a 60 kg/mm (85 ksi) material under leadership of the Building Research Institute (BRI) of which Taisei is a member.

Dr. Toru Sueoka addressed questions dealing with soils. Taisei has 20 employees working in its soil laboratory because of the critical effect earth conditions have on construction. In addition to performing soil research, these people support the soils needs of Taisei's projects, and are investigating deep ground water flow.

He reviewed the problems of liquefaction that Japan must be concerned about because of seismic events and showed a series of maps which:

- A. Identified areas of liquefaction over the past 100 years
- B. Located the alluvial soil distribution in Japan
- C. Showed volcanic soil deposits in Japan. Approximately 20 to 30 percent of the country is volcanic soil

This group is looking into methods of stabilizing soil to minimize liquefaction problems and is exploring new methods of tunneling and other soil improvements for "soft" soils. It is also involved in developing methods to remediate contaminated soils. The Institute is constructing a centrifuge that will, among other uses, be used to test tunnels.

Mr. Masato Majima talked about foundations. He reviewed many of the same concerns that Dr. Sueoka discussed, but also talked of such problems such as trench collapse, structural settlement, and the need for a stable structure during earthquakes. Taisei is currently working on large-scale ground retaining, soil improvement, improved pile design and stronger footings. He mentioned that Taisei must balance foundation construction costs with performance.

His three basic research themes were

1. Improving the efficiency of foundation construction by modifying Taisei's approach to foundations. Rather than using temporary materials for soil stabilization (shoring,

etc.) during construction, use permanent materials in the construction of foundations. Taisei is experimenting with caissons and shoring that become a part of the final structure (called the pneumatic caisson method). This is currently under development and is being used on a limited basis for building construction. In the U.S. this method has been used for bridge pier construction. This approach lends itself to automated construction. Taisei has also formed a research team that consists of R&D personnel and design and construction personnel who are looking into the prefabrication of such subsurface construction members. Advantages include limited effect on adjacent buildings. One disadvantage is the higher material costs of such a system.

2. Prediction, control, and prevention of settlement of buildings.
3. Stability of soil structure during earthquakes and how to design structures to withstand liquefaction-induced problems. In addition, Taisei is looking into ways to prevent liquefaction. This includes draining water away from the ground, compacting the soil surrounding a foundation, and injecting soil-cement mixtures into the ground.

This group anticipates looking into slope stabilization, but no specific work has yet been done in this area.

TOUR OF THE TAISEI TECHNOLOGY RESEARCH CENTER

We saw the color/sound laboratory where Taisei performs tests to determine the most desirable colors and sounds for the office work environment. A demonstration was given in the acoustical lab of various sounds and how they would sound in a concert hall.

We were also shown the seismic base isolators used on the north portion of the Institute's building. The position monitoring target showed an offset between the two portions of the building of approximately one eighth inch as the result of a relatively recent earthquake. A portion of the 250 cubic meter concrete foundation for the centrifuge was pointed out. Taisei used Biocrete-21 for this placement and did not use mechanical vibrators to consolidate the concrete.

The hydrology and concrete labs were very impressive. The hydrology facility has a wave generating tank that is approximately 55 feet by 120 feet. A model of a portion of the Kawasaki artificial island was setting near the end of the tank. Taisei had been performing tests on its performance.

DISCUSSION ON R&D FUNDING

After the field tour, a video on Taisei's research in biotechnology, narrated in Japanese, was shown, and the panel members were invited to ask questions dealing with R&D funding issues. Responses to the panel's prepared questions on finance were provided in a multipage booklet (in Japanese).

Most of Taisei's R&D funding comes from internal company sources (overhead or project), with a small portion coming directly from outside R&D contracts. There is some joint research with the government, though it is not funded by the government.

Around 30 percent of the Institute's budget is devoted to basic research. The remainder is for more directed research required to solve immediate construction problems. The total Taisei corporate R&D budget is approximately ¥12 billion (U.S. \$80 million,) of which approximately ¥1.2 billion (U.S. \$8 million) is for basic research. The Center's budget is

about ¥4.5 billion (U.S.\$30 million), and it performs most of the basic research done by the firm.

A technical planning department decides the direction of the research that the Center will perform. This group is located in the main office and consists of a number of company officers. To support company aims, R&D focuses on

- a. Taisei's large-scale construction
- b. Improvements in craft productivity,
- c. Reinforcement of Taisei's technical capabilities in new materials and biotechnological and environmental areas

In response to a question by Dr. Kitamura as to why NSF had sponsored this trip, Mr. Uyehara gave a brief description of JTEC in general, and Dr. Watson explained the JTEC Panel was in Japan to better understand the Japanese approach to R&D and the implementation of new technology in construction. This visit is also to identify areas where the United States research and its transition to industry can be improved and to see where joint research is possible.

Dr. Kitamura discussed Taisei's joint research with Stanford's Center for Integrated Facility Engineering (CIFE) and Lawrence Berkeley Laboratory (nuclear waste disposal). Taisei is also planning on working with a U.S. company toward the development of a tunnel-boring machine (TBM). This will provide Taisei with its own TBM. He also emphasized Taisei's continued dialogue with Bechtel senior management and the ongoing Bechtel/Taisei technology exchange.

Additional questions asked by panel members were

What is the process to change the building codes? Typically there are no code changes. What Taisei and other contractors do is present and justify a change and then, after a Building Center of Japan review, the Ministry of Construction either allows or disallows the use of the new technology on a specific building.

Who accepts the responsibility for the performance of the new technology? The designer would accept the responsibility. In this case, it would be Taisei. This is in line with the sense of responsibility that is felt by construction firms toward the final product and their client.

SIGNIFICANT FINDINGS AND IMPRESSIONS

There appears to be a close relationship between the Institute and the engineering and construction operations of Taisei. This may be the case because of the emphasis in solving the pressing project-related needs that surface on any construction project, and the direction to improve construction efficiency. It also comes because of the rotation of employees through the Institute's facility. This would certainly be a benefit when a problem surfaces on a project because the field managers would have a clear understanding of who and what was available to assist them.

As noted earlier in the visit report, tax incentives do not appear to be major motivators for R&D. Rather, the prime drivers are the need to make more efficient use of field crews, to identify more cost-effective materials and techniques, and to position the firm for future work.

TAKENAKA TECHNICAL RESEARCH LAB

Date and Time: Tuesday, July 17, 1990, 2:00 p.m. to 5:00 p.m.

Participants: JTEC - Shirley Tucker, Ken Chong, Dan Halpin

 Takenaka Corporation:

 Mr. Satoru Aizawa, Chief Research Engineer
 Structural Control Unit
 Dr. Yasuzo Fukao, Chief Research Engineer
 Advanced Structural Engineering Unit
 Dr. Eiji Muro, Chief Research Engineer
 Construction System Unit
 Dr. Yoshikazu Sasaki, Chief Research
 Engineer Construction System Unit
 Dr. Hitoshi Seya, Chief Research Engineer
 Computational Mechanics Group
 Mr. Yoshiyuki Tsushima, General Manager
 Mr. Masatoshi Ueda, Research Manager
 Computational Mechanics Group
 Mr. Hiroto Uchida, Manager in Charge of Administration

NARRATIVE OF ACTIVITIES

Two video tapes describing the company and the focus of research activities were presented. Some of the areas of research interest as presented in the video are

1. Water quality
2. Turnkey-based systems
3. Numerical control machines for use in construction
4. Clean room technology
5. Nuclear power construction
6. Air-supported structures
7. Traveling construction system
8. Health facilities
9. Improved workplace amenity

Research areas presented in the video on new technology included

1. Large space structures
2. KB export systems for maintenance

3. Retractable shield domes
4. Super-high/tall buildings
5. Under-floor air-conditioning systems
6. Concrete distribution systems
7. Base isolation systems to damp wave propagation in buildings during earthquakes
8. Filter technology for air cleanliness
9. Antimagnetic shielding in clean rooms
10. Automated climbing form system
11. Concert hall acoustic technology
12. Liquefaction of sandy ground
13. Structural dampers
14. Sky City 1000

Projects in progress within the Laboratory include

1. Wind Simulation
2. Floor vibration mitigation system.
3. Tapered slip forming systems.
4. Deep shaft construction project

During the tour of the laboratory facilities, the team visited a six-story steel frame structure representing (in full-scale) a building. This frame was equipped with a roof damping system. The computer-controlled damping system immediately offset building movement and resulted in mitigation of building side sway during a simulated earthquake or wind loading condition.

The Takenaka Base Isolation System (BIS), also designed to damp earthquake movement, is under investigation in a full-scale mock-up. The rubber material used in the BIS allows for 40 cm of lateral movement. A four-stage bearing will support up to 150 tons of building weight. A five-stage bearing will carry up to 90 tons of weight with greater lateral deformation possible. A system for damping microvibration in clean rooms was also demonstrated.

Finally, a demonstration of the concert hall acoustics design facility was given. This facility is called STRADIA and is used for design of concert hall facilities throughout Japan.

During the closing discussions, questions as follows were asked

1. How are computers used at the job site?

Most job site data collection is done using manual systems. In some cases (e.g., if the client requests), a scheduling program, which was developed in-house at Takenaka, is used.

2. Do you use 3-D CAD in field office or design applications?
Do you have a program with interference checking capabilities?

Some R&D is being pursued in using 3-D CAD as a scheduling tool. Sometimes a 3-D program will be used to do site planning and layout. However, the use does not provide for interference checks.

3. Do you form alliances with banks and other organizations to pursue complex projects?

Very seldom. Less than one percent of the time.
The research center has no knowledge of this.

4. Why are Japanese firms so innovative?

Competition among companies generates innovation.
Two factors also support innovation:

- 1) attitude of the owner of the company
- 2) freedom of action in R&D

5. How does Takenaka choose research topics for the laboratory?

Research projects are selected by the Board. Suggestions are received from individual researchers, the Committee for Development and Marketing and Production divisions. Long-term projects may last up to 10 years. Short-term projects are usually for a 2-year duration.

The closing discussions related to the shortage of skilled workers and engineers. This is a crisis and Takenaka is very concerned about this situation.

Takenaka concentrates on the building construction sector. This is its specialty. The company invests about one percent of gross sales in research. The company has approximately 6,400 employees with technical backgrounds and is very proud of having received the Edward Deming Prize for Total Quality Control in 1988.

SIGNIFICANT FINDINGS FROM DISCUSSIONS

1. Computerized cost and time control systems are not used widely on construction sites. Most coordination and data collection is done using manual systems or is done in the context of meetings held on site.
2. The Japanese are very aware of and sensitive to the impending shortfall of skilled craft workers as well as engineering professionals.
3. Research in robotics does not appear to be an active topic at the Takenaka Research Laboratory at this time.

OHBAYASHI CORPORATION TECHNICAL RESEARCH INSTITUTE

Date and Time: Thursday, July 19, 1990, 2:00 p.m. to 5:30 p.m.

Participants: JTEC - D. W. Halpin, B. C. Paulson,
R. L. Tucker, G. H. Watson

Ohbayashi:

Dr. Toshikazu Takeda, Director, General Manager,
Technical Research Institute
Mr. Yoshio Yokoyama, Director, Overseas Civil
Engineering Department
Mr. Masayasu Higashi, Manager, Project Administration
Department, Technical Research Institute
Mr. Hidetaka Komiya, Technical Research Institute
Mr. Sunao Nakane, Manager, Asst. Sup. Researcher,
Env. Eng. Dept., Structural Materials Laboratory
Mr. Hajime Ohuchi, Asst. Sup. Researcher, Structural
Engineering Department, Technical Research Institute
Mr. Hiroshi Okada, Manager, Structural Engr. Dept.,
Technical Research Institute
Mr. Tatsuya Wakisaka, General Manager, Building
Construction Department, Technical Research Institute

NARRATIVE OF ACTIVITIES

The JTEC team was picked up at the Misawa Homes office site of their morning visit by Mr. Yokoyama, taken to lunch, and then travelled to the Ohbayashi Corporation Technical Research Institute in Kiyose, a rural town some 20 km northwest of the Shinjuku section of Tokyo. They first met with the above-listed people for a briefing and a discussion, and then took a tour of the laboratory facilities and advanced prototype buildings that house some parts of the research organization's staff.

1. Introduction The century-old Ohbayashi Corporation, a diversified construction firm with a major in-house design capability, is one of the "Big Six" Japanese contractors, not only in terms of annual construction volume (about ¥1,200 billion or \$8 billion), but also in maintaining a substantial in-house research capability. Its stock is publicly traded, so its financial and business information are subject to external review. Ohbayashi has 17 subsidiaries and 8 affiliates; 16 branches and 59 business offices in Japan; and 13 branches and 12 subsidiaries overseas. It employs 11,200 people, including 800 architects, 3,200 construction engineers, 2,100 civil engineers, and 1,000 mechanical and electrical engineers, among others. Over 6,000 of its people have advanced degrees or technical licences. Its broad-ranging R&D program operates in this context.

The research activity in Ohbayashi began formally in 1948 with the establishment of a research department in the Osaka main office. This was redesignated as the Research Laboratory in 1951, and a branch was established in Tokyo in 1957. Most of the

operation moved out to a new facility in Kiyose in 1965, which was the year that the Technical Research Institute was officially established.

2. Organizational Setting The Technical Research Institute that we visited comes under the Technical Research and Development Division of Ohbayashi which, in parallel with the major operation divisions, reports directly to the President of Ohbayashi Corporation. While the Technical Research Institute is certainly the focus of basic research and much of the company's applied research, it still accounts for only about 40 percent of Ohbayashi's annual R&D spending of about ¥12 billion (over \$80 million). Other major efforts take place in technology departments under the operations divisions (15 percent), in development groups within the Engineering Division (2 percent), in project-specific R&D groups that draw from several departments and divisions (35 percent), and others such as the Machinery Department and the Materials Department (8 percent), which in turn may collaborate with manufacturers on building prototypes and products based on the R&D of the other types of groups.
3. The Technical Research Institute The Technical Research Institute is a largely self-contained facility consisting of 13 small and medium size laboratory buildings and one administrative building, totalling some 18,000 m² of floor area (200,000 ft²) on 70,000 m² (17 acres) of land. Some of the buildings serve a dual role as demonstration prototypes of advanced technologies.

The site employs 310 people, including 160 research engineers (most with advanced degrees), 80 lab technicians, 40 administrative staff, and 30 technicians from subcontractors. The Institute has a director and a deputy director, and is organized into two administrative departments and 19 research departments.

4. Funding and Budget There are many misconceptions about the sources of funds (many Americans assume major government subsidies or tax benefits) and the nature of the research expenditures by the major company research laboratories (many assume that they are mainly focussed on applied problem solving).

In this particular case, the facts are as follows:

SOURCE OF FUNDS		ALLOCATION BY TYPE OF RESEARCH	
Support from company overhead	89%	Lab's self-proposed projects	72%
Fees from in-house clients	6%	In-house client-sponsored R&D	16%
Fees from outside clients	5%	Outside client-sponsored R&D	12%
Government subsidies	<1%		

Note: The left-hand column is for the Technical Development Division, while the right-hand column is specific to the Institute. We do not have data for a direct comparison, but the implication is that most of the client-sponsored research is also done by the Institute.

5. **Research Divisions** The 19 research departments are organized into 12 main groups with some of the larger groups containing multiple departments. A listing of the main groups and the nature of their activities is given below:

Civil Engineering (5 groups) -- Geotechnical engineering, structural materials, tunneling technologies, offshore structures, observational methods.

Building Construction Engineer (3 groups) -- Building technologies, rationalized systems, building methods, construction robotics, structural materials, non-structural materials.

Structural Engineering Departments (3 groups) -- Strength, deformation and design for buildings, nuclear plants, silos, LNG tanks, offshore structures, base-isolated structures, membrane structures, underground diaphragm walls, and foundations; wind engineering analysis for buildings; earthquake engineering.

Soil and Foundation Engineering Department -- Structures for deep foundations (including bearing capacity, settlement, liquefaction); earth retaining structures; fluidities of bulk solids.

Vibration Engineering Department -- Ground-structure interactions; vibration hazard prevention; machinery foundations; micro-vibration elimination for super-LSI factories.

Environment Engineering Department -- Facilities and environment impact on buildings, solar energy and heat storage, energy conservation, rainwater utilization, clean rooms, animal experimental facilities.

Bio-environmental Engineering Department -- Wastewater and air quality analysis, water treatment, bio-engineering, hazardous waste treatment and removal.

Acoustic Engineering Department -- Acoustical design for studios, concert halls, chapels, etc., noise prediction and countermeasures, sound insulation systems.

Chemical Engineering Department -- Materials properties and control of slurry walls, physic-chemical behavior and stabilization of soil and rock, metal corrosion, concrete deterioration, chemical pollution, new materials.

Computational Engineering Department -- Computational engineering with supercomputer; static and dynamic response of structures, foundations, etc.; simulation analyses of offshore structures, fluid dynamics and acoustics.

Consulting Department -- A new department, the focus of inquiries from field construction sites, design operations, and external clients. Assembles expertise and coordinates response from Institute staff.

Fluid Engineering Department -- Wind engineering analysis for buildings and bridges; hydrodynamic loadings and motions for large marine structures; marine environment evaluation of surrounding field of marine structures.

Note: The departments occasionally reorganize subject to changing needs. Indeed, three of those above departments (Consulting, Bioenvironmental and Fluid) are recent developments that were mentioned during our visit but which do not show on the literature we received.

6. Facilities and Equipment The 19 research departments are well supported by research equipment and facilities that rival the best found in university, government, or industrial labs anywhere. Just a few examples are as follows:

The Super Energy Conservation Building houses administrative offices, research rooms, and meeting rooms, but is itself a living laboratory containing some of the most advanced energy-saving technologies for buildings, both passive and active. It is instrumented and monitored for long-term performance evaluation. The building won the 1984 ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers) Energy Award, the first to a foreign winner.

The High Technology R&D Center is a prototype base-isolated building that has already demonstrated Ohbayashi's MENSIN base-isolation system in a 1987 magnitude-6.7 earthquake by damping the vibrations to less than 25% of those felt in nearby buildings. It houses a prototype clean room designed for less than 1 particle contaminants per cubic foot; a robotics facility (called a mechatronic development room); and environmentally isolated bio-technology research facility; a super computer center (NEC SX-IEA supercomputer, plus advanced work stations and an IBM 4381 that link this center to the company's IBM 3090 mainframe in Tokyo and to other supercomputer sites in Japan); and provides a nearly vibration-free environment for delicate experiments.

The Large-scale Structural Engineering Laboratory includes a pair of large reaction walls 12 meters (39 feet) high with a maximum loading capacity of 2,400 tons that enable full-scale testing of smaller structures and components. It also includes a variety of more conventional structural testing facilities.

The Concrete Laboratory not only includes conventional materials testing equipment, but also a high-performance batch plant, cryogenic and high-temperature environment simulation testing apparatus, and a weather reproduction room.

The Large-scale Geotechnical Engineering Laboratory includes a pit for large-scale experiments (e.g., soft-ground tunneling), a deep pit for model experiments on structures in cohesive soil, a pit for testing the uniform compaction of sand using a water jet system, and a dynamic load simulator facility for studying the dynamic characteristics of ground and foundations (e.g., those which caused so much damage to buildings and freeways in San Francisco's 1989 earthquake). The latter facility consists of a shaking table 6.6 m long by 3.3 m wide (22 ft by 11 ft) that can take specimens up to 50 tons and exert shaking forces of up to 50 tons at frequencies of from 0 to 30 hertz.

SIGNIFICANT FINDINGS AND IMPRESSIONS

There are numerous technical results that have emanated from Ohbayashi's research. Also important is the relationship of this Institute to the on-going operational side of the company. For example, the research at the Ohbayashi Technical Research Institute is mostly funded from retained earnings. Furthermore, the focus is primarily on researcher-originated projects. While these projects do originate from a proposal and budgeting process that runs on an annual cycle, the typical planning horizon is 5 to 10 years, and current conceptual research extends out at least 60 years for a lunar colony conceived for the year 2050! In other words, this and the other technical laboratories of the major contractors are genuine research organizations, with considerable freedom as well as resources to conduct long-term research. The companies respect their labs as keys to their future growth and survival, economically as well as technically. A few significant examples of the research results to date will be included in the list below.

1. Civil Works On the civil engineering side, Ohbayashi has been especially well known for its advanced tunneling technologies, its soil improvement methods and its deep diaphragm wall construction methods. The Large-scale Geotechnical Engineering Laboratory mentioned above supports this work, and in itself is larger than any comparable facility in the U.S. Results include the soft-ground tunnel-boring machines that began successfully penetrating the U.S. market in 1979 and the Super Hydrofraise excavators (initially licensed in 1961 and since developed jointly with France's Soletanche Company) that continues to give Ohbayashi at least twice as large a share of this market as its next largest competitor. Recent developments in tunneling include participation in a national effort to develop a double-bore tunnel boring machine that substantially reduces excavation quantities and has some mechanical advantages relative to single-bore machines for transit and highway tunnels, and a foam injection method to improve materials stability and transport as well as reduce the environmental problems associated with shield tunneling in very soft soils. The Super Hydrofraise excavators have evolved to include computer-based instrumentation and automation that help assure precise excavation tolerances at trench depths as great as 170 meters (560 feet).

2. Base-Isolation for Structures While there are comparable efforts in the U.S. to build structures using base-isolation systems, Ohbayashi's research is perfecting these techniques and exploring a number of different design approaches. It also has good experience from the structures that it has already completed and that have been well instrumented when subject to large earthquakes. These factors would appear to make it well poised to be a major player in this new market, and one could expect it to develop an export capability at the component level and probably for the design and construction of base-isolated buildings. There could become a large market for these capabilities not only for buildings in areas prone to earthquakes, but also for other structures such as manufacturing facilities for integrated circuits and other applications, where even the vibrations from nearby truck traffic can cause problems that can be eliminated by base-isolation.

3. High-Tech Buildings While we did not observe any major advantages over other advanced competitors for the construction of super clean rooms (class 1 or better) or bio-clean rooms, Ohbayashi clearly is up there with the leaders, although the market potential will probably remain fairly specialized relative, say, to base-isolated buildings.

4. Energy Conservation The award-winning Super Energy Conservation Building was completed in 1982, and global interest in such structures has declined somewhat since then as global energy prices have come down. Nevertheless, with the renewed interest in energy efficiency that was stimulated by the actions of Iraq, it would appear that Ohbayashi will be well poised to take a leading role in the design and construction of such buildings in the future. With the permanent employment system, the expertise it has accumulated remains in the company and it also now has eight years of operational test data as well.

5. Large-Scale Fuel Storage Over 10 years ago, one of the panelists saw a well coordinated program of research at Ohbayashi and other companies to develop large-scale fuel storage facilities for oil and liquified natural gas. They had to solve many problems related to deep excavation, building concrete structures for use at cryogenic temperatures, soil mechanics under freezing conditions, etc. The results have since been applied in building up Japan's fuel storage capacity to over six months, and this helped insulate it from the price rises that took place in the U.S. almost immediately after the Kuwait event. This research continues--reflecting Japan's typical long-term commitments--and is a good example of a focused client-sponsored research effort (in this case, Japan's gas companies). It has also had spin-offs for the deep foundation diaphragm wall construction that is extensively used for building foundations, subway stations, and even the Akashi Kaikyo bridge anchorage A1 that is described in another of our trip reports.

6. Automation and Robotics Ohbayashi is one of the leading players in Japan's efforts to apply robotics to construction. A major motive is to substantially reduce labor requirements in view of demographic considerations that point to a dwindling supply of skilled craft workers in the years ahead. To date, however, its efforts have been focused on relatively isolated machines for specialized applications, and it has mainly borrowed from other sectors the technologies for sensors, computer software, control systems, etc. Even cumulatively, the isolated robots of the type developed thus far seem to have limited potential for the needed labor savings from a system perspective.

Thus, we were particularly interested to learn about a most ambitious Ohbayashi research effort focused toward the nearly full automation of the construction of a high-rise building (variously called ABCF, for automatic building construction floor, or SCF, for super construction factory). This indeed will require an overall system approach to construction and a high level of coordination among the various automation elements. As conceived, SCF or ABCF is a platform that jacks itself up above the building and allows the successive floors to be built under it as it goes, kind of like a vertically moving factory production line. It would have tracks and other means to mount, move and manipulate a variety of suspended robots for lifting materials up through the open atrium or elevator shafts of a building under construction, move them to their installed locations, align them precisely, and weld or otherwise fasten them in place. The complete platform would be weather protected and have some noise and dust barriers so that it could operate 24 hours a day, thus cutting construction time (and thus construction finance costs) in half.

Although the project has only been underway for three years, Ohbayashi already has one or two buildings planned that may be ready to employ this method within the next two years. This would not be a fully automated implementation at first, but would have the major platform and jack-up components and some robots for welding and/or materials handling. Presumably, it would be working out details for a modular approach to the platform configuration so that the components could easily be reconfigured for buildings of varying geometry (both circular and rectangular are now being studied, but probably with a constant floor plan as the building goes up).

Although it is moving rapidly from concept to implementation, it appears now that Ohbayashi has concentrated mainly on the structural aspects of the building. When asked how our hosts will accommodate the piping, electrical, air ducts, fire lines, and other systems that go into each floor of such buildings, as well as the finish materials, they indicated that they were still thinking about that. Given that the ABCF platform lacks conventional tower cranes or other means to hoist materials up the outside of a building, it seems that if the nonstructural systems are not erected concurrently with the beams and columns, these other systems will have impeded access and will thus have to be brought up piece-wise, thus reducing opportunities for prefabrication and other cost-saving methods that seemingly ought to be integrated into the overall automated building system. It remains to be seen in the next few years how Ohbayashi will make these trade-offs and how it will work out the details to the point that the approach becomes economically competitive. However, in contrast to the isolated and specialized robotics efforts thus far, if this concept does succeed, it has the potential to be a major technological breakthrough with substantial economic implications.

As elsewhere, our team spent too little time at Ohbayashi's Technical Research Institute, and, even with a generous provision of reading material from our hosts, we have had only a glimpse of its operations. A half-day visit by four members of our JTEC delegation was woefully inadequate, but happily a number of American faculty members and students have recently been benefitting from the openness of some of these Institutes in welcoming them for longer term visits of three months to a year or so. We will need to rely upon them for building even stronger communication ties with our colleagues in Japan.

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KUMAGAI GUMI
TSUKUBA INSTITUTE OF CONSTRUCTION TECHNOLOGY

Date and Time: Thursday, July 19, 1990, 9:00 a.m. to Noon

Participants: JTEC - Robert Hanson and Richard Wright

Kumagai Gumi, Institute of Construction Technology:
Dr. Sachio Masuzawa, Director and General Manager
Mr. Hiromu Ikeda, General Manager
Structural Development Department
Mr. Kazuyoshi Tamura, General Manager,
Research Planning Department
Mr. Takehiko Kato, Chief Research Engineer
Structural Development
Mr. Takeyasu Suzuki, Civil Engineer
Structural Development Department

Kumagai Gumi:
Mr. Ryohei Koyama, Manager
Overseas Contract Management Department
International Operation Division
Mr. Yasumasa Ueno, Assistant Manager
Computer Office

NARRATIVE OF ACTIVITIES

1. A 1988 video tape described the worldwide construction activities of Kumagai. Its BOT system for public works provides private financing and toll operations for a contracted period 20 to 30 years, following which the facility is renovated, maintained, and operated by the client government.
2. The Tsukuba Institute of Construction Technology has been in operation for two years. Its buildings are bright and well finished and landscaped.

Mainframe computer service is at a remote site. An on-site mainframe is planned. Personal computers or workstations were not seen in the researchers' large workroom; Silicon Graphics workstations were used for seismic wave studies.

Chemistry laboratories with scanning electron microscope and a large variety of automatic analysis equipment were studying sewage treatment processes. Kumagai is developing automatic monitoring and control processes for modular, odorfree sewage treatment systems for a housing corporation.

A highperformance clean room, 0.1 1 micron fibers per cubic foot, is used to study clean room technologies. An environmental chamber, 10 by 6 by 5 meters, is controllable from -50 degrees C to +50 degrees C and can provide artificial snow.

The structural laboratory has a reaction wall and a shaking table, 5 meters square with 6 degrees of freedom, 70 ton capacity for 3g acceleration, 150 cm/s velocity and 26 cm

stroke. The control system was provided by the U.S. firm MTS. Shaking table studies were underway on braced steel frames.

Laboratory studies were observed of pretensioned, carbon-fiber-reinforced concrete beams. Failure zones are localized with such high yield to ultimate ratio reinforcement. Technicians were manually recording data from electronic load and displacement measuring devices.

Seismic modeling studies of utilities in soil deposits involved nonlinear 2-D and 3-D finite element models.

A 50-meter-long wave tank supports studies of wave forces on model structures.

3. Research is defined by a Technology Development Committee in Kumagai Headquarters. Its working groups include information, research planning, and research results evaluation. Research at the Institute is centrally funded through this process. Research funding has been 0.4 to 0.5 percent of Kumagai's total activity, which has increased about 5 percent annually.

Kumagai's most important research activities, which have involved other research institutes, too, have been concerned with earthquake resistance of tall buildings. Studies include active and passive control systems and behavior of innovative structural systems.

Advanced information system studies provide information processing systems for construction, including systems for schematic and preliminary design, construction management systems, and expert systems.

Kumagai is developing building management and control systems. The Institute's buildings use a prototype fiber-optic system.

Kumagai's construction robots include wall painting, concrete finishing, forms for concrete dams, and tunnel segment placing for shield driven tunnels.

Kumagai is working for an integrated project information system and is participating in STEP for international standardization of information exchange interfaces for construction.

Automation and prefabrication are seen as an important means to improve construction quality and productivity with a declining construction workforce. New connection techniques are needed for automation.

Advance materials R&D has produced products such as an admixture (cellulose ether), allowing underwater deposition of concrete without segregation.

Technology transfer is promoted by participation of design and construction staff in research and visits of research staff to design and construction sites.

SIGNIFICANT FINDINGS AND IMPRESSIONS

1. Kumagai shows a strong commitment to construction research by developing and staffing an excellent Tsukuba-Institute of Construction Technology. Equipment is new and excellent. Staff are well qualified and interact effectively with design and construction staff.

2. Major research efforts are focused on automation in design, construction and operation of constructed facilities. Kumagai is participating in international standardization for automation in engineering and construction.
3. The fundamental attention given to sewage and water treatment processes show the attention Japan is giving to improvement of the environment.
4. The growing Japanese market for infrastructure construction should support continued and expanded Kumagai research activities. These, in turn, will give Kumagai technical leadership and economic strength for great competitiveness in international construction.

NIPPON STEEL CORPORATION HEADQUARTERS

Date and Time: Friday, July 20, 1990, 9:30 a.m. to 12:30 p.m.

Participants: JTEC - John Fisher, Robert Hanson,
Cecil Uyehara, Richard Wright

Nippon Steel Corporation, Construction and
Architectural Materials Development and Engineering
Service Division:

Mr. Masayuki Okamatsu, General Manager
Mr. Hachiro Sakata, Group Manager
Marketing and Engineering Service Department
Mr. Tanemi Yamaguchi, Manager
Architectural Materials Development
Department

Nippon Steel Corporation:

Dr. Mamoru Iwata, Department Manager
Technology Development
Building Construction Division
Mr. Mitsuhiro Yazaki, Manager
Standardized Building Division
Dr. Hitoshi Kuwamura, Senior Manager
Civil Engineering Division
Plant Engineering and Technology Bureau

SUMMARY OF DISCUSSIONS

Four major research efforts were presented: fire resistant steel, the hyperbeam, applications of high-strength steels in buildings, and systems buildings.

Fire-resistant steel has a yield point of 51 ksi and tensile strength of 82 ksi. The yield point rises up to 200 °C and retains 2/3 of room temperature yield strength at 600 °C. The tensile strength declines with elevated temperature as for normal structural alloys. Fracture toughness at low temperatures is as good as normal alloys. Heat-resistant bolts and weld metal have also been developed by Nippon Steel. Heat-resistant steel provides savings in fireproofing expected to repay its higher initial cost.

Hyperbeams are rolled by a new method to maintain constant depth, web thickness and flange width while varying flange thickness for moment resistance. Depths of 400 to 900 mm are provided for a total family of 177 shapes. (Traditional American Standard I-beam shapes also have constant depth and flange width, but are shallower and narrower in cross section.) The constant depth and flange width simplifies connections. Japan's system of steel encased in reinforced concrete provides restraint of web buckling. This is a declining market in Japan because of high labor costs in preparing reinforcement and form work. Why does the Japanese government support concrete research more than steel? As in the U.S., the steel industry is composed of a few large firms considered to be capable of funding their own research, while the smaller construction companies providing reinforced concrete at the site

or small enterprises providing ready mixed concrete are considered to be unable to provide all needed research.

Nippon Steel is developing new, high-strength (50-70 ksi yield strength) steels for buildings. Continuous on-line control (CLC) and thermomechanical control processes (TMCP) provide at modest additional cost (perhaps 10 percent) high weldability (low carbon equivalent), low yield ratio, and narrow yield point range. Nippon Steel research shows that low yield ratio improves ductility in earthquakes. This is demonstrated simply with a hyperbolic-sided tensile testing coupon, and by extensive computer simulations. Nippon Steel research shows that reduction of the coefficient of variation of the yield point in structures designed by the strong-beam-weak-column principle and lower yield point ratio, give improved structural ductility in earthquakes.

The speakers were not aware of the use of TMCP steel for pipes, but such applications should improve fracture toughness in elevated temperature service. Nippon Steel sold its fabrication subsidiary in 1987, and uses Ohbayashi Gumi's fabrication services for overseas projects.

Metal building systems provide about 10 percent of the floor area of Japanese commercial and industrial buildings, and Nippon Steel is the largest supplier. Nippon Steel provides "Stan Package" for stores and warehouses, "Stan Office" 3-dimensional modules for offices and schools, and systems buildings for multi-story office buildings. The latter provide column-free interior spaces and panel wall systems carefully detailed to avoid visible exterior bolting. A CAD system is used for design from the catalog of components. It is not yet integrated with production. Nippon Steel is considering automation in field activities, but the subject is not ready for discussion. Increased use of wood in interior finishings is planned to provide a more traditional ambiance. R&D amounts to 0.4 percent of the Building Division's budget.

SIGNIFICANT FINDINGS AND IMPRESSIONS

1. R&D for advanced technology is vigorous at Nippon Steel. The cutbacks that have nearly eliminated research for construction in the U.S. steel industry have not been matched in Japan.
2. Fire-resistant CLC and TMCP steels and hyperbeams illustrate Nippon Steel's capability to control manufacturing processes to produce improved steel properties. These products should be of high value to U.S. and international construction, and the general capability shows potential for development of other highly competitive new steel products.
3. Application studies of the importance of yield ratio and reliability of steel properties provide incentives to owners, designers, and constructors to select steels of higher quality. Nippon Steel is working effectively to improve its products and create markets exploiting the qualities of its products.
4. Computer-integrated construction knowledge systems and construction robotics are not yet applied in Nippon Steel's programs, but these technologies seem to be under development.

NIPPON STEEL R&D LAB #1
(at Hiyosi)

Date and Time: Friday, July 20, 1990, 9:30 a.m. to 5:00 p.m.

Participants: JTEC - J. W. Fisher, R. D. Hanson,
C. H. Uyehara, R. N. Wright

Nippon Steel R&D:

Dr. K. Sugita, Executive Counselor
Dr. I. Aoki, General Manager
K. Arihara, Manager, General Affairs Department
I. Sawada, Computational Science
Dr. M. Hashimoto, Researcher
Future & Frontier Field Research Lab.
Dr. M. Hashiguchi, Researcher
Materials Characterization Lab
K. Maruyana from Central R&D Bureau, Tokyo

NARRATIVE OF ACTIVITIES

1. Nippon Steel has about 2000 employees in the Central R&D activities. There are four major laboratories: R&D Lab #1 at Hiyosi on advanced materials and electronics; R&D Lab #2 at Sagamihara City on steel and iron products; R&D Lab #3 at Kita-Kyushu City on steel and iron-making process; and the Electronics R&D Lab at Sagamihara on electronics. R&D Lab #1 is primarily concerned with research on advanced materials with focus on more refined materials and innovative processes. There are 411 personnel with 224 researchers, 130 support staff, and 36 general staff. A new laboratory complex is under construction near the Kimitsu Works where all of the laboratories may eventually be housed. The timetable for R&D #1 is not known.
2. The research at R&D #1 on advanced materials includes chemicals and composites (carbon fiber, advanced composites, organic chemicals and polymers, carbon, and composites); ceramics (engineering ceramics, electronic ceramics, powder syntheses, processing technologies and analysis, and reliability technology); advanced metallic materials (other than steel, metallic materials for electronic use, metal-matrix composites, shape memory alloy, powder metallurgy, seawater-corrosion-resistant alloys); and magnetic materials (soft-ferrites, rare earth magnets, magnetic recording materials, magnetic devices and components, amorphous alloys).

Basic research is being carried out on materials science and materials characterization: element and phase analysis, surface analysis, organic molecule analysis, on-line analysis, electron microscopy, and X-ray analysis.

The Future and Frontier Field Research Lab is examining processing technology, advanced materials, surface technology, computational science, new analytical methods, and superconducting materials.

3. There is work underway on sensing corrosion of automobiles using electrical sensing technology. Electrical chemical behavior will be a tool used for this process.

4. The work underway at R&D Lab #2 appears more closely related to the construction industry. The new technologies it is working on will undoubtedly have a major impact on construction areas in the next century. Electrical sensing of corrosion could be applied to many infrastructure areas.
5. Nippon Steel's diverse subsidiaries and extensive real estate permits it to develop and try new concepts and applications with its own housing and other real estate development. It can provide designs using new concepts and have them built as part of its real estate development and management program.

INSTITUTE OF TECHNOLOGY,
(SHIMIZU CORPORATION)

Date and Time: Tuesday, July 17, 1990, 9:00 a.m. to 1:00 p.m.

Participants: JTEC - Dr. Ken. P. Chong, Dr. Shirley Tucker

Shimizu Corporation:

Dr. Toshihiko Ota, Managing Director
Institute of Technology
Dr. Hiroshi Kobayashi, General Manager
Planning Department, Institute of Technology
Mr. Masanori Tatebe, Manager
Planning Department, Institute of Technology
Dr. Tetsuo Saito, Manager
Planning Department, Institute of Technology
Mr. Akio Shindo, Deputy General Manager
Planning Department, Technology Division
Dr. Tadahiko Okumura, Manager
Planning Division, Technology Division

NARRATIVE OF ACTIVITIES

1. Slide Presentation Shimizu has two research and development organizations: The Technology Division is responsible for developing process innovations, product innovations, and business innovations. The Institute of Technology is responsible for basic research, applied research and research consultation. The Ohsaki Research Institute works with the Institute of Technology.

The Institute of Technology started in 1944 with a staff of 3. In 1990, the staff numbered 348. In all research facilities of Shimizu, the R&D staff totals 843. Of this 843, 401 are research staff and 442 are development staff.

Of the 843 R&D staff, 32 percent are architectural engineers and that includes building construction. Civil engineers are an additional 17 percent.

The 1988 budget for Shimizu R&D was \$92 million. The 1990 budget for the Institute of Technology was \$39 million.

Major areas of research at the Institute of Technology include

- Earthquake Technology
- Tunneling technology and underground technology for such uses as storing oil and gas, storing valuables such as art and books, large cold storage areas, and living space
- Maintenance technology for diagnosing the strength and durability of existing buildings, particularly related to earthquakes. Once a diagnosis has been made, a plan of action is recommended.

- Solar optic systems for lighting underground spaces.
- Clean room and clean garments.
- Smart houses for multiple dwelling structures, including communication systems.
- Biotechnology for compact water treatment plants for release of water from a household.
- Robots for spraying fireproofing material.
- Floor grinding and cleaning robots.
- Exterior wall spray-painting robots.

2. Tour of the Institute of Technology Research Facilities

Model tower with earthquake stabilization device.

Solar optic system model.

Stabilizer for building sitting on "liquid soil" (model).

Steel framework model where all joints and connections snap together.

Wave action damping device for use in resort areas near the shore line.

Shake table.

Wind tunnel.

Clean room and clean garments.

Strong wall.

See attached material for further details.

3. Future Research Projects

Comprehensive environmental studies

Natural resources and conservation

Energy

Recycling

Biology

Materials

Marine Structures

Ecology

Changing social conditions

Shimizu Research Chronology

Year	Historical Events	Significant Events	Major Research Breakthroughs	Awards
1944		• Research Section formed in Design Department		
1949		• Research Section renamed Research Department	• Manually operated sliding form • Shimizu Column Foundation Method	
1960		• Research Department renamed Research Laboratory	• Automatic conveyor-controlled batch plant	
1969		• Technology Development Division formed	• HPC prefab method • LNG underground tank construction technology	
1970		• Introduction of PCPV technology from Sir Robert McAlpine & Sons Limited of Great Britain	• Cast-in-Site Substructure System (SSS)	
1971			• Air Purification System (ALSUS)	
1972		• Main lab built in Etchujima, Koto-ku	• Building Environment Control System by Shimizu (BECSS) • Automatic Land Development Design (SPL) • Building Air Purification System (SACS) • Recycled Hot Air Heat Pump System (S-Pac)	
1973	• Oil crisis	• Cooperative agreement formed with Civil and Civic of Australia	• Building Manufacturing Method (SQUP System) • Large-scale test method for steel pipes • FEM analysis program	
1974		• Introduction of LPG underground storage tank technology developed by Conch of the Bahamas	• Flexible slip-form for tower-shaped structures • Crane control system for safer crane operation • Earthquake analysis method for weak subsoil • Participation in the ADL solar project	
1975		• Introduction of base-rock oil storage technology developed by Skanska AB of Sweden	• PIPW Method • Ultra-sonic testing apparatus for steel plate welds • Vibration analysis program for tall smokestacks	
1976		• Introduction of LPG and underground oil storage tank technology developed by Lebeaux of France	• Steel plate and concrete silo construction method • Factory Noise Analysis Program • Evacuation Simulation Program	
1977			• Slab system for the manufacture of factory floors • Demec Method for foundation improvement • Simulation model for fire prevention in urban areas • ACRUSS Automatic Surveying System • Frozen soil experiments for underground LNG tanks • Nox Method for placement of water-saturated concrete • Waste water disposal system	
1978		• Introduction of PC bridge technology developed by the West German company Pollensky & Zöllner	• Ocean data processing system • Horizontal Steel Plate Ware Reduction System • Deep Underground Continuous Wall Construction Method	
1979			• Pollution control system for tall smokestacks • Automatic moving form technique • Free-access floor for computer rooms • Fire simulation program	• The Land Development Design System receives the Ishikawa Award from the Japan Science and Technology Federation

Year	Historical Events	Significant Events	Major Research Breakthroughs	Awards
1980		• Introduction of base-rock cold LPG storage technology developed by Skanska AB • Introduction of ocean platform design technology developed by Sea Tank of France • NATM technology jointly developed with Müller Hereth of West Germany	• Water pipe system • Motion analysis system • Procedure for analyzing the motion of ocean structures • Dam design system	• Awards from the Prime Minister and the Japan Manufacturing Technology Society • The Japan Society of Concrete Engineering award for wireless data transmission technology • Architectural award for the 82 Bank Office Building
1981	• First launch of space shuttle		• Control system for the placement of mass-concrete • Experiments on ocean thermal energy conversion • Solar-heated steam generation system • CAD planning and design system	• Award from the Air Purification Engineering Society for BECSS
1982		• Ohsaki Research Institute established	• Fireproofing Spray Robot • Base-Rock Food Storage System • Gas-engine heat pump • Chemical plant production planning	• Architectural awards for the Matsumoto Showa Building, the Nagano Prefecture Public Housing Corporation Building, and the Nagoya branch of Lion Corporation for energy efficiency
1983	• Opening of Tokyo Disneyland	• Introduction of air-supported technology developed by Skidmore, Owing and Merrill of U.S.A. • Offshore oil platform technology jointly developed with Sir Robert McAlpine & Sons of Great Britain	• Air-Supported Dome Model Test System • Tests for solar and ocean thermal conversion systems • Clean room testing apparatus • Continuous hopper coal silo	• Oil Study Group's Technical Achievement Prize for underground storage technology • Tanaka Prize of the Japan Society of Civil Engineers for the P&Z Method
1984		• Main lab renamed Institute of Technology	• Acoustically controlled feeding system for marine ranches • Construction method for offshore residences • SST-R Method	• Nikkei Annual Prize for Product Excellence for the Fire-Proofing Spray Robot • Japan Science and Technology Federation's Ishikawa Prize for the Building Diagnostic System • Winner of the design contest sponsored by the Science and Technology Agency of Iran
1985		• Introduction of radioactive waste disposal technology developed by AECL of Canada	• Super Concrete • RCD Construction Method for concrete dams • KST Method for temporary ocean-bed shafts • Bioreactor Waste Disposal System • PBS Technique • Silo lining system • RCSS Method	• Japan Society of Civil Engineers Technology Prize and the Oil Study Group's Award for Technical Achievement for offshore platform technology
1986		• Mediatrix Corporation, a company that researches data transmission between non-compatible computers established	• "Super Wing" structural member for large spans • "Nefmac" structural material • Ocean-based solar energy system • Aseismic construction methods • LAN for high-rise condominiums • Factory automation design system • Energy-absorbing aseismic structures • Hybrid structural membrane • Ice anchors	• The Sapporo Clock Tower and the Niigata Engineering Co., Ltd. Plant receive architectural awards for energy efficiency • The Niigata Engineering Co., Ltd. Plant receives an award from the Air Purification Engineering Society • Award from the Japan Society of Civil Engineers for temporary seabed shaft technology • Super Concrete receives the Excellence in New Urban Housing Award
1987		• Nihon Facility Service, a building management company, established • Purchased equity in Dic-Degremont Co., Ltd., a waste water disposal firm	• High-productivity pork plant • Non-Segment Shield Tunneling Method • Electromagnetic wave-shielded building • Steel bar placement robot • Base-Rock Bore Hole Scanner System • Ceiling Panel Placement Robot	• The Shimizu Shibaura Building is awarded the Intelligent Building Award by the Japan Economic Journal
1988	• Completion of Seikan Tunnel		• Large-Span Composite Roof Technique • Mechanical Shield Docking System • Ocean Cultivation System	• Winner of the West German International Media Park Contest
1989		• New Tech Presentation '89 held • Tsukuba Technopolis established • S Technology Center established in the United States	• High-efficiency bio-reactor • High-strength concrete	• The Pre-Cooked Sand Method is awarded the Japan Society of Civil Engineers' Technical Development Prize • The Technical Promotion Prize from the Air Purification Engineering Society for the Stream Storage System

SIGNIFICANT FINDINGS AND IMPRESSIONS

1. R&D efforts are not required for a contractor to bid on a government project, but it is necessary for keeping a competitive edge.
2. The Big Six have comparable R&D efforts but seldom join in on a research project. There is a strong network system of the exstudents of a given professor and they exchange information on an informal basis.
3. Shimizu sees its R&D program as superior to that of an academic institution because academic R&D is separated by disciplines, it is slow, and it is not business oriented.
4. Each of the Big Six has "secret projects" that the aforementioned network system keeps secret.
5. On some government projects, committees may consist of representatives of different companies.
6. There is no tax incentive for R&D, but there is an incentive for staying competitive with the other companies.
7. In order to use a new material on a project, Shimizu must have permission from the Building Center of Japan. It is a special use permit for four of five projects and so becomes a case study for product evaluation.
8. A new construction method such as the spray paint robot is completely under the control of Shimizu.
9. Research topics are determined by a corporate committee composed of representatives from top management, business development, sales and marketing, and research and development.
10. There are 100 technical staff, 170 researchers, and 70 clerical positions that are permanent.
11. A typical research team is four or five technicians with one or two researchers.
12. Most of the technicians are multiskilled craftsmen.
13. Most teams are organized like a construction crew with a leader or foreman.
14. Safety and quality are prime concerns.
15. Most technicians are graduates of junior high to senior high schools. On-the-job training is provided as necessary.
16. The work is stable, the wages are higher than that of the typical construction worker, and employment is full-time. These may be some of the reasons the work force is stable.
17. There is a shortage of carpenters and cement finishers.
18. The craftsmen do not go to construction sites to initiate a new construction method. They work strictly for the lab.

KAJIMA INSTITUTE OF CONSTRUCTION TECHNOLOGY

Date and Time: Tuesday, July 17, 1990, 2:00 p.m. to 5:30 p.m.

Participants: JTEC - R. L. Tucker, J. W. Fisher, R. D. Hanson

KICT:

Dr. S. Momoshima, Director
M. Nishimura
M. Kobayashi
Dr. K. Aoki
N. Nakagawa
K. Koseki
N. Mitsuka
T. Tsujimoto
M. Sakamoto

NARRATIVE OF ACTIVITIES

1. Tour of Portions of Facilities (Structures Lab, Fire Lab, Base Isolation of Laboratory, and Displays in Administration Building).
2. Introduction by M. Nishimura and Overview of KICT.
3. History of KICT Development by Director Momoshima.
4. Discussion of Aseismic Structure System.
5. Discussion of Rock Cavern Construction Technology.
6. Discussion of Fiber-Reinforced Concrete Research.
7. General Question and Answer Session.

The Kajima Institute of Construction Technology has two facilities. The one visited is the newest and largest. The facilities include a large structures lab, a radio isotope lab, a geotechnical lab, an ocean and hydraulics lab, an environmental lab, a fire safety lab, a shake table, and an open-air experiment yard among the total of 20 identified facilities. The Institute's budget for 1990 is approximately \$50 million out of a total R&D budget of \$120 million (one percent of sales). KICT has a total staff of about 270 engineers and scientists, including approximately 80 in the Civil Engineering Department, 110 in Building Engineering, 40 in Environmental Engineering, and 40 in Mechanical and Process Engineering. The relative research efforts are roughly proportioned to the Kajima business sectors. The Kabori Research Complex is not located at KICT but is included in the total \$120 million research effort. The KICT management estimates that approximately 50 percent of its effort is in R&D, 25 percent in cooperation and consultation with its operating divisions, and 25 percent in training and extension activities.

SIGNIFICANT FINDINGS AND IMPRESSIONS

KICT has a large and diverse program. Although the staff attempted to answer all questions submitted in writing earlier and oral to questions during the visit, time limitations prevented in-depth understandings of KICT's activities. The findings listed below are thus admittedly incomplete.

1. Kajima has developed leading-edge technology in earthquake engineering, both through the Kabori Research Complex and KICT. Its Active Mass Driver (AMD) system for seismic damping is state-of-the-art and is referred to as a Dynamic Intelligent Building (DIB). The first prototype building using the system was completed in 1989 and has experienced one earthquake to date.
2. Kajima has a major program in geotechnical engineering and particularly in design and construction of large caverns. The key elements are the finite element analyses and CAD Systems, the establishment of measurement systems for in-place behaviors, and the actual construction methods. It has used the systems and technology for several locations at the Kuji Test Plant.
3. Kajima has a considerable research effort in construction materials for buildings and, in particular, work with fiber-reinforced concrete. Various fibers are utilized, including carbon, steel, aramid, and nylon.
4. Considerable R&D relates to building components, some of which involves modifications and testing of systems developed elsewhere.
5. A growing area of attention relates to biotechnology and environmental systems for buildings.
6. Most of the emphasis at KICT is on applied technology. It is assumed that basic research is to be conducted elsewhere. At most, about five percent of the Kajima R&D effort is related to "radical" or "blue sky" research.

MISAWA HOMES CO., LTD.

Date and Time: Thursday, July 19, 1990, 9:00 a.m. to Noon

Participants: JTEC - Dan Halpin, Boyd Paulson,
Richard Tucker, George Watson

Misawa:
Dr. Naoto Ando
Arch. Koji Ogawa

NARRATIVE OF ACTIVITIES

We were met at the Hotel (Ginza Tokyo) by Dr. Ando and proceeded by car to the Misawa Homes Institutes of Research and Development. Dr. Ando is Manager of the Furniture Development Division. He gave us a short introduction to the company's operations and covered the following points:

1. Misawa Homes is the biggest prefabricator of single family housing units in Japan. The firm produces about 40,000 units per year. Sekisui produces more housing units per year, but a large number of these are multi-family units.
2. Three basic materials are used in the fabrication of housing units: (1) Wood, (2) Lightweight Concrete, and (3) Ceramics. Ninety percent of the units are fabricated using wood. Misawa has worked to develop a system for walls and partitions called the PALC system. PALC stands for Precastable Autoclaved Light Ceramic/Concrete. Misawa sees this development as the building material of the future for industrialized prefabricated housing.
3. The most popular high-end housing unit is called the Century and has a floor area of approximately 200 square meters. Sales of this unit amount to approximately 500 per year.
4. A house of 120 square meters area (approximately 1260 square feet) costs around ¥30 million (\$207 thousand) not including the land cost. Land would cost an additional \$100,000.

Following these opening discussions and review of several company brochures, Dr. Ando took us on a tour of the laboratory. The tour started with a video tape describing the company's production facilities. Misawa has 17 production factories distributed throughout Japan. The walking tour consisted of visits to model homes on the site as well as laboratory areas. The laboratory has a wide array of structural testing equipment and equipment for materials testing. It also has an impressive all-weather test room in which full-scale models can be tested for weather extremes.

Furniture design is part of the housing package and various types of furniture are also tested in the laboratory.

Again, the concept of "Amenity" and improvement of living standards was a key orientation and concept in designing and marketing housing. Chiyoji Misawa, President of the company, indicated in a brochure we received that: "Social needs now mandate that shelter fulfill a broader responsibility than in the past, that it contributes actively to enjoyable, satisfying lives. We refer to this function as 'Amenity.'"

This is a driving issue both in building construction and in housing as indicated in the attached newspaper article which was published during our stay (See following page).

Questions that were asked following the laboratory and model tour were as follows:

1. *Does Misawa have contact with the Housing Industry Division of MITI?*
Actually, there is very little contact.
2. *How can the average Japanese worker afford to buy such expensive housing \$240-\$340/sq ft including land?* Companies loan money to their employees at a low rate and favorable terms.

SIGNIFICANT FINDINGS AND IMPRESSIONS

1. A unique feature of the model homes visited was a centralized control board which consolidates functions in the operation of the house (e.g., wake-turn on and shut-down, prepare for bed, short absence from house; long absence, etc.) into a single button on a stylized panel. For instance, when leaving the house for an extended absence, a single switch activates the security system, regulates temperature, provides for random turning off and on of lights in the house, etc. It appeared to be a very low level smart house feature.
2. The extremely high cost of land in Japan has a pervasive effect on the design, operation, and maintenance of all housing and buildings in Japan. It poses a major problem for the Japanese in improving their standard of living as indicated in the newspaper article which follows.
3. The total number of units of housing constructed in Japan each year is approximately the same as that constructed in the U.S. (1.6 million/year).

Mainichi Daily News

Dedicated To International Understanding

Wednesday, July 18, 1990

Better Infrastructure Key To Improving People's Lives: Report

Infrastructural improvements are the key to improved living conditions for the people, who currently do not fully enjoy the nation's economic prosperity, the Construction Ministry said in a report Tuesday.

In an annual white paper on construction submitted at Tuesday's Cabinet meeting, the ministry said the country's economic success should be more reflected in the living standards of its citizens.

Though topping the world in terms of per capita gross national product, the country lags far behind other major industrialized nations in terms of lifestyle, the paper said. It added that nearly 90 percent of the public believe their country

is rich, but only half of them think they are affluent.

According to an "affluence index" created by the ministry to measure real living standards, which comprises such figures as the per capita GNP, per capita consumption, working hours and housing space, the nation is ahead in per capita GNP, but far behind in other areas when compared with the United States and Britain.

The "affluence index" also took into account such things as crime rate, plumbing facilities, parkland and roads.

To come up with a base for the index the ministry set the combined average affluence of the U.S., Great Britain and Japan in 1980 at 100.

The ministry gave Japan a score of 85.7 and the U.S. 115.1, for the year 1988.

The ministry also introduced another index, called "Life GNP," which indicates the nation's per capita GNP after allowing for working hours and the purchasing power of the yen at home.

The Life GNP put Japan at two-thirds the level of the U.S., though its per capita GNP is 15 percent larger than America's.

The paper traced the wide gap in living standards largely to inadequate infrastructures, including housing and parks.

The housing space available for individuals is 40 percent less than that for the average person living

in the U.S., Britain, West Germany, and France. The Japanese have only one-tenth of the park space of the average citizen of these nations, it said.

The paper is apparently intended to pressure the government to fulfill a pledge to substantially boost spending on domestic infrastructures, which it made in the final report of the Structural Impediments Initiative talks conducted with the U.S. The talks were aimed at eliminating bilateral barriers to trade and investment.

At the recently concluded talks in Tokyo, Japan promised to spend 430 trillion yen on public works projects over the next 10 years.

SEKISUI HOUSE, LTD.

Date and Time: Thursday, July 19, 1990, 9:00 a.m. to 5:00 p.m.

Participants: JTEC - Shirley Tucker, Cecil Uyehara, Reed Nielsen

Sekisui: CAD Center
Mr. Akio Ohta, Chief
Building Systems Research Division
Ms. Etsuko Kamo

Factory:
Mr. Hiroshi Tada, Plant Superintendent
Mr. Hiroteru Wayama, Technical Section Manager

Translation Service: Ms. Reiko Kurosawa

NARRATIVE OF ACTIVITIES

Mr. Ohta began our visit at the Ikebukuro office by reviewing several graphs (Figures 1 to 5 below) that pictorially represent the state of residential construction in Japan. Figure 1 identifies the number of buildings constructed each year since 1979, making a distinction between residential and non-residential. Figure 2 further breaks down the number of residential units built per year by the following categories:

- a. Houses for rent
- b. Houses built by companies and the government for their employees
- c. Ready-built homes (defined as tract homes)
- d. Owned homes or those homes custom built for a purchaser

Figure 3 shows the average floor space per home per category per year. An interesting fact is that even though custom built homes and tract homes have increased in average floor space since 1976, the cumulative average has dropped. This appears to have happened because the large number of rental units and those homes built for employees have become smaller in size. Figure 4 gives the types of residential units constructed each year since 1981 and figure 5 shows the dramatic increase in the number of prefabricated units that have been constructed each year since 1980.

Sekisui has been in business for thirty years and, in addition to single family homes, builds apartment/multi-family units. In 1989, it constructed over 60,000 prefabricated residential units for the Japanese market. Examples of several of its homes are shown at the end of this report. While Sekisui specializes in steel-framed construction, Mr. Ohta pointed out that wood stick built homes (2x4 homes) were introduced to Japan in 1970.

He defined a unit as any abode that contained a kitchen and toilet. The construction prices for Sekisui homes (this is the building price only and does not include land) range from ¥30

million (U.S. \$200 thousand) downward to ¥10 million. The size of the most expensive is approximately 200 square meters (2150 sq ft) and requires a yearly income of around ¥10 million (\$67,000), while the smaller home has nearly 80 square meters (860 sq ft). The average home built by Sekisui has 160 square meters (1720 sq ft) of living space.

Japanese typically purchase a home for life, and these homes have historically provided shelter for three generations; children, parents, and grandparents. Sekisui attempts to meet these and other special needs of each buyer by using a flexible planning system with each home buyer. Sekisui is very proud of this "custom" approach.

Each buyer goes through a series of questions to help determine his needs. Once a basic design is identified, it is reviewed in detail and changes are made that allow that design to best meet the buyer's needs. These changes are made by hand on a floor plan and then delivered to the CAD center in another part of the building.

Once finalized, these changes are entered into the CAD system and a floor plan is made of the newly configured home. This is prepared in less than an hour and given to the buyer for final approval. When requested, a physical model is prepared for the buyer even though in a video we were shown, there were several 3-D screen images of a home under construction. When panelists asked about this, we were told that 3-D images were not used in the sales effort and that only about 10 percent of the buyers requested the physical models, which are provided free of charge.

Once the final selection is completed, experienced CAD operators, using Unisys work stations, digitizing tablets, and custom software created by Unisys, call up the structural plans of the unmodified house and make the necessary changes reflected in the floor plan. Member sizes are determined by the computer based upon rules established by the firm. With this information, the computer generates a cost estimate. Two-dimensional detailed drawings are then prepared for the factory, outlining all of the materials that will be required in the production of the particular house. In addition to the fabrication and erection of the house, Sekisui provides landscaping details. After fabrication at one of a number of fabrication facilities in Japan, the materials are palletized and delivered to the construction location.

Construction is done in a number of ways. If desired, the buyer may contract with outside firms to perform the erection or Sekisui will provide subsidiary craftsmen or subcontractors to perform the work. These subcontractors rely on Sekisui for approximately 50 percent of their work, according to Mr. Ohta. Sekisui subsidiaries specialize in foundation work and steel frame erection. Sekisui guarantees its foundations and structures for 10 years.

The firm has access to a test facility for fire and earthquake testing, for the verification of strength of the various components of the houses, and for material research (e.g., research into light-weight durable concrete for exterior finishes). It also has a horticulture research center. Sekisui is actively developing passive solar homes and is doing research into elderly and handicapped housing needs.

The CAD system consists of a Unisys mainframe system (Sekisui has three centers in Japan) that is exclusively used in the sales and estimating effort. There are several terminals in each sales office. The personalization of each home is done in 2-D; however, the structural database contains 3-D information that allows the plotting of 3-D images. It is interesting that the dimensional and material information required by the factory for each home is printed out and delivered to the factory on hard copy. When asked why, we were told that the technology exists, but it has not implemented electronic transfer of data yet.

FABRICATION FACILITY

After lunch, we traveled by train to Ibaraki to view one of Sekisui's five fabrication facilities. There are approximately 600 workers at the factory; 450 are Sekisui employees; the remainder are subcontractors or independents that can be released when work is slack. The facility produces 750 buildings per month which, taking into account the apartment complexes that Sekisui produces, equals between 1500 and 1800 residential units.

When the two-dimensional drawings are received from the sales office, material quantities are taken off and entered by unit into the facilities computer by hand. These computers contain over 1.2 million component and material types for both current designs and older models. Over 200,000 components are shipped from the factory each month.

Three weeks is the average time from the receipt of drawings until the erection crews begin site work. About three days are required to do the quantity take off. When that is complete, the plant waits at least one week before they make any orders or begin any production runs for that house. When asked why, we were told that it was to account for any changes the buyer may want to make. Near the tenth day, preliminary orders are placed with outside supplies. Not until about four days prior to delivery are final supplier and plant manufacturing orders placed.

We were taken on a tour of the fabrication facility which consists of equipment to fabricate the structural steel members required for columns and joists; the steel frames that form the walls, floors, and ceilings of each house; the insulated panels themselves; and the wood trim that is used in the house. The facility was well automated with automated cutting, welding, punching, and protective coating equipment. There appeared to be nearly 750,000 square feet of covered fabrication area divided between at least three buildings.

We were given a tour of two completed demonstration homes located at the factory site. Both appeared to be sturdy and well built and compared favorably with homes constructed in the United States. The larger of these two homes had an exterior of light-weight concrete that was cast to resemble brick. The likeness was very good, and it was difficult to find the panel joints without specifically looking for them.

Sekisui has a comprehensive research institute located near Kansai. This is part of a larger research park that also contains institutes belonging to other large prefabricated home builders. Because of government estimates that by the year 2025 over 25 percent of the population will be over 65, it is looking into the modification of existing homes to meet the needs of the aged.

In addition to the research institute, Sekisui has established an employee training facility where new hires learn how the homes are built and go through a formal company training exercise.

SIGNIFICANT FINDINGS AND IMPRESSIONS

It was interesting that with all the design and sales automation used by the firm, it had not implemented a system for transmitting drawings to the factory by some means other than hard copy, such as disk or tape, or phone.

The factory appeared to be well managed. At the model homes site, the area around those homes under construction was conspicuously lacking waste material that would normally be seen at typical residential construction in the United States.

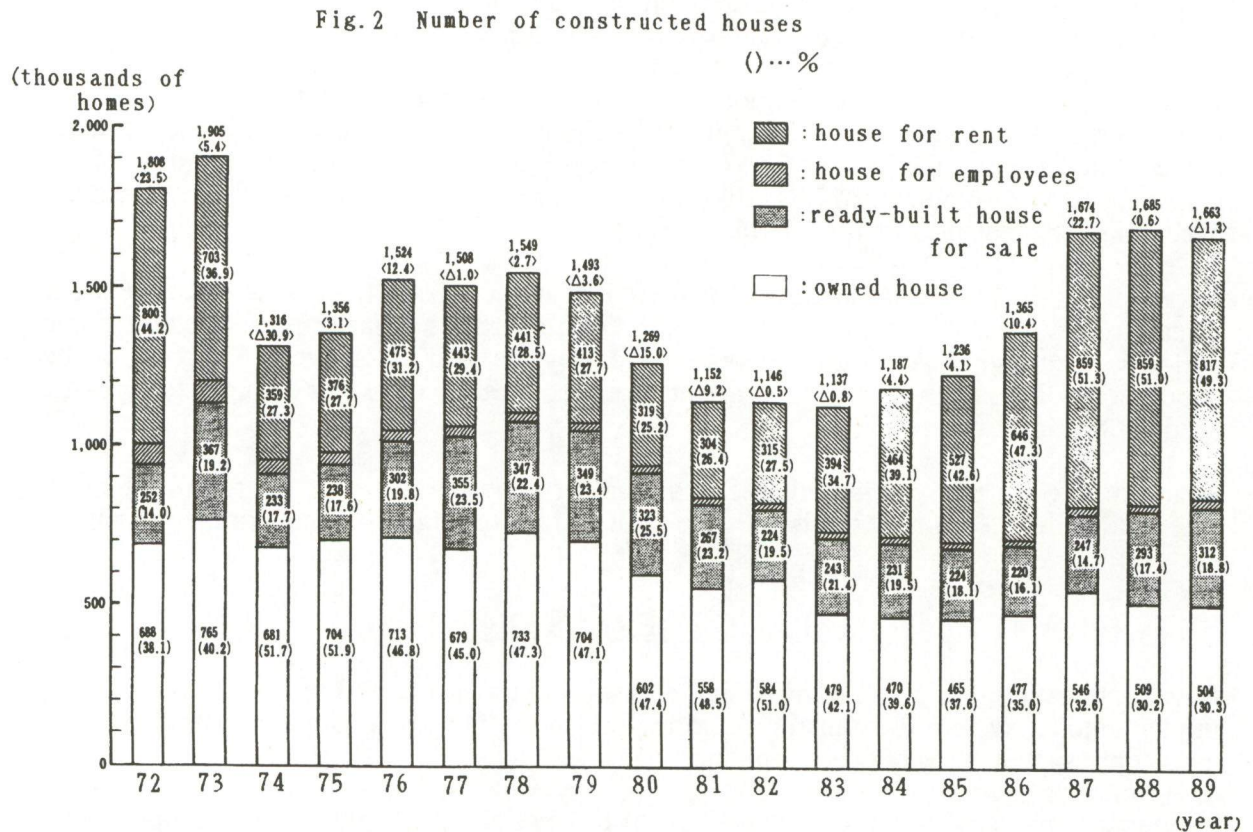
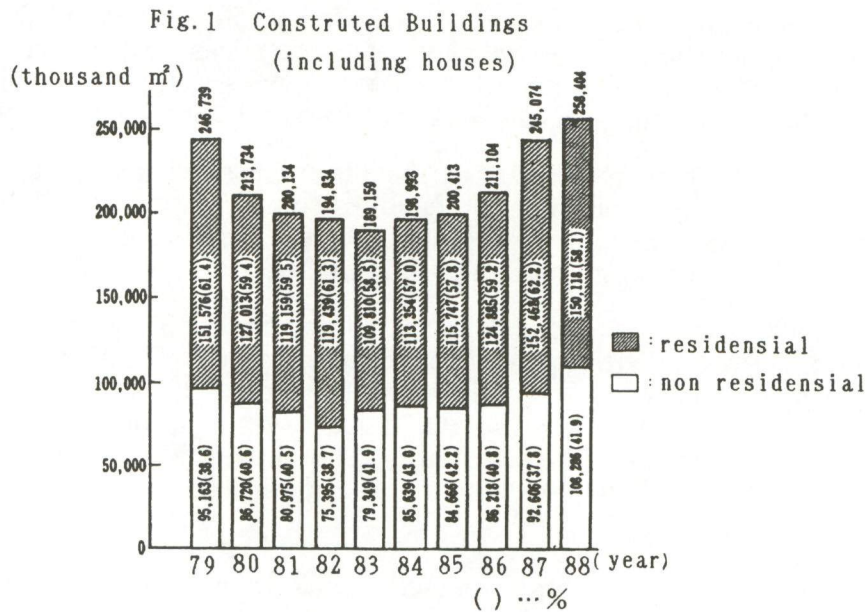


Fig.3 Floor space

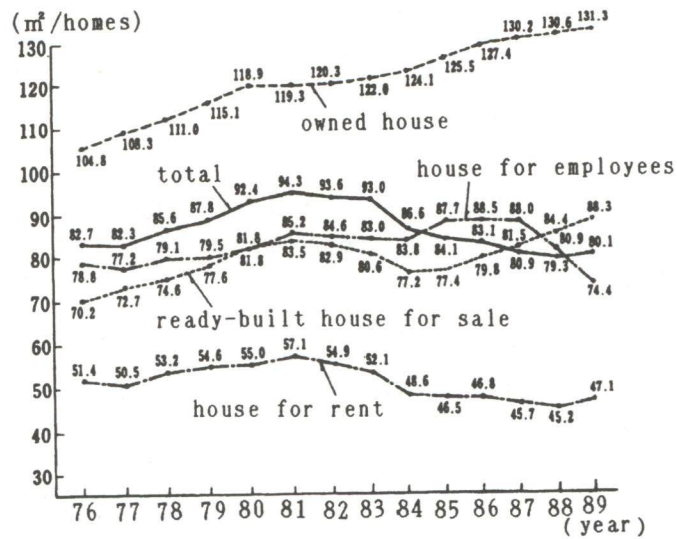


Fig.4 Constructed architecture

(THOUSANDS OF HOMES)

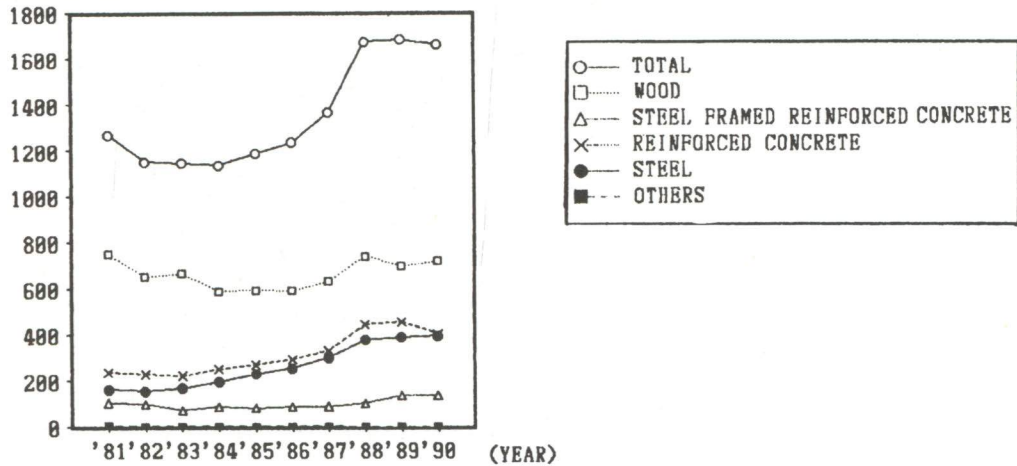
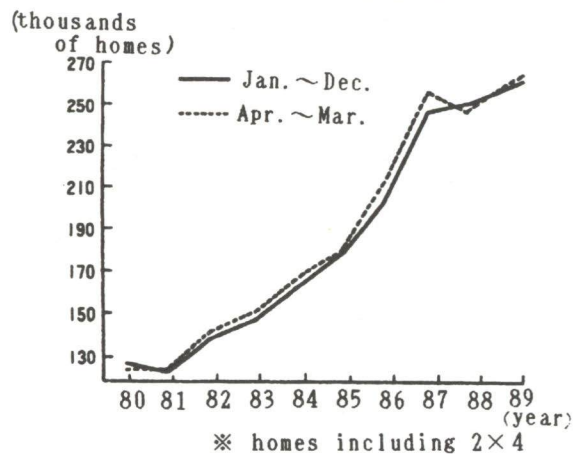


Fig.5 Number of prefabricated houses



SEKISUI HOUSE CAD SYSTEM

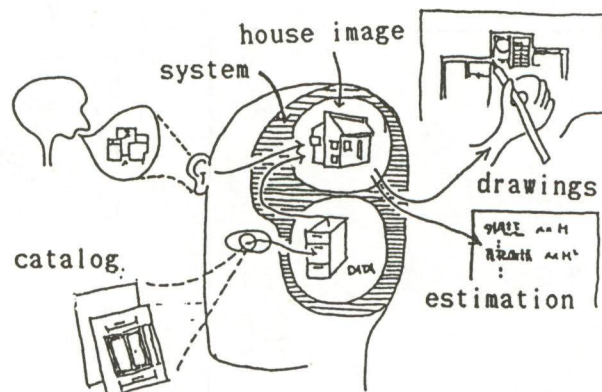
Automatic Drafting And Estimation System In Sekisui House

AUDESEI-III

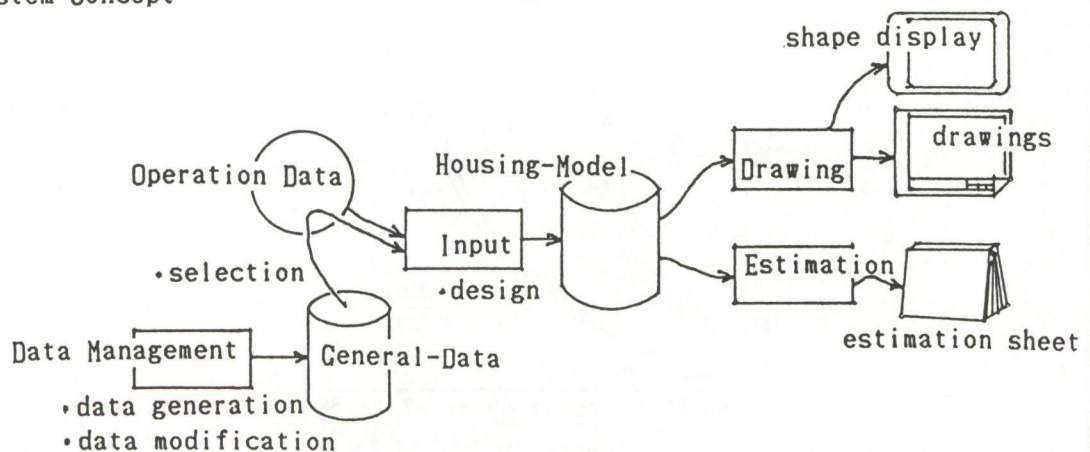
Our CAD (Computer Aided Design) system; AUDESEI-III is designed to generate drawings and to estimate the housing cost by automatically creating three dimensional solid model with the computer just as same image as a man designs a house in the human brain.

AUDESEI-III enables us to dramatically reduce manpower in the drawing and estimation. And it enables our client to be able to acquire sufficient information to build their house, through to provide with the external appearance of a house in a very short time.

Concept of "Design"



System Concept



Background

The following two environments require the AUDESEI-III.

First, clients are eager in pursuit of their ideal houses. They buy drawing papers and try to draw themselves their room layout charts again and again. This is a joyful task for those clients wishing to make their dreams realize. However, this will change annoying or difficult task once they reach the stages of drawing elevation and perspective. Most people can easily draw room layout charts, but generally it is a hard task for them to recognize their house as solid.

Further, though the cost needed to build every house is immediate and important factor for each client, the client is obliged to wait until results are calculated by constructor involved.

The second is relative to our company itself. Our company is engaged in designing, constructing and selling various kinds of houses, particularly of industrialized houses. As common natures of house design, the drawing charts needed in the design phase is small in number, because the size of each house is relatively small and details are mostly standardized. But in our company the final number of drawing charts will likely be large because the number of houses to be constructed by us is large. (20,000 houses/year)

Since 'drawing chart' is a very important medium for use as the starting point for marketing activities, the timely delivery of drawing charts to our clients is required.

Major roles

AUDESEI-III is a strong tool when our clients and our company try to pursue their suitable design.

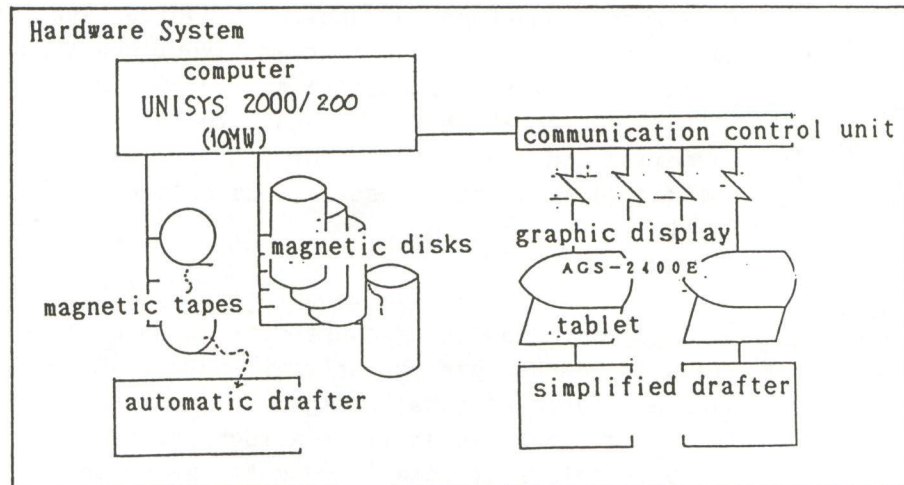
- AUDESEI-III can immediately display perspective of room layout chart desired by the client.
- AUDESEI-III generates a rough estimate sheet simultaneously.
- AUDESEI-III draws easy-to-see drawings with a color-pen.
- AUDESEI-III generates houses in the computer as three-dimensional solid model. The model can be modified immediately and repeatedly, thereby allowing people to refer to the modified appearance repeatedly.
- AUDESEI-III never make discrepancy between plan and elevation.
- AUDESEI-III can generate a drawing chart in accordance with sketches within an hour formerly needed one day.

Designers design House Model by watching screen display run under the AUDESEI-III. During the design phase, models are often modified. If our client joins this House Model design phase, they will be able to enjoy their joyful task on the screen. And at the same time, they can obtain elevation, perspective and necessary cost. Drawing sheets are then automatically generated by the computer.

Hardware and Operation

A Sperry Univac large computer with 10 mega words of main memory capacity is used as a host computer, and a display, tablet and plotter are used for input/output terminals.

If communication lines are available, the I/O terminals can be installed in any locations where an user can operate the terminals just like he occupies his host computer.

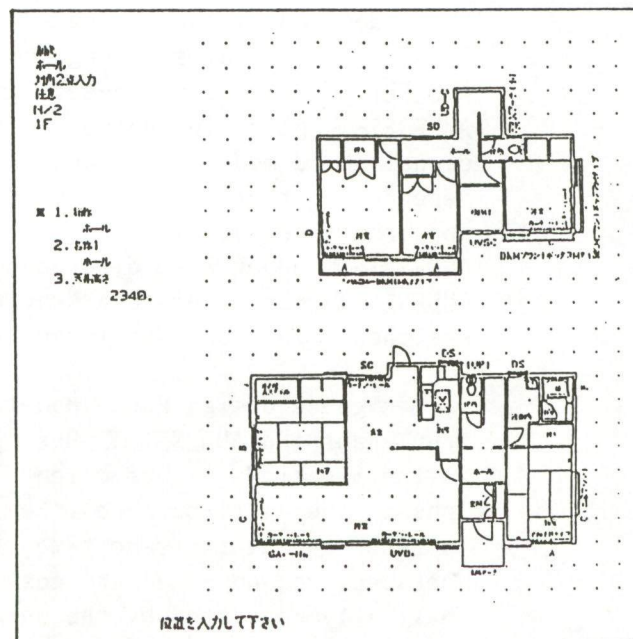


Input(model designing) operation is accomplished by selecting General Data containing attributes for each of the OUTLINE, ROOF, ROOMS(floor, wall, ceiling) of a house by subsequently indicating the shape or place it is installed.

Since this operation can be very much simplified and every person can operate the machines after having only two-day training, when operators become skilled in the operations, it takes only 40 minutes to design one house model.

The house model design process can be monitored with display unit.

Display Screen

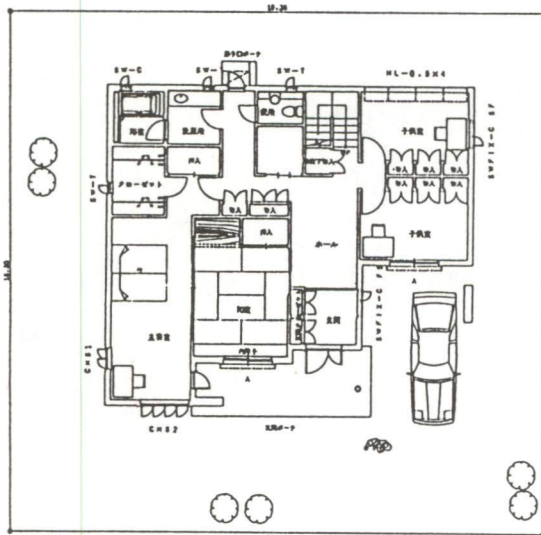
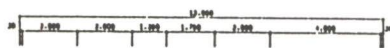
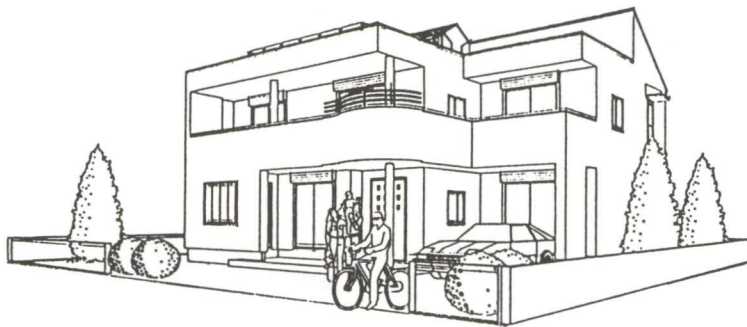


Output

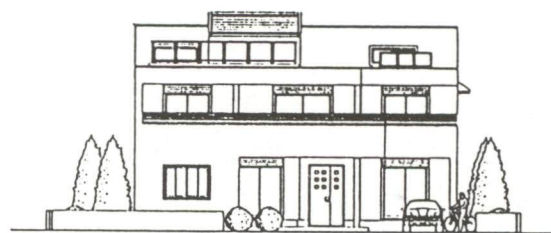
Every house model just designed is developed on the drawing paper by the drawing instruction about 20 minutes later and then an estimate sheet is generated by operation.

AUDESEI-III can output following drawings.

- Plan 1/50, 1/100
- Elevation 1/100
- Perspective 8 directions
- Foundation Plan 1/100
- Specifications, Finish Schedule
- Estimate Sheet



1階平面図 1/100



西立面図 1/100



イズ・ステーション：移りゆく季節や年月とともに、ゆとりで暮らす。100年を考えた、先進のダイコンクリート住宅です。



陸屋根の家 し(エル)：科学が生んだ「SGセラミックウォール」を採用。おおらかな表情を持つ、高性能住宅です。

クレフォートR-90A：個性を主張しながら、街並みに溶け込む。住む人の感性が香りとなって漂う、クオリティの高い住まいです。



奇蹟の家2BKW：洗練された美しいシルエット。豊かな暮らしを育む、広いバルコニーのある住まいです。

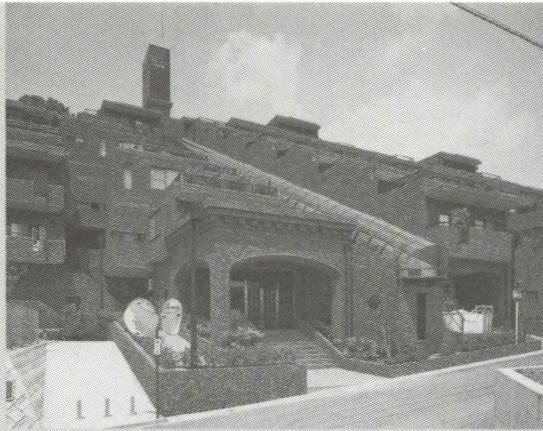


数寄屋の家 切妻タイプ：伝統が育んだ陰影の奥床しさ、造形の錯綜な美しさを現代の感覚で表現した住まいです。



フェニーII：独自の空間創造と斬新な生活提案が盛り込まれた、コストパフォーマンスに優れたシンプルな住まいです。

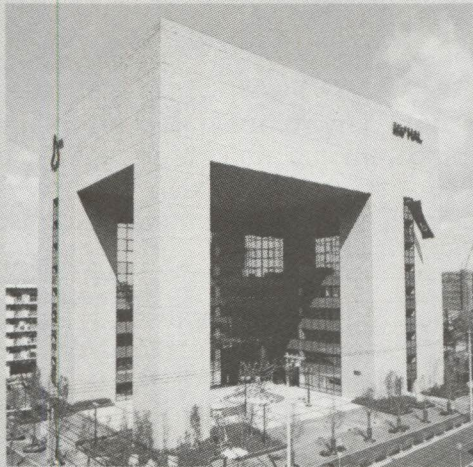




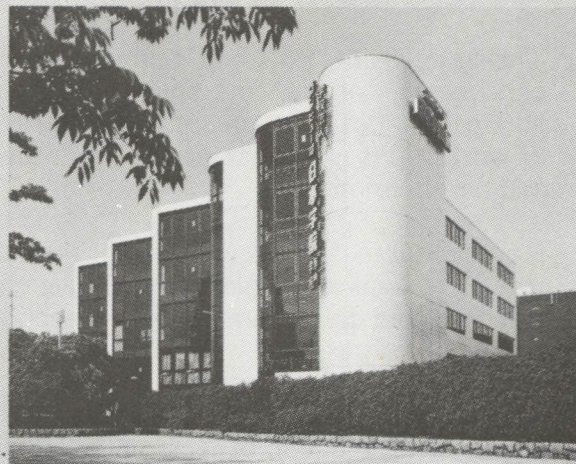
山の斜面を有効的に利用、斜行タイプのエレベーターなど、さまざまなアイデアが生かされた、高級分譲マンション。



先進のノウハウと、独自の情報ネットワークを活かして企画・設計された、最新設備を誇る総合病院。



豊富な経験と独自のノウハウを活かし、キメ細かな配慮と入念な企画・プランニングのもとに生まれた教育施設。



そこに求められる特殊性を十分に理解し、人が集い、学ぶための理想のスペースを総合的に考えて創られた教育施設。



風格に満ちた美しい外観、環境との調和と優れた居住空間の創造を追求した、邸宅風のハイクオリティ分譲マンション。



魅力あるデザインと機能性に優れたプランニング。快適で豊かなひとときを演出する、収益性の高いファミリーレストラン。

THE KAJIMA INTELLIGENT BUILDING

Date and Time: Tuesday, July 17, 1990, 9:30 a.m. to 11:30 a.m.

Participants: JTEC - J. W. Fisher, R. D. Hanson, R. L. Tucker

Kajima:

Dr. T. Kobori, Executive Vice President
N. Mitsuta, Civil Engineering Technology Division
K. Koseki, Civil Engineering Technology Division
F. Tsubouchi, Architectural Design Division
M. Matsuda, Information Processing Division
T. Suzuki, Information Processing Divisions

NARRATIVE OF ACTIVITIES

1. The Intelligent Building features deal mainly with environmental control and enhancement of the work area. Primary focus is on communication, information and automation, flexibility and amenities for refreshment and private life. Extensive surveys of work habits and office practice preceded the design. The goal is optimum office use and the environment.
2. Kajima found 50 percent of the workers' time spent on communication. Hence, extensive steps were taken to facilitate communication activity. Conference areas are extensive and near an atrium; multi-functional telephones are provided to each employee. Pacific Telesis assisted with communication assessment.
3. Design considered workspace area, high ceiling open space with acoustic dividers to isolate areas, modular offices, and computer simulation of the work flow. Light and air conditioning are controlled at each workspace. Flexibility was a major focus of the work areas so that conversion and diversification of space, furniture, building service systems, information communication systems, computer services, and shared services was possible.
4. Printed document information was centralized in three storage spaces: (1) the system furniture at the work area; (2) data corners; and (3) data center. We were shown the Visual Information Center which provides visual databases and visual services. It had 3-D CAD walk-through capability that was developed in-house. It has slides stored on disk for computer retrieval; 20,000 are now on file. These can be retrieved and displayed on-screen. It was stated that all Japanese construction companies develop their own CAD capabilities.
5. Considerable space was devoted to rest and refreshment areas. This included guest lounges, roof garden, cafeteria, employee club, and atrium with nature link. Each day at 10:00, a 10-minute closed-circuit TV broadcast keeps employees apprised of current events at Kajima. We were filmed for its July 18, 1990 broadcast. Kajima considered the fragrance of the environment and has a computer-controlled system to introduce it.

However, there does not appear to be any research done to establish its effectiveness. The water landscape in the atrium and biomusic are a part of the environment.

6. At the present time, 850 people work at the KI Building complex. They include 200 structural engineers, 350 architectural engineers, 170 mechanical engineers and 130 office support staff. Kajima claims a 25 percent drop in dissatisfaction with work, a 13 percent increase in productivity, and a 15 percent decrease in fatigue. Young people no longer want to work in its older buildings.
7. The structural systems in the two buildings that are linked with a passive type steel post seismic damping system at each floor level. The framing is conventional with steel-reinforced concrete columns and composite steel beams. It did not instrument the structural system and used composite beam design criteria developed at Lehigh by Fisher et al.

SUMMARY

It's an impressive building with outstanding workspaces. Kajima has developed computer applications such as CAD to cut model materials for the model-building lab, its own walk-through program, other applications such as lighting and views for changing times of day, and has four years experience with expert systems development. Six expert system programs have been prepared; initially the shell KEY (Palo Alto) was used, but it is now using a Hitachi Shell.

General R&D Issues

We also discussed issues related to R&D. It was viewed that tax incentives are small and based on an increase over an average of the past 20 years. It was universally noted that competition is the driving force for R&D expenditures. There is little cooperative R&D with competitors. Kajima does work jointly with suppliers.

The Information Processing Center has 150 people and provides R&D as well as service. Employees have an account to identify time for R&D.

It was estimated that about 7 percent of the planning section time was spent on R&D.

About 5 percent of R&D effort was exploratory (new areas). The balance is devoted to improvements in existing technology.

It was noted that the faculty at Japanese universities are reluctant to join in R&D or to affiliate with any one company. They are not interested in applications. Any joint research is driven by one of the government agencies (MOC or MITI).

A company's R&D activities must be shown to MOC. R&D personnel are also used to solve technical problems on the work site as they develop. R&D is funded by the annual budget at the research laboratories and from special funds for troubleshooting projects.

We were provided data on the annual budgets of the research laboratories of the "Big Six" construction firms (This does not include the special funds cited above which appear to equal or exceed the annual budget). These values are given in Tables 1 and 2 and the attached figure.

TABLE 1
BUDGET AND NUMBER OF ENGINEERS IN RESEARCH
LABORATORY OF MAJOR CONSTRUCTION FIRMS

	CONSTRUCTION FIRM					
	Kajima Corp.	Shimizu Corp.	Taisei Corp.	Takenaka Komuten	Ohbayashi Corp.	Kumagai Gumi Co.
1988 Accounting Year (US\$, millions) *	32 (0.44%)	29 (0.39%)	19 (0.28%)	19 (0.35%)	23 (0.40%)	25 (0.42%)
Research Engineers	240	175	135	200	150	140
Total Area of Lab. & Office (m ²)	28,000	17,500	17,000	13,000	14,500	18,000

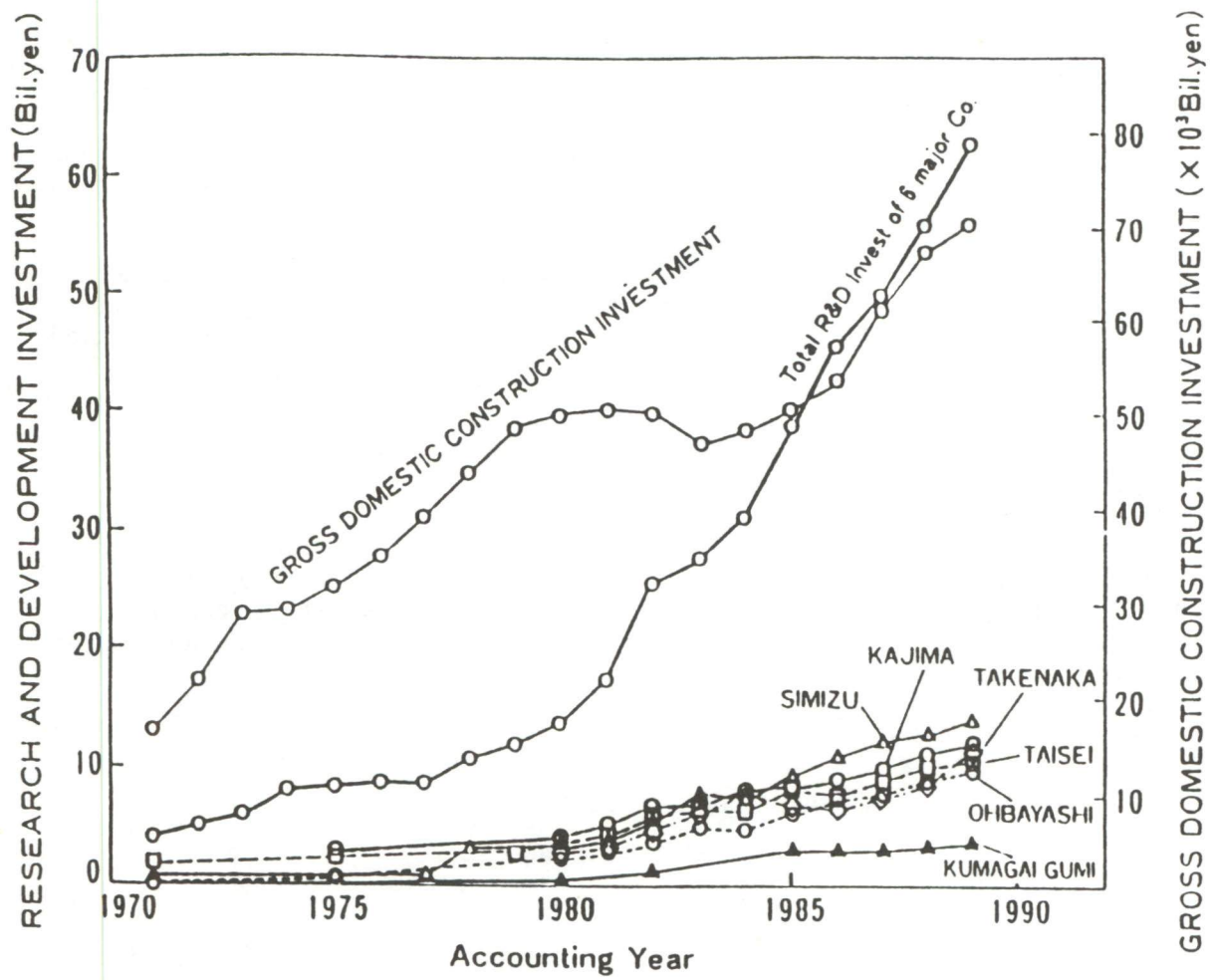
* Percentage for the annual turnover

TABLE 2
BUDGET AND NUMBER OF RESEARCH PERSONNEL*

Sector	Annual Budget** (US \$, millions)	Research Personnel	Budget/Person/Year (US\$, thousands)
Universities	364	4,500	80.9
Governmental Research Institutes	214	1,050	203.8
Construction Co. Research Institutes	371	2,500	148.4

* Estimated from 1988 Year Book published by The General Administration Agency of Japan

** The figures include salary



THE TOSHIBA AND NEC INTELLIGENT BUILDINGS AND THE NEW SHIMIZU HEADQUARTERS COMPLEX

Date and Time: Wednesday, July 18, 1990, 9:00 a.m. to 5:00 p.m.

Participants: JTEC - Dan Halpin and George Watson
Toshiba, NEC, Nikken Sekkei, Shimizu

NARRATIVE OF ACTIVITIES

Three buildings which incorporate intelligent or smart systems were visited. The Toshiba building was visited in the morning (9:00 a.m. to Noon), and NEC and New Shimizu Headquarters buildings were visited in the afternoon.

The Toshiba building has been in operation for over five years. The NEC building was just completed and opened in March of this year. The Shimizu Headquarters building is under construction and is scheduled to be opened in the Spring of 1991. Each building reflected different levels of sophistication and slightly differing approaches to intelligent building design.

Hosts at the Toshiba building were members of the concept engineering division. Members of the construction division were also present.

The Toshiba building is the world's first intelligent building. According to information provided, it was completed in 1984. The building was constructed jointly by Shimizu and Kajima. The design was done by Shimizu. The building was constructed to consolidate at one location employees previously scattered at a number of sites/offices throughout the Tokyo area.

The building has improved company performance by

- (1) Enhancing the corporate culture
- (2) Improving the morale of the employees
- (3) Generating new business areas

The expression "Amenity" was used numerous times throughout the briefings held at all three buildings. The enhancement of the work environment so that the employees are more productive is a theme which is echoed in the concept of "Amenity." The work place should be so attractive and stimulating that employees want to go there and work productively. The building should provide a "work" home away from home.

This is realized in the intelligent building context by making it easier and more interesting to work based on advanced support systems (mainly computer-based). Amenities include better environmental systems. Electronic devices such as magnetic ID card readers allow for security/access to building as well as payment of lunch/food costs and withdrawal of funds from banking machines in the building. The computer workstation environment is designed to allow the employee to work "smart" locally using PC level support, a minicomputer located on the same floor, or using files in a mainframe host computer which supports the

information needs of the entire building. The Toshiba building is linked worldwide by telecommunications satellite links which provide data on sales and other information in a real time mode.

The concept of the intelligent building is approached as a system developed to be marketed as a unit such as a refinery support system, a mass transit control system, an electric power station support system, etc. Mr. Kato, General Manager of the Concept Engineering Division at Toshiba made the point that the building "is our showroom." It demonstrates how sophisticated building support systems can enhance the work environment and make employees more productive. As such, it represents a new dimension in building concept and design which can be marketed as a system. The building in this sense is shown to potential customers and generates new business.

This same theme was echoed at the NEC building which dominates the skyline several blocks from the Toshiba building. Our hosts at the NEC building were representatives of the design firm Nikken Sekkei and the owner, NEC. Most of the presentation was made by Mr. K. Misu of Nikken Sekkei and Mr. K. Onoda of NEC.

As at Toshiba, we were briefed regarding building design characteristics and capabilities, and we then toured the building. The building is called the NEC Super Tower and includes 43 floors above grade and 4 subbasements. The building has a large atrium which can be opened to the sky and has a side elevation profile which makes it look like a space shuttle. Sophisticated workstations for the employees are used that integrate telephone and computers at each employee desk. This concept uses an Integrated Voice Data LAN (IVD-LAN) concept to multiplex data to host computers on each floor as well as to the building support mainframe computer. Cabling to support systems is routed through a ring duct system which is located at the periphery of each floor. This system appears to be proprietary and will be marketed by NEC. Again, the word "Amenity" is key, and items in the building such as fitness centers, banking facilities, shops, and restaurants are designed to allow the employees to be comfortable and happy without leaving the building.

One interesting design feature of the building is the sophisticated Super Truss System, which supports three divisions or multifloor modules of the building. The super truss is designed to support the three major sections of the building (Floors 1-12, 13-38, 39-43) as sub-buildings or modules which could be (theoretically) removed and replaced. A large opening in the building between the 12th and 16th floors is a feature to reduce turbulence at the base of the building during wind storms and typhoons. It also allows the opening of the atrium at this level. Again, the building is a showplace illustrating the concept of "Amenity" and indicating what systems NEC can provide to support this concept.

The final visit of the day was to the New Shimizu Headquarters which is under construction. Mr. Uchiyama of the Technology Division met us at the NEC building and accompanied us to this site (which is directly next to the Toshiba building). Our hosts here were Mr. Okamoto, the principal architect in charge, and Mr. Nakajima, the project construction manager (both of Shimizu). Both occupy large on-site offices with 20-40 employees in each group. The project consists of twin towers which are connected by a barrel vaulted atrium.

The site was developed as a partnership with Nippon Telephone and Telegraph (NTT). The North Tower will be occupied by NTT and the South Tower by Shimizu Corporation. These two firms will own and operate the buildings. The atrium will be a public area. This was a stipulation of the building permit issued by the Tokyo Building Authority. The two towers are both less than 100 meters in height. Mr. Okamoto explained this height constraint was imposed so that the building permit could be issued in less than one year. Tall buildings, such as the NEC and Toshiba Towers are often delayed three to five years based on

environmental reviews. Therefore, the decision was made to build two 100-meter towers. The appearance of the building in construction is very similar to that of buildings in the U.S. It is a steel frame building as are the Toshiba and NEC buildings. No unique structural features or construction techniques were noted. The site construction personnel indicated that they utilize manual methods to control the construction. Most information is transferred in the framework of many meetings through the course of the day. No computer-based management systems were observed. Computers at the site are used by the design team and mainly for CAD applications.

A unique composite piping of soft insulation material is used for the air conditioning-system. Upon observing fireproofing material on the steel girders in the building, we asked whether the SSR-3 robot was used in this application. The superintendent indicated that they had tried to use it on the 22nd floor. The robot was not able to spray tight and unique areas in the frame and manual methods were resumed. The superintendent appeared to assume that such devices are only research vehicles and not intended to be used in a practical context. At any rate, the robotic device was not efficient.

SIGNIFICANT FINDINGS FROM DISCUSSIONS

1. The intelligent building concept represents a product or product set which can be sold as a package.
2. The concept of "Amenity" is a driving and unifying concept in all new building design.
3. Computers are not used as management tools at the construction site.
4. Robotic devices are not being used on the construction site observed other than as laboratory prototypes to be tested.

NEW OTANI INTELLIGENT OFFICE BUILDING TAISEI CORPORATION

Date and Time: Wednesday, July 18, 1990, 1:30 p.m. to 4:30 p.m.

Participants: JTEC - John Fisher and Richard Wright

Taisei Corporation:

Mr. Fujiwara, International Department
Mr. Koreishi, New Otani Tower Chief
Mr. Kazuhiro Arai, Manager
Mechanical and Electrical Design Section
Design and Proposal Division
Mr. Takehisa Yoshiie, Manager
Technology Development Department

NARRATIVE OF ACTIVITIES

1. The name, after completion, of the New Otani Tower will be the Garden Court office building. The building will be 30 stories tall. It has a mat foundation on the Edo sand and gravel layer, steel frame, precast concrete, tile finished facade panels, tiled carpeting, and a system ceiling.
2. Conservation and recycling features requested by the City include a cogeneration system that will provide power to the Garden Court (main daytime load) and New Otani Hotel (main nighttime load) and uses waste heat for space and water heating and absorption chilling for air conditioning. It is powered by gas with fuel oil backup fuel. A waste water recycling system will provide "gray water" for water closets. A garbage recycling facility is provided for kitchen wastes from the hotel. A five-year return on investment is projected for water and garbage recycling.
3. Site work crew is 420, about 10 percent Taisei employees. Nominal work schedule is one eight-hour shift daily with subcontractors prone to working additional hours. Schedule is for a construction period of 24 months, now in the 17th month and on schedule, with erection at the 24th story.
4. New TMCP (thermomechanical control process) low-carbon, high-strength steel is used for steel frame. Preheating is used for thicknesses exceeding 40 mm. Sections include H-section beams welded from three plates and box section columns. Seismic resistance is provided by moment resistant frame with subframes, not shear walls or braced framing, in central elevator core walls. Beam-to-column connections use bolted webs and welded flanges.
5. It is designed as a rental office building to be adaptable to clients' needs. Column spacing is 3.6 m (normal is 3.2), floor-to-floor height is 2.7 m (normal is 2.6), and floor

load is 500 kg/m² (normal is 300). Structural concrete has strength of 270 kg/cm² (normal is 220 to 240). Taisei's laboratory is seeking 800 kg/cm² concrete. Exterior tiles are fastened to precast panels in the factory using a special hanger based on Taisei research. Precast panels use galvanized steel connections to the framing for durability and are backed up by a gravity connection detail. No fiber reinforcement is used in the project, but carbon and stainless steel fiber reinforcement is being researched by Taisei. Interior finishing is gypsum board on metal lath. Glassing is heat absorbing, reflective glass. Air conditioning is subject to control by occupants through a special terminal. Security system provides manual lockup and elevator bypass of unoccupied floors with video surveillance. Prewiring, including an optical fiber system, is provided for state-of-the-art communication and information systems. The fire safety system includes smoke detectors, sprinklers, emergency communications to occupants, leading lights for exiting, pressurized stairwells, and a smoke exhaust system. Control systems are integrated to a central computer with independent backup for the fire safety system. Taisei designed the service systems and controls using manufacturer's standard components. An open system protocol is not available, but Taisei is developing one. Seismic motion recorder will be installed at five levels in the building.

6. The excavation used the Taisei underground diaphragm wall which employs prefabricated wall sections supported by earth anchors. Steel erection uses the "layered method" developed by Taisei. Two 300-ton tower cranes and two materials handling cranes support erection. Columns are three stories in height. The remote control for release of the column to crane lifting connection is the only "robot" used on site. Deck and facade installation and utilities follow close behind girder and beam installations. The cycle for an individual story is 15 days.
7. A computerized ID system is used for worker access to the site. A computer-based project management system tracks progress daily. The system was developed for the project by Taisei's Computer Services Division. No knowledge systems are used on this project, but Taisei has knowledge systems for tunneling and bridge construction. As-built drawings will be developed at the end of the project. Female workers on the job site are limited to employees of a scheduling subcontractor.

SIGNIFICANT FINDINGS AND IMPRESSIONS

1. The project is state-of-the-art in design and construction practices, with effective use of techniques developed in Taisei's laboratories. No extraordinary innovations or demonstrations of advanced technologies were noted.
2. Substantial efforts were evident for energy conservation and utilities load leveling in the cogeneration, water recycling, and kitchen waste recycling systems. Japan and its construction industry are giving serious attention to environmental improvements.
3. Seismic details for avoidance of nonstructural damages were not evident in installations of ceiling systems or anchorages of utilities piping. Equipment appeared to be anchored firmly.

OHKAWABATA HOUSING - RIVER CITY 21

Date and Time: Wednesday, July 18, 1990, 9:00 a.m. to Noon

Participants: JTEC - Ken Chong, Bob Hanson, Reed Nielsen

Ohkawabata Housing:

Hiroshi Ueda, Deputy Section Chief
Architectural Planning Division
Architecture and Construction Department
Housing and Urban Development Corporation
Katsunori Otomaru, Senior Researcher
Housing and Urban Development Research Institute
Mr. Kadino
Mr. Katori

NARRATIVE OF ACTIVITIES

Mr. Ueda welcomed the panel members and explained that the Ohkawabata Housing project is one of a number of projects whose purpose is to encourage people to live in, as well as work in, the City of Tokyo. Other projects being planned will include reclamation of portions of the Tokyo Bay.

A video, in English, explained that the project is approximately 2 kilometers from the Tokyo Station and close to the Ginza. The property had been industrial prior to its acquisition by the Housing and Urban Development Corporation and Mitsui Real Estate. The project is being constructed on over 17 hectares and consists of a combination of public and private residential units, commercial and cultural facilities, an elementary school and middle school, and a bridge to connect the complex more directly with the Tokyo Station and Ginza areas of Tokyo. It also includes more than five hectares of riverside park and recreation areas. The floor-space-to-ground-area ratio is 400 percent for the residential portion of the development and 600 percent for the commercial and cultural developments.

The master plan was developed by the Tokyo Metropolitan Government, and design was performed by Mitsui, the Housing and Urban Development Corporation, and the Tokyo Metropolitan Government Bureau of Housing, in conformance to the master plan. Construction involves a number of different entities including Mitsui Construction, Ohbayashi, and Taisei. Design review for all of the buildings was performed by the Building Center of Japan.

Underground parking is included in the development, as is electronic security controlled from a high-tech security center. Access to the residential building is controlled by security, and closed-circuit television is used to monitor security of the facility. Each apartment contains an information panel that provides fire and gas leak warnings in addition to containing the phone and entrance communications.

The 2500 condominium units range in size from 70 meters square to approximately 100 meters square and have from one to four bedrooms. Fifty applications for each available unit are being received for those managed by the government. Occupants are determined by

lottery. Rental prices for the public units range from ¥180,000 to ¥250,000 per month (U.S. \$1200-\$1660). Those units being managed by the private sector have an eight-to-one ratio of applicants to available units. Monthly rentals can be as high as ¥960,000 (U.S.\$6400) per month for these private sector condominiums.

Those with whom we met were not familiar with any innovative techniques or materials employed in the construction of the buildings.

SITE TOUR

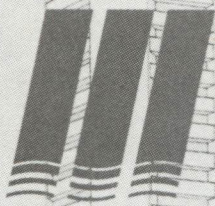
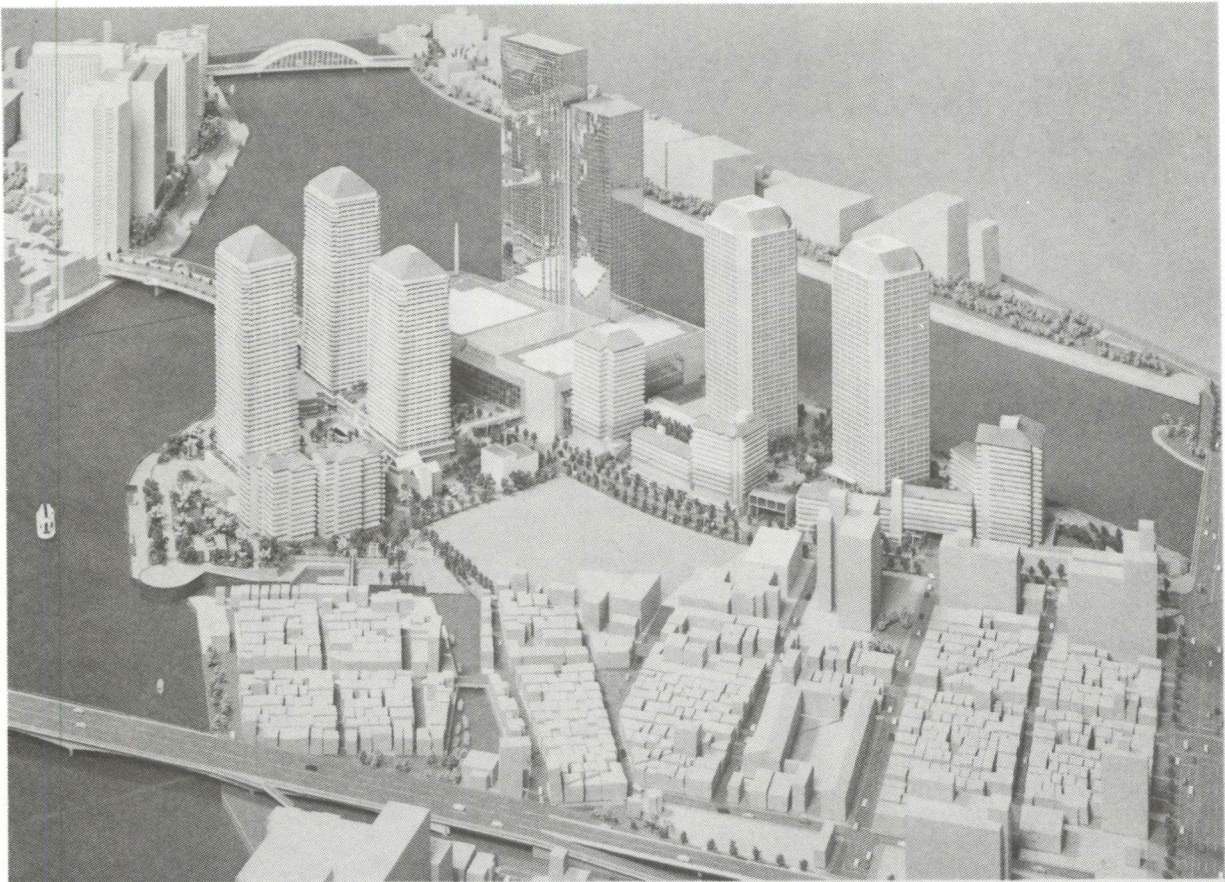
The site we visited is being built by Mitsui Construction and was exceptionally clean and well laid out. There was a minimum of debris or other material on the site. We were told there were about 250 workers at the site. The tour guide did not speak English, and we had a difficult time obtaining adequate translation of the responses to the technical questions that we asked.

The construction elevator took us to the top of the building, approximately 35 stories, where built-up roofing was being applied. Once again, the area was exceptionally clean given the type of construction. We were told that there were three or four plies of roofing being installed and that a thin layer of concrete was to be placed over the roofing after installation was complete. Although we could not see it because it was covered by precast concrete panels, we were told that the structural columns of the building consisted of rectangular structural steel shapes filled with concrete. All of the beams that we saw were precast concrete. Interior walls were made of a preformed calcium material with stiffeners on one side. Called a "studless wall," these units were placed back to back with stiffeners offset, and insulation was placed between the two sheets. Regular drywall/plasterboard was then affixed as the surface sheet.

SIGNIFICANT FINDINGS AND IMPRESSIONS

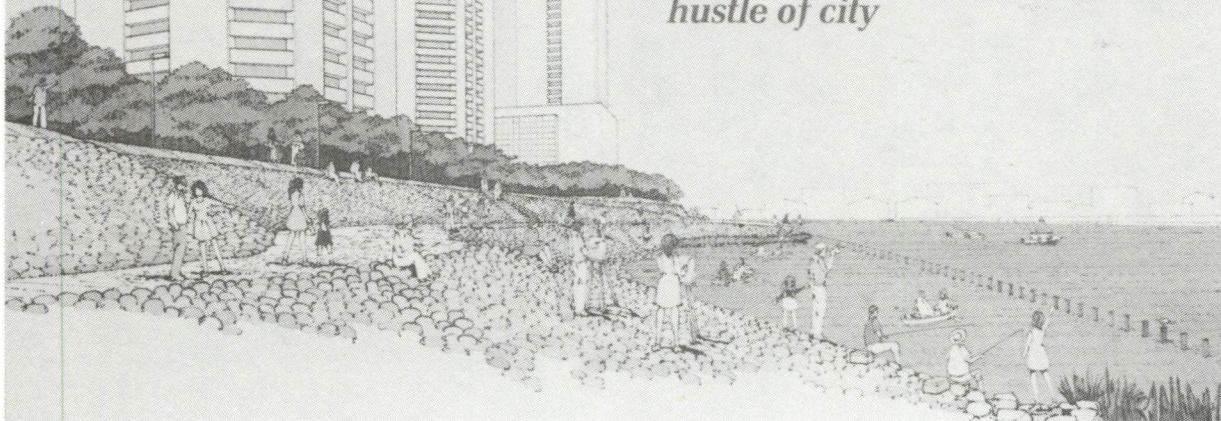
It was clear from the building site that we visited and our observations of surrounding structures under construction that as much prefabrication as possible is done. The "studless wall" panels minimize the amount of field labor required, as well as the lay down space needed. This approach also allowed the drywall to be fastened any place on the panel rather than just at the studs, in addition to removing the need to design or cut the drywall to end on a stud. We were told that a building under construction to the east of the one we visited had a reinforced concrete structure below the thirteenth floor and pre-cast columns, beams and slabs above that level. A building under construction to the west was in the process of installing pre-cast slabs at about the twentieth story. With limited laydown space, these panels were being hoisted from what appeared to be the delivery truck and placed in the building at their final location.

Laydown space for materials and equipment was limited both at the building we visited and at other buildings in the near vicinity. In spite of this, or perhaps as a result, the areas both in and around the buildings were neat, clean, and well arranged.



A Pride of Tokyoite Communities **River City 21**

*A choice of residence
because of a restful comfort
of river and yet an exciting
hustle of city*



Recreational Waterfront and Spectacular Waterscape

The first of its kind

Tokyo has a woe. Inhabitants of its central districts have so constantly trickled out of the city that school enrolments, for example, diminish every year. Among others, businesses are to blame. They are increasingly squeezing into the already-standing-only space and eventually edge them off the lucrative city zones. The trend is deplorable because it violates the principle of the well-balanced community membership and therefore impairs the healthy workings of city function.

River City 21 aims at helping arrest the undesirable flow.

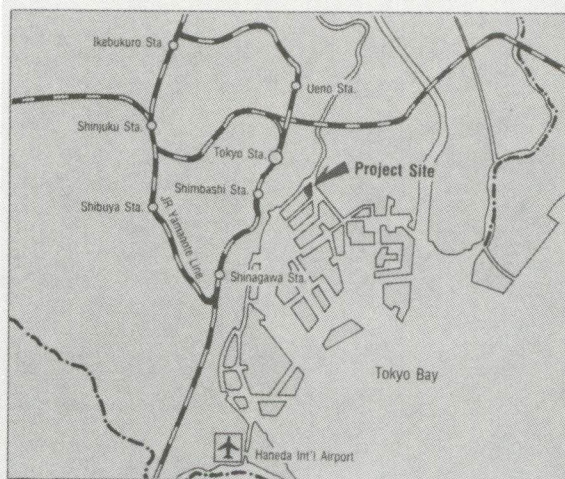
Close coordination between government and business has given rise to the project to generate a 7,500-population community on the former site of plants and factories with environment offering an attractive quality of life. The project, the first of its kind, is a joint undertaking by such government and governmental corporations as Tokyo Metropolitan Government Bureau of Housing, Tokyo Metropolitan Housing Supply Corporation, and Housing and Urban Development Corporation and private sector Mitsui Real Estate Development Company.

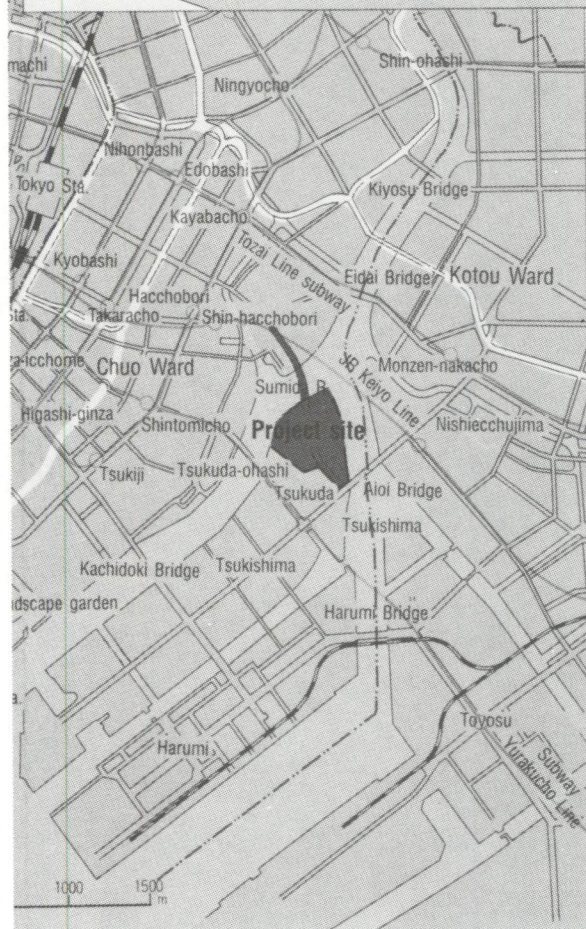
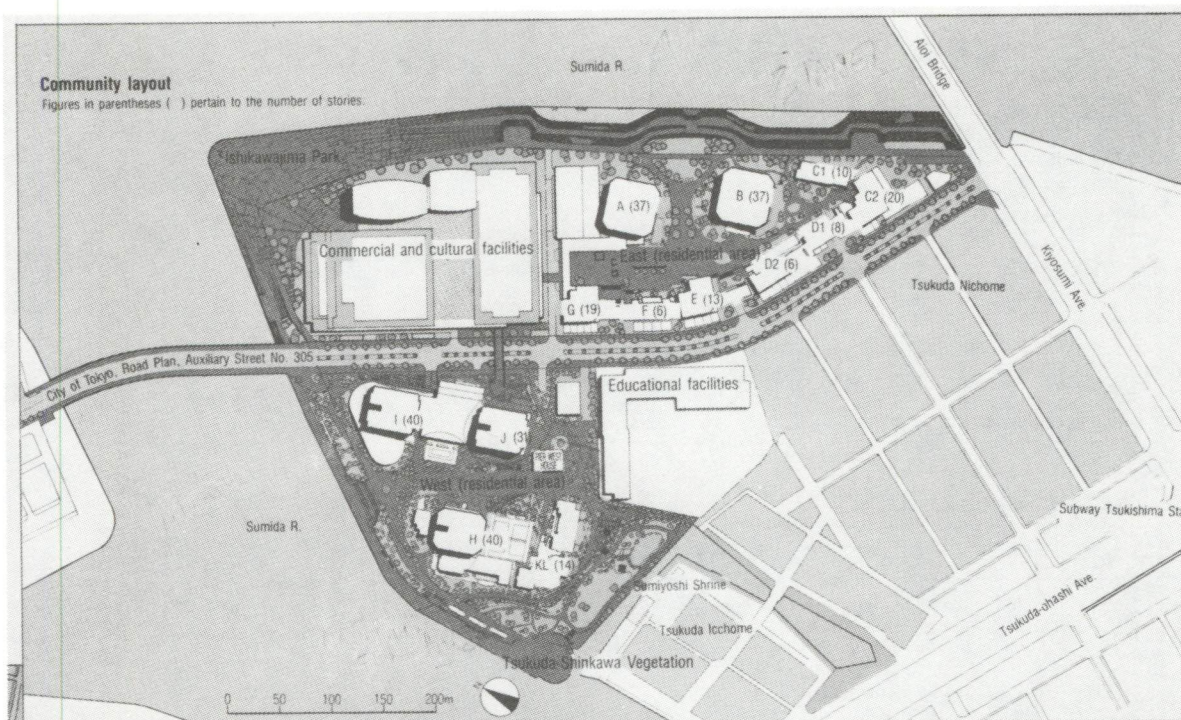
Landmark venture

The plan to develop a residential, commercial, cultural and educational complex in the heart of city is literally an attempt to reconstruct value which was once taken for granted by all urbanites: life with shelter and workplace conveniently located around. Thus, River City 21 is expected to serve not only as a factor to discourage urban deserters but as a landmark venture in the long-range development plan of the nation's capital.

The project is part of what is called Ohkawabata Redevelopment Plan. Ohkawabata, or the Greater Riverside, is the most favorite districts of downtown Tokyoites, and the plan is considered highly significant because of the Sumida, a traditional geographical symbol of Tokyo, like the Seine for Paris and the Thames for London.

With its 2,500-unit high and medium high rise condominiums, River City 21 offers a wide variety of floor plans from which to choose according to individual needs. Perhaps worth mentioning is a unique multipurpose structure to accommodate offices, halls and chambers for businesses and various cultural activities such as concerts and conventions.





Forerunning plan

Urban convenience is incorporated with environmental excellency. It is a choice of residence because of a restful comfort of river and yet an exciting hustle of city.

The project includes an innovative civil engineering scheme. The expansion of gently sloping waterfront areas with parks and vegetation provides a wealth of safe recreational opportunities such as angling, wading, jogging, cycling and walking. And, there will be a spectacular waterscape with lush trees rustling in the Tokyo Bay breeze. Technically, the top of these areas is level to the ground of the community so that it can hold back water without help of any embankment.

Tokyo residents are already enthusiastic with the forerunning plan to lead the way into the 21st century. This project launched in March 1986 to complete in March 1993.

Convenient location

Although located near Ginza, a hub of commercial activities, the site is completely independent of the blight of a megalopolis. And yet the world's famous mass transit system is readily available; Tokyo train station, for example, is only 2 kilometers away. Subway Yurakucho Line will open its new station Tsukishima, only a block away, in early 1988. In 1992, a large bridge will complete over the Sumida for an additional access to the community as well as a shortcut to Tokyo Station.

Address: Nichome, Tsukuda, Chuo-ku, Tokyo

■ Development plan

Residential	6.4 ha.	Condominium: 2,500 units (1- to 4-bedroom) (Height: 120m. at highest)	River City 21
Commercial and cultural	2.6 ha.	Mainly retail stores, cultural facilities (fl. area: 150,000sq.m.) (Height: 180m. at highest)	
Educational	1.4 ha.	Primary schools (grade and intermediate)	
Street	1.2 ha.	Width: 22-25m. (incl. tree-lined sidewalk) Length: 1.1 km. (incl. overhead bridge connecting Shinkawa and Tsukuda districts) Designation: City of Tokyo, Road Plan, Auxiliary Street, No. 305	
Park and vegetation	5.6 ha.	Mainly gently sloping waterfront areas; lush vegetation	
Riverside		Gradual, safe waterside	

Expected population is 7,500. All figures are rounded.

■ Construction plan

		Developer	No. units	Bldg., no. stories & height	Parking & amenities	Area	Fl. space ratio
Resi- dential	East	Tokyo Metropolitan Government Bureau of Housing	280	C1 (10 ; 34 m.) C2 (20 ; 65 m.) D1 (8 ; 30 m.) D2 (6 ; 24 m.)	10,000sq.m. (incl. 600-vehicle parking area)	Premises: 3.25 ha. Fl. area: 15.4 ha.	400%
		Tokyo Metropolitan Housing Supply Corp.	425	B (37 ; 115 m.)			
		Housing and Urban Development Corp.	625	A (37 ; 115 m.) E (13 ; 46 m.) F (6 ; 21 m.) G (19 ; 65 m.)			
	West	Mitsui Real Estate Development Co.	1,170	H (40 ; 120 m.) I (40 ; 120 m.) J (31 ; 100 m.) KL (14 ; 45 m.)	16,000sq.m. (incl. 1,000-vehicle parking area)	Premises: 3.15 ha. Fl. area: 15.0 ha.	
Commercial and cultural		Activity, lodging, office, etc.: 150,000sq.m.				2.60 ha.	600%
		Parking: 600 vehicles					
		High rise heights: 150m.; 180m.					

All figures are rounded except for numbers of units and stories.

Chronology and timetable

- 1982 Ohkawabata Special Residential-centered Comprehensive Redevelopment Plan approved by Minstry of Construction.
- 1984 Ohkawabata Zoning Plan formulated (including street and riverside development and building utility plan).
- 1985 River City 21 plan filed; starts following environmental assessment procedure.
- 1986 River City 21 project begins. (March)
- 1988 Phase 1 residential construction completes and occupancy ensues; Techno Plaza construction begins; subway station Tsukishima (tentative name) opens.
- 1989 Gentle-sloping waterfront construction completes.
- 1992 New bridge completes
- 1993 River City 21 project consummates.

Tokyo Metropolitan Government Bureau of Housing
Tokyo Metropolitan Housing Supply Corporation
Housing and Urban Development Corporation
Mitsui Real Estate Development Company

AKASHI KAIKYO BRIDGE

Date and Time: Wednesday, July 18, 1990, 9:00 a.m. - Noon

Participants: JTEC - B. C. Paulson, R. L. Tucker
S. S. Tucker, C. H. Uyehara

Akashi Kaikyo Bridge:

Dr. Satoshi Kashima, Head, Tarumi Construction Office
Mr. Kensaku Hata, First Construction Bureau
Mr. K. Mori, Manager of Tower Construction Division,
Tarumi Construction Office

NARRATIVE OF ACTIVITIES

The JTEC team travelled to Kobe on the evening of July 17 to spend the following day on the Akashi Kaikyo Bridge Project and the New Kansai Airport Project. We were picked up at our hotel on the 18th by Mr. Hata of the Honshu-Shikoku Bridge Authority's First Construction Bureau (responsible for the bridges and land segments on the whole Kobe-Naruto route) and arrived at the Akashi Kaikyo Bridge to meet with Dr. Kashima, who is head of the construction of this bridge at the site, the longest span in the world. He provided a general introduction to major features of the project. Mr. Mori was also in the orientation meeting and accompanied us on the site tour. For the tour, we were taken on a large boat to visit the P2 pier site and the A1 anchorage. While en route, we also met with Mr. Reizo Yamaoka, project manager for the A1 Construction Joint Venture, who showed us some construction features of the A1 anchorage. Given that this JTEC visit was primarily a job site inspection rather than a group meeting or laboratory visit, the points below will tend more to address the project itself than provide a summary of a discussion.

1. Introduction The Akashi Kaikyo Bridge, which in itself is a megaproject of world renown, is actually a part of a much larger project, the Honshu-Shikoku Bridge System. This enormous system, which got underway in the mid-1970s after years of study, consists of some 17 major bridges plus connecting highways, railways, and tunnels. They are distributed over three routes, which provide the first land links between two of Japan's four principal islands, Honshu and Shikoku. The scale of this system is so immense that, when completed late in this century, nine of its bridges will be among the world's 20 longest spans, displacing such well-known structures as the San Francisco-Oakland Bay Bridge from that elite list. In its scale, variety of structures, and level of bridge technology applied throughout, the Honshu-Shikoku Bridge System is unprecedented. As the world's longest bridge span—indeed, at nearly two kilometers pier to pier, longer by a margin of over 40 percent than Britain's Humber Bridge which it surpasses—the Akashi Kaikyo Bridge is clearly the crown jewel of the whole system. It was a privilege to visit it during construction.
2. Economics In 1988 terms, the Honshu-Shikoku Bridge Project is slated to cost approximately ¥3 trillion (\$20 billion), not counting interest. The budget is justified partly on the highways and partly on the railways. Methods of financing for the

highways portion include investments with about two-thirds coming from the national government and one-third from 10 regional governments whose jurisdictions are the primary beneficiaries, plus bonds and loans from public and private sources. The benefits of the land links will include providing more rapid and reliable alternatives to the weather-vulnerable sea links that previously were used, and opening not only Shikoku but many smaller islands in the Seto Inland Sea to economic development and closer ties to the mainstream of the Japanese economy.

3. Environment Regardless of location, a project of this scale involves an enormous environmental impact. This particular location happens to be the Seto Inland Sea, which simultaneously is a national park of great scenic beauty and cultural value, a rich fishing ground for a nation where fish is a primary food source, and a transportation network carrying literally thousands of ships per day. In keeping with the scale and importance of the project, enormous efforts have been made to mitigate the potentially negative social, economic, and environmental impacts, and indeed to turn the bridges themselves into scenic attractions that complement their surroundings.
4. Major Design Features The Akashi Kaikyo Bridge is located on the Honshu side of the Kobe-Naruto route, the easternmost of the three routes in the bridge system. It is a suspension bridge with a central span of 1990 m and two side spans each 960 m long, for a total length of 3910 m. The piers under each of the two main towers sit on foundations some 60 m (200 ft) below sea level, are about 80 m (260 ft) in diameter, and are constructed from caissons floated out, sunk, and each filled with about 350,000 m³ of concrete. The cable anchorages on either shore are mass concrete structures of similar scale, with that on the Honshu side particularly notable for being built within a 75.5 m (250 ft) deep, 2.2 m (7 ft) thick concrete wall constructed using a slurry trench method. In total, some 1.42 million m³ of concrete will go into these substructures, enough for a major dam! The steel towers will rise to 297 m (975 ft) above sea level, taller than any building in Japan. The steel stiffening truss, which carries the deck for a 6-lane highway, is hinged at each tower, making three main segments. A total of 200,000 tons of steel will go into the superstructure. The twin cables are each 1.1 m (3.6 ft) in diameter, and each is made up of 37,000 steel wires. Each will support up to 60,000 tons of maximum tension when the bridge is completed and in operation. The design criteria should enable the bridge to survive earthquakes of magnitude 8.5 (Richter), winds of over 80 m/s (180 mph), and the piers will resist scour from twice-daily tidal currents of up to 4 m/s (8 knots).
5. Construction Methods The Akashi Kaikyo Bridge has the benefit of technological experience developed and tested on earlier spans in the system, particularly the twin suspension bridges on the Bisan-Seto segment of the Kojima-Sakaide, whose schedule led Akashi Kaikyo by about 10 years.

Starting with the pier foundations, advanced sensing and control systems were used to monitor and control seabed excavation by the clamshell dredge with its 200-ton grab bucket. However, while the Bisan-Seto piers were blasted and ground into the rocky seabed at their location, the Akashi Kaikyo piers were in softer material. Therefore, after setting the caissons, large mats of bagged rock debris were placed around the bottom edge to resist scour from the fast-moving tides. There was also a major difference in concrete placing. At Bisan-Seto, prepacked aggregate was filled with cement mortar from an adjoining batching barge through tremie pipes preinstalled in the caisson. This procedure was used 10 years ago because it was the only system suitable for placing mass concrete in the sea. Meanwhile, they have sufficiently advanced the formulation of concrete mixtures to be both fluid enough to fill voids and yet be viscous enough to remain undiluted when placed underwater, so large concrete production barges replaced

the mortar barges used on the earlier project. The Honshu side cable anchorage A1 was notable for the large slurry wall mentioned above, especially so because, at a depth of 75 meters (246 feet), the excavating machines' sensors and computer systems were able to control tolerances within about 5 cm (2 in), which is remarkable for a "blind" excavation under nearly this depth of slurry mud.

Erection of the superstructure was about two years off at the time of our visit. However, already the design has been subject to extensive seismic and wind tunnel testing. It is expected that construction will use similar machine-tool precision and advanced, fatigue-resistant welding quality standards that were proven on the structures recently completed. In the Kojima-Sakaide route, they also paid special attention to the expansion joints and to the dynamic wave motion of the structures that occurs as heavy trains come hurtling across at up to 160 kph (100 mph). Given that the Kobe-Naruto route has been redesigned primarily as a highway structure since the 1985 decision to not put rail on those bridges, the vehicle loading will not be so concentrated on the Akashi Kaikyo Bridge.

SIGNIFICANT FINDINGS AND IMPRESSIONS

Advances in Technology It is risky to say that any specific technology was new or unique to the Honshu-Shikoku Bridge Project. If published claims were made, say, in a magazine article based on this visit, one could soon expect any number of letters to the editor recalling when that technology, albeit in a variant and probably at much smaller scale, was used many years ago. Indeed, thinking back to the 5-year schedule and \$40 million cost of the San Francisco Golden Gate Bridge that was completed over 50 years ago¹, there does not appear to have been any major breakthrough in schedule or cost. Furthermore, with \$20 billion of capital at stake, the Honshu-Shikoku bridge builders seem, most appropriately, prudently conservative. What is most evident on this project, however, is a systematic evolution and massive scale-up of a technological heritage that extends back to the suspension bridges of the last century. The Honshu-Shikoku Bridge organization is appropriately called the "Authority," and bridge builders from around the world are making regular pilgrimages to this showcase of bridge technology.

With that background, we will highlight some construction designs or procedures that nevertheless seem noteworthy, and some of these are undoubtedly of unprecedented scale.

¹ As an historical note, the detailed geotechnical investigations for the Golden Gate Bridge took place from August 22, 1929 to about February 1930. The design was submitted for approval in August 27, 1930

The actual costs were \$27,125,000 for construction, \$2,050,000 for engineering and inspection fees, and administrative and preconstruction costs of \$423,000 for a total of \$29,598,000. For consistency, \$4,068,000 construction interest and below-par bond sale losses are omitted in the \$30 million approximation. (Information from Golden Gate, by Allen Brown, Doubleday & Co., Inc., NY, 1965.)

The actual steel and concrete quantities were only about a third of those being used in the Akashi Kaikyo Bridge, so this note is not intended as a direct comparison. Rather, it is simply a bit of nostalgia for those concerned about the apparent declining value of the construction monetary unit, whether expressed in yen, dollars, or otherwise, as we near the end of the 20th Century.

1. The multicolumn foundation method for the piers of the Ohnaruto Bridge allows swift tidal currents (which produce world-famous whirlpools) to pass through the piers with minimal disruptive resistance.
2. The concrete mix designs and placement procedures for the prepacked aggregate method on the Bisan-Seto structures and the direct underwater placement of the viscous mix used at Akashi Kaikyo are worth further investigation by persons interested in the underwater construction of mass concrete structures.
3. While the deep slurry wall technology is generally thought of as being of European origin (indeed, two of the three machines at the A1 pier were of French design and manufacture), the Japanese contractors appear to have enhanced the instrumentation and computer controls and to have made routing the achievement of excellent tolerances on very deep structures. While this method is used extensively on other types of structures in Japan (e.g., deep LNG storage tanks), the A1 pier was still a good place to see it in action.
4. One aspect of the structural work that seems to warrant further investigation is the analysis and testing procedures used to prove the designs against wind, tide, and earthquake loads before construction even began. They have involved top experts from government laboratories, universities, and the major engineering construction companies in what must be the most extensive analysis and testing to ever accompany a major structural project. Of special note is the fatigue analysis and large-scale testing that was conducted in anticipation of literally millions of cycles of heavy and dynamic train loading, as well as wind and seismic loading, particularly for the bridges on the Kojima-Sakaide route, during the expected 100-year lifetime of these bridges. Corrosion has also received a great deal of attention.
5. The cable spinning has employed a variety of methods, but these appear to be evolutionary in nature. Nevertheless, there is no better place today to see them in action.
6. Structural fabrication and erection seem especially notable for the careful attention to detail and quality in machining and welding, and for the off-site prefabrication of large modules that are then placed by some of the world's largest floating cranes.
7. The expansion joints and hinge mechanisms for the stiffening trusses, especially for the rail connections on the Kojima-Sakaide route, seem to merit further investigation.

In fairness, our team spent far too little time on-site, and, even with a generous provision of reading material from our hosts, we have had only a glimpse of what these bridge projects have to offer. It was interesting to note that the Danish engineers who are planning a major bridge and tunnel to connect their islands are often making visits to study, monitor the progress, and have technical exchanges with the engineers of the Honshu-Shikoku project. A half-day visit by four members of our JTEC delegation pales by comparison, but hopefully will stimulate Americans interested in following this technology more closely. If nothing else, the extensive provisions of the Honshu-Shikoku people have made for bridge maintenance should be useful to those charged with preserving our own bridge infrastructure. Significantly, the Golden Gate Bridge District does have such an exchange under an official "sister bridge" arrangement.

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MAKUHARI VISIT

Date and Time: Friday, July 20, 1990, 9:30 a.m. to 4:30 p.m.

Participants: JTEC - George Watson, Dan Halpin, Reed Nielsen

Chiba Prefecture:

Mr. Hanada, Mr. Nakaya, Mr. Shinichi Nakanishi

Makuhari Techno Garden:

Mr. Kurukawa, Mr. Mikami

Makuhari Messe Visit:

Mr. Jun Watanabe, Maki & Associates

Mr. Arakawa, Shimizu Makuhari, Project Manager

Mr. Keizo Hamamoto, Chiba Prefecture

Mr. Shimazaki, Chiba Prefecture

Mr. Tomofumi Setsuda, Manager,

Exhibition Affairs Section, Business Affairs Section,
Makuhari Messe

Translator: Ms. Reiko Kurosawa

NARRATIVE OF ACTIVITIES

TOUR OF THE TECHNO GARDEN

The Techno Garden is a newly constructed office building in the Makuhari development. Here, Mr. Hanada reviewed the program for the day and showed a video that described the Makuhari area. Makuhari Messe, the largest convention center in East Asia, was the first major construction in the Makuhari New City, sponsored by the Chiba Prefecture. The area, when fully developed, will have employment for about 100,000 people and provide housing for almost 26,000. It is approximately midway between the City of Tokyo and the Narita International Airport.

In the early 1970s, a five-year reclamation of approximately 522 hectares of land from the Tokyo Bay began. Even after almost ten years, settlements of up to 10 centimeters have been experienced. The Techno Garden building was constructed on piles, up to 50 meters long.

The Chiba Prefecture originally owned the land but has over the past few years sold nearly one-half to building developers. Recently the Prefecture considered leasing the remaining land to minimize the impact of rising land costs. Nearly 160 developers have expressed interest in buying the remaining 30 building sites. The area has its own sewage treatment facility, whose treated water is recycled for nonpotable uses. The Prefecture employees were not able to answer construction-related questions and suggested that we might ask them of the people that we would meet later in the day.

Mr. Kurukawa of Makuhari Techno Garden gave an introduction to the building. It has a 100-megabit network with local networks of 10 megabits. A personal computer is provided to each tenant in the building that is used to schedule conference rooms, arrange for extra hours of heating and cooling, and to transmit special information about the building and its activities. Employee identification cards for access to the building services are also provided at no charge, as long as the firm maintains an average of 12 square meters or more per employee.

Regular keys are still required for building access, but the identification cards provide information to the computer of the number of occupants within the various areas of the building. When the computer is aware that no one is using a particular floor, the HVAC systems in the area are shut off and the elevator does not stop at that floor.

In R&D areas of the facility, card-key locks are used. Access is denied if the proper authorization level is not presented.

Tenant stores use the Techno Garden system of Point of Sales. A fee, dependant upon sales volume, is charged to each tenant store. When a sale is made, the value is recorded on the building's computer, and the sale amount is deposited in the building's security safe. Twice per month the money is returned to the tenant, less the fee and rental amount.

A debit card for those who work in this building is available. Used to make purchases from vending machines or from the building's coffee shop, a company can be issued from 5 to 6,000 cards for its employees. A 7 percent discount is provided those who use the cards for purchases.

The building's telephone exchange has 6,000 lines available, and over 90 percent of the tenants are expected to use this exchange. If a firm subscribes to the in-house exchange, interior calls are free. Currently, 75 percent of the facility is occupied (approximately 5,000 people).

Following our visit to the Techno Garden building, we were given a tour of a Japanese garden and a Japanese tea room, where the traditional tea ceremony was explained.

TOUR OF THE MAKUHARI MESSE

After lunch at the restaurant of a yet-to-be-completed hotel located across the street from the Makuhari Messe, a tour was taken of the Makuhari Messe. Representatives of Maki and Associates (the architect), Shimizu (the construction manager), and the Chiba government talked about the building and its construction. A video was shown of the project.

The Makuhari Messe, whose construction began on December 21, 1987, is approximately 54,000 meters square (588,000 square feet). The facility consists of a large exhibition hall, a convention center, and a sports arena. It is set on 30-meter-deep precast concrete piles. Five main trusses that provide roof support were assembled on the ground and erected using two 300-ton cranes. There were four of these rigs on the site at some time during construction. Walkways, piping, HVAC ducting, equipment, and protective coatings were installed or performed while the truss sections were on the ground. The cross trusses were assembled in the factory and shipped to the site intact.

The floor of the exhibition hall consisted of precast concrete panels which were set between cast-in-place equipment trenches and grade beams. After alignment was made, a cover slab of approximately 6 inches was placed over the panels. Glass curtain walls are permanently hung between the sections of the convention building directly over the movable folding

divider doors. The roof is made of stainless steel corrugated metal. Computers have a significant role in the control systems used in the finished structure. Rather than using a typical multiple sprinkler system for fire protection, water cannons provide fire control in the exhibition hall. Recycled water is used for nonpotable water and an automatic valve turns off the gas in the event of a seismic event.

The roof of the exhibition hall is 540 meters x 122 meters. A video produced by the subcontractor who installed the roof explained that the stainless steel roofing material was formed at the site into corrugated sheets 60 meters long and approximately 75 centimeters wide. A movable platform was positioned on the roof for carrying the stainless sheets and other roofing materials. First a bottom piece of the steel panel was installed, insulation laid, and a top piece put down. As the top sheets of roofing did not overlap, there was a capping piece, also 60 meters long, that would lock into place over the full length of the open seam. All installation was done by hand, but did appear on a video to progress quite rapidly because of the design and the movable platform to handle material.

The exhibition hall was completed on July 1, 1989, and required 510,000 craft man hours over the 20-month construction schedule. Construction of all three buildings in the complex was by joint venture teams who managed a number of subcontractors who actually performed the physical labor. The exhibition hall was a five-company joint venture (headed by Shimizu), the convention hall joint venture included three firms, and the sports arena joint venture consisted of two contractors. The joint venture approach to construction began over 20 years ago, and is a normal part of Japanese construction today.

Mr. Arakawa was the Shimizu manager responsible for the exhibition hall joint venture. Safety was a significant concern. In addition to regular safety meetings, and as a part of a Japan-wide Ministry of Construction's safety week, the site sponsored a coloring contest for the children of employees and handed out safety information that the craftsmen took home to their families. A copy of the weekly safety schedule was distributed. Mr. Arakawa said Shimizu has a formal safety plan which to he, as project manager, is free to add his own site-specific ideas. He also gave us a copy of the daily instruction sheet.

Project management was done by Maki and Associates. It would receive reports from the various contractors as to whether or not their contracts were on schedule. The original schedule submitted by the contractors had to conform with the project schedule prior to approval being given by Maki. Weekly meetings were held to review schedules and receive reports from contractors. These status reports were done manually. At the Makuhari project, computers were not used for schedule and report generation.

The project manager is responsible to know the budget and to allocate funds to different members of the project's joint venture team. He checks every month to verify that the participants are within budget and to identify any unusual costs incurred during the month. The subcontractors are responsible for tracking their own costs. Cost information is maintained by hand and compared regularly to a computer-generated original budget.

Shop drawings were generated at the site using Auto CAD. There were two workstations on Makuhari Messe for this purpose. Mr. Arakawa's current project uses four workstations. Two of the four computers are used to keep track of employee entry and exit from the site using magnetic badges. He did not think this would have worked at Makuhari Messe because of the number of gates, even if the computer systems had been available.

Both on- and off-site prefabrication was used on the project. An example is the main roof trusses which were delivered in pieces and assembled at the site. The secondary trusses were totally assembled off site and shipped to the job. Likewise, the event hall trusses were fabricated in the factory. The design of the event hall roof allowed the ceiling panels to be

fitted into a track at the peak of the roof, and slid to their final position without the need for scaffolding or having men work in unsafe locations.

Mr. Watanabe said that architects in Japan expect certain subcontractors to always work with a particular general contractor. Because of Makuhari's difficult steel structure, Maki and Associates looked to Shimizu to provide a qualified structural steel subcontractor that Shimizu has apparently worked with on a number of occasions.

SIGNIFICANT FINDINGS AND IMPRESSIONS

While traveling from the train station to the Techno Garden, a building being built for IBM was pointed out. The response to the question, "Was the construction being performed by a joint venture?" was interpreted as being, "Of course, is there any other way! The responder was also apologetic that there were no U.S. firms involved in the joint venture. Indications were also given that if construction costs increased significantly and were beyond the control of the contractor, an adjustment to a contract would be considered.

Construction appears to be very regimented and well planned and scheduled. The video showed a project that was much cleaner than the majority of construction projects in the United States.

KANSAI INTERNATIONAL AIRPORT

Date and Time: Wednesday, July 18, 1990, 2:00 p.m. to 5:00 p.m.

Participants: JTEC - R. L. Tucker, B. C. Paulson,
S. S. Tucker, C. H. Uyehara

Kansai International Airport Co., Ltd.:

Hiroshi Endo, Deputy Director, Construction Site Office
Kan Oikawa, Manager, Technical Division
Shuji Yamamoto, Manager, General Planning Division
Chigusa Oshima, Chief, International Affairs Division

NARRATIVE OF ACTIVITIES

The team departed from Kishineda Port for a boat tour and inspection of the project. The tour included a brief departure from the boat to the site job office, which was located in an offshore platform built near the site for that purpose. The visit concluded with a meeting in the Osaka headquarters of the project. Videotapes describing the project were shown and literature was distributed.

PROJECT CHARACTERISTICS

The Kansai Airport will be Japan's first 24-hour airport. It will consist of a large man-made island in Osaka Bay with a 3.5 km bridge to connect the island to the mainland. The major constraints for the project are the water depth, the soft ocean floor, and the short time available to meet a completion date of 1995. The project has a total anticipated cost of approximately \$7 billion. It was initially considered for an onshore site, but noise concerns dictated that it be located offshore. Several offshore sites were appropriate, but fishermen's concerns prevented use of the shallow water sites. Because of limited funds and high costs related to the geography of the site, no cross-wind runway is included in the project.

The construction of the airport consists of four major elements: (1) the airport island, (2) the seawall, (3) the access bridge connecting the island to the coast, and (4) approximately 11 km of railway.

The island is constructed in approximately 18 m of water underlain by a 20-m-thick soft alluvial layer above a 400-m-thick diluvial layer. Including anticipated settlement of soft layer, a reclamation of approximately 30 m of fill will be necessary to form the island. Extensive use of the sand drain method has been made to accelerate and control the anticipated settlement. In addition, sand compaction piles and deep cement mixing are utilized to improve the foundation for much of the seawall.

Three types of seawalls, totaling 11.2 km in length, enclose the island. A rubble mound, constructed by laying sand and stones, accounts for the major portion. A steel cellular type is used for approximately 15 percent of the length and an upright wave dissipation caisson is used for a slight portion to allow ship berthing.

The reclamation effort to form the island involves seven major steps: (1) spreading of a 1.5-m-thick sand layer across the areas, (2) installation of sand drain piles on 2.5 centers, (3) additional sand laying by bottom hopper barges, (4) direct fill dumping by bottom hopper barges to a water depth of approximately 6 m, (5) a waiting period for soil consolidation, (6) additional direct dumping by shallow draft barges, and (7) final filling by box barges and conveyers to the final soil site.

The access bridge is a two-level steel and concrete structure founded on piles as deep as 60 m below the ocean floor.

In general, construction activities involve conventional technology but with a very high engineering component. Because of the engineering component, the number of contractors, involved and the ambitious schedule, considerable coordination of all activities is necessary.

TRANS-TOKYO BAY HIGHWAY PROJECT

Date and Time: Friday, July 20, 1990, 9:00 a.m. to 12:00 Noon

Participants: JTEC - R. L. Tucker, B. C. Paulson, K. H. Chong

TTBHC:

Toshiaki Fuji, General Manager,
Project Planning Department
Eiji Shiba, Assistant Manager,
Project Management Section
Hiroshi Shinohara, General Manager,
Design Department
Dr. Shunichi Nakamura, Design Division

NARRATIVE OF ACTIVITIES

The visit was conducted via a boat ride to the project site on a launch belonging to the Trans-Tokyo Bay Highway Corporation. The project is in its early stages and no above-water facilities are yet visible. Literature describing the project was distributed, numerous questions were answered, and considerable verbal information was transmitted.

PROJECT DESCRIPTION

The Trans-Tokyo Bay Highway will total approximately 15 km and will connect the cities of Kawasaki and Kisarazu. It will allow an alternate route to Narita Airport for those persons living south of Tokyo. The project is under the general direction of the Ministry of Construction, but will have two principal owners when completed. The Trans-Tokyo Bay Highway Corporation is responsible for everything except the access roads, which are the responsibility of the Japan Highway Public Corporation. The Trans-Tokyo Bay Highway Corporation is a joint venture of approximately 350 public and private companies including about 50 small, local companies. The total project cost is anticipated to be \$8 billion.

The structure will consist of two 10-km-long shielded tunnels under Kawasaki waters, a 5-km-long bridge over Chiba waters and two man-made islands. The structures are large, the water is deep, the ground is soft, and the likelihood of earthquakes is high. Thus, advanced technologies are involved in both design and construction. It is planned that slurry shields will be used to bore the underwater tunnels.

A cylindrical reinforced concrete ventilated shaft with an inside diameter of 100 m will comprise the Kawasaki man-made island and will be located at the mid-point of the tunnels. The Kisarazu man-made island is a transition from the tunnels to the bridge. It will be an embankment fill approximately 650 m long by 100 wide in a water depth of 23 m.

A third man-made island, the Ukishima Access, is located on the Kawasaki side and consists of a ventilation shaft, tunnel work yard and workshop area, and an underwater embankment of 700 m long extending from the existing seashore to the bay bottom.

To date, about 20 percent of the construction contracts have been awarded.

TECHNOLOGY FEATURES

Because of the many technological challenges, considerable design and construction innovation will be involved in the project. The use of the slurry shield tunnel method has been selected instead of the immersed tube method because of the high level of boat traffic in the area. Automated equipment will be utilized in carrying and assembling precast concrete segments for the primary tunnel lining. Additional technology will be utilized to connect shield machines coming from opposing directions instead of the conventional freezing method.

The Kawasaki man-made island is in a water depth of 28 m underlain by very soft soil to a depth of 30 m below the seabed. The soil will be stabilized by sand compaction, followed by construction of outer and inner steel jackets, with an outer diameter of 200 m, that will function as a retaining wall, a mole structure, and a working platform. Fill materials will be placed between the inner and outer jackets. A sophisticated excavation method will be used to form a circular diaphragm wall 2.8 m thick and 130 m deep within the fill materials. A reinforced concrete permanent wall 100 m in diameter and 75 m deep will then be constructed, followed by casting bottom slabs and intermediate walls. Seismic analyses have been conducted for all erection stages, as well as for various superstructures that are still under design. The differences in deadweight of the main structure during tunneling work and after completion cause additional technical problems.

The Kisarazu man-made island will be constructed over a relatively thin layer of soft soil. The soft soils will be dredged and replaced with sand and gravel. Steel sheet pile cells will be formed around the perimeter prior to the reclamation effort. The 22m-diameter cells will be prefabricated, towed to the site, placed by a floating crane, and driven by vibro-hammers. The reclamation will involve sands that may include mixing with a hardening additive before placement in order to improve shear and liquefaction resistance.

Composite steel and concrete piers are anticipated, utilizing epoxy coatings and other materials for corrosion resistance. Consideration is being given to utilization of recently developed steel alloys for the piers and bridge superstructure.

WASEDA UNIVERSITY

Date and Time: Tuesday, July 17, 1990, 9:30 a.m. - 11:30 p.m.

Participants: JTEC - B. C. Paulson, R. N. Wright

Yukio Hasegawa, Director of WASCOR, Waseda University
Naruo Kano, Professor of Architectural Engineering
Kasuhiko Arai, Kajima Corporation
Tahashi Shiokawa, Ohbayashi Corporation
Ryoji Yohitake, Fujita Corporation

SCOPE OF DISCUSSION

The overall discussion had two main components. First was an overview of the Waseda robotics effort under WASCOR. This was led by Dr. Hasegawa and had input from the three industry representatives. Second was a discussion of the Waseda academic structure, particularly for civil engineering and architectural engineering. This was led by Dr. Kano.

WASCOR Section

1. General welcome and introduction of participants by Dr. Hasegawa.
2. Began with WASCOR videotapes -- first was an overview of several companies' robots;

Second tape was on more recent work, including combined crane and beam positioning experiment at WASCOR via table-top robot arm integrated with 3-D model for dimensional control of robot.
3. Dr. Hasegawa introduced System Science Institute: started in 1961 with aid of U.S. government; in an initial exchange, 50 U.S. professors came to Japan in first 5 years to help accelerate Japan's rebuilding. Another 50 industrial specialists and Japanese professors went to study in the U.S. (e.g., Dr. Hasegawa went to the U.S. from Seiko, then came to Waseda in 1964).
4. WASCOR now also has "manufacturing future" project with some U.S. and other professors who come to visit (e.g., management policy for restructuring industry).
5. Another study on production control is underway with APICS and JPICS.
6. Along the way, Waseda received a MITI grant in 1978 to start robotics research in construction, starting with wooden panel forms.
7. It got industry involvement in project teams about eight years ago. The focus is on various ways to introduce robots into the construction industry.

8. It now has 11 companies (9 contractors and 2 machinery makers) working with several professors and students from architectural engineering, civil engineering, mechanical engineering, etc.
9. It has looked at prefabrication, then automatic fabrication of items ranging from oil tanks to furniture.
10. Representatives from the industry members come to WASCOR every Wednesday morning for a two-hour seminar on various aspects of results -- this is very close interaction compared to similar relationships in the U.S.
11. They have recently become involved with the famous Japanese architect Kiyonori Kikutake about designing new schools for automation, integration, etc.
12. Because of high costs from robotics projects in other areas at Waseda (e.g., ¥700,000,000 and 6 years to develop 2 robots for casting steel; and the much publicized music robot that took 3 years, 50 graduate students, and ¥200,000,000 without counting personnel costs), WASCOR now tries to shift the focus to companies at the hardware development stage. The University's role is more to develop supporting technologies (e.g. 3-D simulation, operations analysis, work study via video, modularization techniques, etc.).
13. In response to our question regarding multiple robot integration, Dr. Hasegawa pointed to the Ohbayashi automated building construction effort (covered in the Ohbayashi trip report) as the most advanced he knows of in construction at present. The first stage may be implemented next year, without robots but with integration, then they will work robots into the system over time. The planned system will be six welding robots, one automatic crane, and three automatically guided vehicles (AGVs). In the manufacturing sector, however, Dr. Hasegawa has seen over 170 robots working together on a radio cassette production line.
14. In spite of the success of the WASCOR operation, our hosts observed that it has not drawn many students to careers in this area, and it has not resulted in new courses at Waseda.
15. Some of Waseda's "old boys" (Industry representatives who are Waseda graduates) have written a text on construction robotics. They gave us a copy signed by two of the authors who were present. The book's authors were from five of the "Big Six" Japanese construction companies: Kajima, Ohbayashi, Shimizu, Takenaka, and Taisei.
16. Regarding implementation issues related to construction robotics, there is some concern in the construction industry about over capitalization of this area, vs. the variable construction demand problem vs. the present strongly subcontracted structure of the projects, in order to recover the large up-front equipment investments that would be needed with a capital-intensive robotic approach to construction. Lease and rental systems used in Japan for temporary materials and conventional equipment may help average this out over multiple users.
17. Regarding the future demand for robotics in construction, overall industry demand is very sensitive to interest rates, but the present ¥72 trillion (\$480 billion) in annual construction volume in Japan is expected to be going up 45 percent in the next few years, partially in response to U.S. pressure. There is also the much publicized problem of a declining skilled labor force, presently 5.5 million workers (about the same as 6.5 million in the U.S.). Both of these factors will stimulate the development of robotics and other forms of construction automation.

Architectural Engineering and Civil Engineering at Waseda

1. Waseda is a large private university with approximately 45,000 students, 9,000 of whom are at the Science and Technology campus that we visited near Shinjuku.
2. About 16 percent of Waseda's funds come from government sources, mostly for research projects and equipment.
3. Dr. Kano briefly explained how the equivalent of U.S. civil engineering is distributed between architectural engineering and civil engineering in Japan.
4. The architectural engineering program has 17 faculty members, and about 200 students per year at the 4-year undergraduate level. Administered within architectural engineering, the Construction Materials, Engineering and Management Program has 3 faculty and 9 students in the 2-year masters program, and 1 at the doctoral level. Civil engineering is smaller, with 12 faculty, but we did not get the number of students.
5. Construction-related research in architectural engineering is grouped under "construction economics," "construction industry," "construction management methodology," and "construction process and works." See summary page for details.
6. In general, this division of three faculty members seems to be one of the larger construction programs in Japan, and the total number of construction faculty at major universities is probably under 10.

SIGNIFICANT FINDINGS FROM DISCUSSION

WASCOR Section

1. The WASCOR operation seems to have been a very successful venture in industry-university collaboration for research, and has gained an international reputation. It appears to have been a catalyst for the Japanese construction companies' ventures into construction robotics.
2. However, WASCOR appears to be a very atypical case. Most universities seem isolated from industry (see AIJ trip report for more on this). However, WASCOR does show that such ventures can be successful, and may serve as a model for other Japanese universities to follow.
3. It was surprising that WASCOR has not had a larger impact on Waseda's engineering curriculum, and that more students have not been motivated to pursue this line of work.

Architectural Engineering and Civil Engineering at Waseda

1. Engineering education at Waseda and at Japanese universities in general, is still focussed primarily at the undergraduate level, much more so than at universities of equivalent stature in the U.S. The student/faculty ratios (47 to 1 in architectural engineering at Waseda) seem two to four times higher than those in the U.S. at similar

universities. The ratios may be lower than Waseda's at the top state-supported universities in Japan.

2. In general, there do not appear to be many incentives for university-industry interaction in Japan. The separation seems much greater than in the U.S.
3. The U.S. version of "civil engineering" divides into "architectural engineering" (a mixture of the technical side of architecture and the structural side of U.S. civil engineering, mainly as applied to building construction) and "civil engineering" (confined in Japan mainly to nonbuilding public works structures such as bridges, highways, tunnels, dams, ports and harbors, waterways, etc.) in Japan. There does not appear to be much communication between these two divisions in Japan, and this poses some difficulties for establishing links with their counterparts in the U.S. The "architectural" side seems to enjoy higher status than the "civil" side in Japan, and this seems to have some impact on their relative abilities to attract students to their programs.
4. University programs in construction engineering and management are much less common in Japan than in the U.S., where there are a dozen or more well-established graduate programs and numerous large programs at the undergraduate level. This might imply that Japanese industry is assuming the main burden of converting civil and architectural engineering graduates into construction engineers and managers. It is also significant that the Japanese construction industry has sent hundreds of employees to construction programs in the U.S. and Europe for graduate education in the last two decades. While there seems to be strong inertia to maintain the status quo in Japanese universities, the situation does seem ripe for expanded efforts in construction education.

SUMMARY

Construction Materials, Engineering and Management Program Waseda University

Professor Yasushi Tamura
Professor Kohiro Kamiyama
Professor Naruo Kano

Research on Construction Engineering and Management

- 1) Construction Economics
 - Project Evaluation
 - Life Cycle Costing
 - 2) Construction industry
 - Forecasting of Construction Demand
 - Construction Contracting
 - Evaluation of Construction Company
 - Bidding Strategy
 - 3) Construction Management Methodology
 - Project Management System
 - Construction Process System
 - Data-Base/Knowledge-Base
 - Computer Graphics
 - AI/Expert System
 - Office Automation at Construction Site Office
 - Computer Integrated Construction
 - 4) Construction Process and Works
 - Construction Methods
 - Work Study
 - Human Factor Analysis
 - Mechanization/Robotics
- Graduate Students (April 1990)
- | | |
|--------------------------|----|
| Master Course (1st)..... | 5 |
| Master Course (2nd)..... | 4 |
| Doctor Course..... | 1 |
| Total..... | 10 |
- Undergraduate Students (April 1990)
- | | |
|--------------------------------|----|
| Students Preparing Thesis..... | 12 |
|--------------------------------|----|

TOKYO UNIVERSITY

Date and Time: Wednesday, July 18, 1990, 9:00 a.m. to Noon

Participants: J. W. Fisher, R. N. Wright

Tokyo University:

Professor Fumio Nishino

NARRATIVE OF ACTIVITIES

1. Our visit to the Civil Engineering Department at the University of Tokyo was limited to contact and discussion with Professor Fumio Nishino.
2. Our discussions focused mainly on R&D in Japanese universities, the role of government and private industry in university research, and the role of research for advanced degree programs.
3. Advanced degrees are not considered important by industry and professional societies. Tokyo University's doctoral program has never been large. The B.S. degree is what is important. Most engineers take a position for life with a private company or government ministry. The university's mission is to provide the science base. All engineers are given a 6 to 12 month training program by their companies. They must work at least 10 years as engineers before they move into management.
4. At the present time, the graduate program at Tokyo is 60 percent foreign nationals. In the doctoral program, 85 percent are foreign nationals. In part, this has resulted from the development of an international graduate program which was initiated by Professor Nishino in 1982. The support of this program is by Monbusho Scholarships. At the present time, only three Japanese universities are involved with this program (Tokyo, Nagoya, and Yokohama). The funds are provided by the Ministry of Education. These scholarships provide a \$1200/month stipend, tuition, and round-trip air fare. The students can select English or Japanese language courses. The award is for two years for M.S. students, and three years more for the Ph.D.

Nishino's department receives about \$2000/year for each student. The Ministry provides 15 scholars at Tokyo, 5 at Nagoya, and 5 at Yokohama. In addition, the Asian Development Bank provides 5 more at Tokyo. Since Asian students can save 50 percent of the stipend over the 5 years (equivalent to 7 or 8 years income in their native land), they are able to obtain outstanding students, which enhances the R&D programs of the universities.

5. In the Civil Engineering department at Tokyo, 20 of 30 faculty have agreed to the English program, and can draw from this pool of students. This provides on average one new student each year.

6. There are 100 universities in Japan. The Ministry of Education wants teaching and research from the faculty manifested by papers. Faculty serve as consultants without pay to government and industry. The universities cannot hire personnel to work on research, as positions are not authorized. MITI is very influential in setting research policy. It has indicated that universities should work on basics; industry on applications; and the government in between.

MITI has a section on Future Directions of Japanese Industry. It has the best statistics and information. MITI is responsible for Japanese Industrial Standards (JIS). It has 16 Research Institutes.

7. Contract research at universities is very small and is for service to the private sector. It is used for travel, conferences, etc. No reports are expected of any significance (1-5 pages).

On average, the funding available to a Tokyo faculty member is about \$30,000/year. This comes from contract research, Japanese NSF, donations, and the Ministry of Education. The amount is so little that very little experimentation is carried out. Analytical work is preferred. The contract work is mainly on honorarium for service. We were provided data (in Japanese) of the funds made available for these categories. The most extensive research programs are at the Imperial University, Tokyo Institute of Technology, and two other institutions.

8. Nishino noted that design (general) is carried out by a Government Ministry providing concept and details. The routine work is carried out by consulting firms. The government is considering reducing the civil servant ranks and putting more into the private sector. This is not likely to strengthen consulting firms in Japan. It is more likely that design subsidiaries will be created by construction firms.

9. The following statistics were provided.

	<u>82</u>	<u>83</u>	<u>84</u>	<u>85</u>	<u>86</u>	<u>87</u>	<u>88</u>
<u>M.S. Degrees</u>							
Japanese	23	25	24	30	26	28	29
Foreign	2	1	8	8	7	11	9
<u>Dr. of Engr.</u>							
Japanese	2	2	2	2	4	1	0
Foreign	1	1	1	12	7	10	7

JAPAN SOCIETY OF CIVIL ENGINEERS (JSCE)

Date and Time: Tuesday, July 17, 1990, 1:00 p.m. to 4:00 p.m.

Participants: JTEC - Boyd Paulson and Richard Wright

Japan Society of Civil Engineers:

Dr. Kazuto Makazawa, Vice Chairman
Japanese National Committee on Large Dams
Dr. Toshinobu Akagi, Professor
Toyo University
Mr. Yoshio Fujita, Deputy Director
International Affairs Office
Ports and Harbors Bureau
Ministry of Transport
Dr. Mizuhito Iguro, Deputy Director
Civil Engineering and Technology Division
Shimizu Corporation
Mr. Tokuji Tomaru, Director
International Affairs Division
Economic Affairs Bureau
Ministry of Construction
Mr. Masanari Tominaga, Director
Kawasaki Steel Corporation
Mr. Junichi Yagi, Managing Director
JSCE
Mr. Tadao Kawamura, Manager, General Planning and Public
Relations Division
JSCE

NARRATIVE OF ACTIVITIES

1. Comparing Japanese and U.S. Construction Communities

Japanese public works and industrial construction is dominated by private engineering-construction companies that do research and by government agencies that perform their own research, design, and sometimes construction. Consulting firms provide routine engineering services for public and private owners and construction firms. University faculty teach and consult but are not generally active in research. Japanese civil engineering does not include building design engineering. That is part of architecture.

With the exception of engineering construction firms for industry and utilities, U.S. contractors generally do not provide design or research engineering. The U.S. has

technically advanced consulting engineers who provide research and development services, as well as design services. U.S. universities are active in construction R&D.

A Japanese construction project typically has teamwork between owners, designers, manufacturers, and contractors in design for constructability and in resolving unforeseen problems. The U.S. situation is more adversarial. Claims in Japan, typically of subcontractors against general contractors, approximately doubled from 1970 to 1980, but have since been stable.

2. Construction Standards Development

Japanese Industry Standards are promulgated by MITI, which represents Japan in ISO. JSCE prepares recommendations for standards and engineering practices and accepts governmental funding for such studies.

JSCE sees the growing importance on international standards and the need for the U.S. and Japan to be active in ISO.

JSCE notes that the U.S. must accept and use the SI system of units to be influential in international standardization and to correspond to international conditions of practice.

3. Acceptance of Innovation

Private projects in Japan are more receptive to innovation than government projects. The MOC technology evaluation process requires third party review for acceptance of innovation in government projects. Typically, one to two years are required to obtain approval.

4. U.S.-Japan Exchange in Construction Technology

JSCE encourages such exchanges and has an agreement with ASCE that provides for such joint activities.

The U.S.-Japan Panel on Wind and Seismic Effects is a successful, long-term cooperation in construction technology. Additional cooperations can be established under UJNR, but membership would be limited to representatives of Japanese and U.S. government agencies. University and private sector engineers would be able to participate in technical activities. Thus, it may be preferable to establish and exchange in construction technologies under private sector auspices.

5. Addressing Shortages of Engineers

Less than one percent of JSCE members are women, but the numbers are growing rapidly in engineering schools and in JSCE.

6. Activities of JSCE

In addition to sponsoring conferences, publishing papers on research and practice, and preparing recommendations for standards and practices, JSCE conducts technical feasibility studies for governmental agencies. For example, JSCE assessed the economic feasibility of the Honshu-Shikoku bridges.

SIGNIFICANT FINDINGS AND IMPRESSIONS

1. Japan's construction industry is significantly different in organization from the U.S. U.S. design firms and contractors may find specialty markets in collaboration with Japanese general contractors in both Japanese and international markets. U.S. general contractors may need alliances for financial, design, and research services to compete directly with Japanese general contractors in international markets.
2. Japan has a functional process for evaluation and approval of innovations in design or construction for public works with third party evaluation and approval by MOC. The U.S. system is more fragmented, with a variety of federal, state, and local government agencies having approval authority. The U.S. may need to develop a systematic process to comply with treaty agreements affecting trade in construction products and services.
3. Japan has a national system for development of standards for public works construction with private sector inputs and for representing Japan's interests in international standardization. The U.S. will need to work in SI units and develop its representation in ISO to have a voice in international standardization for public works and industrial construction.
4. Japan has a strong interest in ongoing exchanges in construction technology. Because of Japan's stronger investment in construction R&D, it may be in the U.S. interest to pursue vigorously such interactions and speed transfer of technologies to U.S. design, construction, and educational organizations. Such exchanges should be private sector led, but open to participants from government, since government-led exchanges do not allow full participation of industry and educational interests. The secretariat costs for an effective exchange in construction technology will be significant, in the order of \$200,000 annually for each side, and the costs of actual exchanges will be additional.
5. U.S. and Japan have common interests in attracting well-qualified young people to careers in construction. While there are unique differences (attracting women in Japan and minorities in the U.S.), exchanges may be fruitful in motivating students to qualify themselves for construction careers and in making construction careers more attractive to qualified young persons.

ARCHITECTURAL INSTITUTE OF JAPAN (AIJ)

Date and Time: Friday, July 20, 1990, 1:00 p.m. - 5:00 p.m.

Participants: JTEC - K. P. Chong, B. C. Paulson, R. L. Tucker

Architectural Institute of Japan:

Mr. Kenichi Saito, Secretary General
Mr. Toshihiko Yanagisawa, Managing Director
Mr. Kenkichi Ito, Secretariat Staff
Dr. Osamu Furukawa, Professor Kogakuin, University
Dr. Naruo Kano, Professor, Waseda University
Dr. Ben Kato, Professor Emeritus, U. of Tokyo
Dr. Ken-Ichi Kimura, Professor, Waseda University
Dr. Michio Koike, Professor, Tokyo Institute of Technology
Dr. Motoki Kondo, Director, Tech. Res. Lab., Takenaka Corp.
Dr. Toshihiko Ota, General Manager,
Institute of Technology, Shimizu Corp.
Dr. Fukuzo Suto, Professor, Tokyo Denki University
Dr. Y. Tamura, Professor, Waseda University
Dr. Isao Tokunaga, Professor, Meiji University
Dr. Shiro Yajima, Deputy General Manager,
Technical Division, Taisei Corp.

SCOPE OF DISCUSSION

The AIJ visit was coordinated by Professor Tamura of Waseda University, who is the 1990 Vice President of AIJ. The list of attendees included AIJ's professional managers, directors of research institutes from three of the five largest construction companies, and seven other architectural engineering faculty members. Three were chairmen of AIJ standing committees deemed most relevant to JTEC's advance questions, and were prepared to give formal presentations. The meeting was followed by a two-hour reception, and after that we were invited to join another party held after a construction management conference that was underway that day in the main lecture hall of AIJ.

1. General welcome and introduction of participants by Professor Tamura, followed by an extended background briefing addressing how they would approach our questions.
2. Mr. Yanagisawa of AIJ then followed an AIJ brochure (12-pages) in outlining the history and present goals and activities of AIJ.

Briefly summarized, AIJ was founded just over 100 years ago and has evolved into an academically oriented organization of some 31,000 members, many of whom have strong interests in the building side of the construction industry. In addition to individual members and students, it also has corporate members.

3. AIJ has a governing hierarchy and dozens of standing committees that greatly resemble those found in U.S. professional societies such as the American Society of Civil Engineers (ASCE) and the American Institute of Architects (AIA). Three attached pages extract the organizational information from the brochure. The AIJ committees hold some 1600 meetings per year (6 to 8 per day), many if not most using the committee rooms and conference facilities of the AIJ headquarters building. In our visit to AIJ, as well as to JSCE, it was evident that the geographical compactness of Japan, and the fact that a large number of members live in Tokyo or the surrounding Kanto plain, make it more feasible to hold more regular meetings, even after work in the evening, than is possible for AIA or ASCE in the U.S. AIJ funds travel costs for out-of-town committee members.
4. The AIJ building also includes a respectable library (35,000 books and 800 serial subscriptions) and a specialty book shop. AIJ members and committees produce numerous papers, technical standards, monographs, and manuals each year, which are available to the public in the book shop and in the library.
5. In addition to the standing committee activities, AIJ funds special studies, sometimes in response to requests from government agencies. Recent examples include waterfront disaster mitigation, environmental problems related to architecture, and preservation of atomic bomb exposed buildings. AIJ typically commits ¥1.6 million (about \$11,000) to support travel and administrative costs related to such studies, but depends on construction company laboratories for lab-based research or testing that might be needed.
6. Regarding its committees' role in the development of standards for new materials, construction processes, or even contract administration, AIJ members monitor new developments and, for those that seem significant, they consolidate and exchange relevant information, ask developers for additional information or test results, and come to some consensus as to the appropriateness and benefits of the innovation. The results of this investigation can then be written up as an AIJ standard. Note, however, that from a legal perspective, this is more of a recommendation, since the Ministry of Construction and other government bodies ultimately control the building codes for the country, as well as the contractual specifications for its own projects.
7. Some discussion was held regarding the apparent distance of university faculties from industry and government practitioners. One lab director cited the student uprisings of some 20 years ago that may have made professors leery of the criticism they might still receive for seeming too close to industry. He also mentioned the lack of control and long response time that may arise if research were contracted out to universities. The fact that some major Japanese corporations have recently been making generous gifts to U.S. universities (for chairs, fellowships, research projects, and even building funds) has not gone unnoticed by Japanese academics, and may stimulate some rethinking of the traditional attitudes that have generally impeded closer cooperation between universities and industry.
8. Chairmen of technical committees presented brief seminars on the following:
 - Information Systems Technology (Dr. Suto)
 - Environmental Engineering Aspects of R&D in Building Tech. (Dr. Kimura)
9. In general, in addition to focussing on the building side of construction in Japan, it seemed that AIJ (in contrast to JSCE) was much more closely tied to the private sector of the Japanese economy.

SIGNIFICANT FINDINGS AND IMPRESSIONS

1. Although our hosts tried to emphasize the academic nature of AIJ versus a seemingly less respectable professional orientation, it seemed remarkably similar, at least in general goals, organization, and activities, to the counterpart professional societies in the U.S., especially ASCE and AIA.
2. The standards role of AIJ seemed much stronger than its U.S. counterparts, especially ASCE. This aspect of AIJ seems more similar to ASTM, CSI, AISC, ACI, etc.
3. AIJ does seem to be a good forum where academics and industry people do come together to work on common problems. However, while academics may serve as chairmen of committees or in other prominent or honorary positions, the role of academics in the practical aspects of design and construction seems much less than one finds in the U.S. and Europe.
4. There was a strong interest among some AIJ people at the meeting for launching some kind of bilateral symposiums on construction engineering and management issues, with the venue alternating between the U.S. and Japan. However, the gulf between the "civil" engineers and "architectural" engineers may make it difficult to jointly organize something that would represent both aspects of what is generally combined under "civil engineering" in the U.S. Nevertheless, there was also strong interest in the U.S. JTEC panel for encouraging such an ongoing exchange. The main concern on this side was the logistical and financial aspects of making a credible showing on our side, especially when the symposium was held in Japan. Organizational resources and travel funds seem much more readily available in Japan.

APPENDIX B

SCHEDULE OF SITE VISITS

July 16 - 20, 1990

MONDAY: MINISTRY OF CONSTRUCTION
MINISTRY OF INTERNATIONAL TRADE & INDUSTRY

TUESDAY: SHIMIZU INSTITUTE OF TECHNOLOGY
TAKENAKA RESEARCH LABORATORY
TAISEI TECHNICAL RESEARCH CENTER
KAJIMA INTELLIGENT BUILDING
KAJIMA RESEARCH LABORATORY (TOBITAKYU)
WASEDA UNIVERSITY
JAPAN SOCIETY OF CIVIL ENGINEERS

WEDNESDAY: AKASHI-HONSHU BRIDGE
KANSAI INTERNATIONAL AIRPORT
TOSHIBA BUILDING
NEC BUILDING
SHIMIZU NEW HEADQUARTERS BUILDING
OHKAWABATA HOUSING PROJECT
BUILDING CENTER OF JAPAN
UNIVERSITY OF TOKYO
NEW OTANI TOWER

THURSDAY: SEKISUI HOUSING CAD OPERATIONS
SEKISUI HOUSING FACTORY
KUMAGAI GUMI RESEARCH LABORATORY
BUILDING RESEARCH INSTITUTE
PUBLIC WORKS RESEARCH INSTITUTE
MISAWA HOME RESEARCH LABORATORY
OHBA YASHI RESEARCH LABORATORY

FRIDAY: TRANS-TOKYO BAY HIGHWAY CONSTRUCTION
ARCHITECTURE INSTITUTE OF JAPAN
MAKUHARI NEW TOWN
NIPPON STEEL & HIYOSHI RESEARCH LABORATORY

APPENDIX C

JTEC PANEL MEMBERS

Name: Richard L. Tucker (Panel Chairman)

Affiliation: The University of Texas

Address: Construction Industry Institute (CII),
3208 Red River, Suite 300
Austin, TX 78705

Telephone: (Office): 512-471-4640
(Home): 512-327-2790
(FAX): 512-499-8101

Biosketch: Richard L. Tucker, C. T. Wells Professor of Project Management and Director, Construction Industry Institute (CII) at the University of Texas at Austin, is a civil engineer by formal education. His areas of expertise include geotechnical and structural engineering as well as project management. He has authored numerous papers on construction productivity and has consulted on projects and lectured in many countries along with his wife, Dr. Shirley Tucker. A recipient of many honors and awards, he has served as chairman of both the Construction Research Council of the American Society of Civil Engineers (ASCE), and the ASCE Technical Council on Research. He has also been a member of the Executive Committee of the Building Research Board of the National Research Council.

Name: John W. Fisher

Affiliation: Lehigh University

Address: ATLSS ERC
Herbert R. Imbt Lab.
Lehigh University
117 ATLSS Drive
Bethlehem, PA 18015

Telephone: (Office): 215-758-3535
(Home): 215-866-8990
(FAX): 215-758-5553

Biosketch: John W. Fisher, Director of the National Science Foundation's Engineering Research Center of Advanced Technology for Large Structural Systems (ATLSS) and Professor of Civil Engineering at Lehigh University, specializes in structural connections and the fatigue and fracture resistance of riveted, bolted, and welded structures. Two of his books, *Fatigue and Fracture in Steel Bridges: Case Studies and Guide to Design Criteria for Bolted and Riveted Joints*, second edition, are included in the over 165 contributions to various scientific and engineering journals that he has authored. In 1986 he was elected a member of the National Academy of Engineering. He received the Construction-Man-of-the-Year Award from *Engineering News Record* in 1987. In 1989, he was elected an Honorary Member of the American Society of Civil Engineers and Corresponding Member of the Swiss Academy of Engineering Sciences. He is a graduate of Washington University (BSCE) and received his M.S. and Ph.D. degrees from Lehigh University.

Name: Daniel W. Halpin

Affiliation: Purdue University

Address: Division of Construction Engineering and Management
Civil Engineering Building
Purdue University
West Lafayette, IN 47907

Telephone: (Office): 317-494-2244
(Home): 317-447-6711
(FAX): 317-494-0776

Biosketch: Daniel W. Halpin, Head of the Division of Construction Engineering and Management at Purdue University, received his doctorate from the University of Illinois. Prior to coming to Purdue, he held positions as the Director of the Construction Program at Georgia Institute of Technology and the Clark Chair Professor of Construction Engineering at the University of Maryland. He has been a Visiting Professor at the Technical University of Munich, the University of Sydney, Australia, and the Swiss Federal Institute of Technology in Zurich. He is the author or co-author of six books and is recognized as one of the world's leading experts on the simulation of construction operations. His CYCLONE simulation system is used widely to model and analyze construction operations.

Name: Reed W. Nielsen

Affiliation: Bechtel Group, Inc.

Address: Manager of Construction Technologies
Bechtel Group, Inc.
50 Beale Street
San Francisco, CA 94105-1895

Telephone: (Office): 415-768-0564
(Home): 415-827-4116
(FAX): 415-768-0503

Biosketch: Reed Nielsen, Manager of Construction Technologies for Bechtel Group, Inc. in San Francisco, California, is responsible for the identification, development, and distribution of new construction technologies to improve construction processes on Bechtel projects. Prior to his current assignment, he was the Project Superintendent at Bechtel's Basic American I Co-Generation project. Earlier assignments included those of Field Contracts Manager and Field Construction Manager at the Intermountain Power Plant, as well as other contracts, craft supervision, and field engineering roles at fossil and nuclear power plants. He graduated from Arizona State University with a B.S. in construction and is a registered civil engineer in California and Utah.

Name: Boyd C. Paulson, Jr.

Affiliation: Stanford University

Address: 4020 Civil Engineering
Stanford University
Stanford, CA 94305-4020

Telephone: (Office): 415-723-2235
(Home): 415-323-6849
(FAX): 415-725-8662

Biosketch: Boyd C. Paulson, Jr. holds the Ohbayashi Professorship of Engineering in Stanford University's Graduate Program in Construction Engineering and Management, where he has taught since 1974. He earned his B.S. (1967), M.S. (1969), and Ph.D. (1971) in Civil Engineering from Stanford University. He is the author of one book and over 60 papers. Dr. Paulson's research and teaching interests are in computer applications in construction, including operations simulation and automated process control. He is a member of the Association for Computing Machinery, ASCE, the American Society for Engineering Education, and the Institute of Electrical and Electronics Engineers Computer Society. He was past Chairman of the ASCE Construction Division Executive Committee. His honors and awards include ASCE's 1980 Walter L. Huber Civil Engineering Research Prize and 1984 Construction Management Award, West Germany's Humboldt Foundation Fellowship in 1983, and the Project Management Institute's 1986 Distinguished Contributions Awards.

Name: George H. Watson

Affiliation: Amoco Corporation

Address: Amoco Research Center
Post Office Box 400
Naperville, Illinois 60566

Telephone: (Office): 708-420-5774
(Home): 708-420-7184
(FAX): 708-961-7971

Biosketch: George Watson, General Manager of Technology Support for Amoco Corporation, is responsible for supervision of all research and technical service for the corporation in the area of material process control, refractories, process safety analytical service, and geotechnical engineering. He has previously held the positions of Director of Corrosion and Metallurgy and Manager of Engineering Research and Service for Amoco. In addition, he has spent ten years working on environmental and geotechnical problems in the Arctic. He has 25 publications in these technical areas.

Name: Richard N. Wright

Affiliation: National Institute of Standards and Technology,
U.S. Department of Commerce

Address: Building and Fire Research Laboratory
National Institute of Standards and Technology
Building 226, Room B216
Gaithersburg, MD 20899

Telephone: (Office): 301-975-5900
(Home): 301-977-9049
(FAX): 301-975-4032

Biosketch: Dr. Wright is Director of the Building and Fire Research Laboratory. From 1974-1990, he was Director of the Center for Building Technology since 1974. He was Professor of Civil Engineering at the University of Illinois at Urbana-Champaign where he served from 1957 to 1974 and received his Ph.D. in Civil Engineering in 1962. He has published over 90 articles on building research, computer-integrated construction, formulation and expression of standards, performance of structures, structural design for earthquakes and other dynamic loads, flow and fracture in structural metals, and mechanics of thin-walled beam structures. He is Chairman of the U.S.-side of the U.S./Japan Panel on Wind and Seismic Effects, Chairman of the Interagency Committee on Seismic Safety in Construction, Past President of the International Council for Building Research, Studies and Documentation, and Past President of the Liaison Committee of International Civil Engineering Organizations.

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