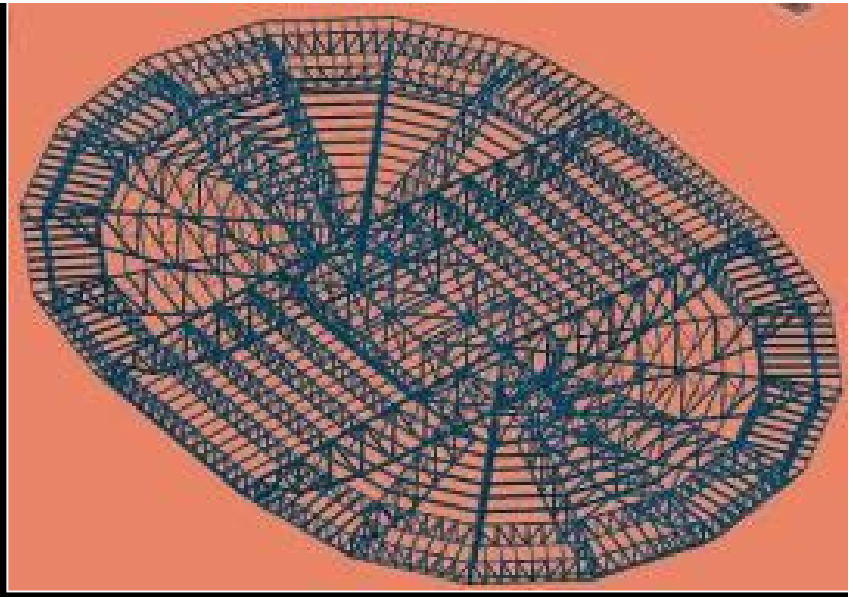

M.Eng. Program Presentation

Lehigh University
January 29, 2010

Daniel A. Cuoco, P.E., President & CEO

Thornton Tomasetti

Topics

- Long-Span Structures
- Structural Failures
- Building Information Modeling (BIM)
- Green Building Design and LEED

Long-Span Structures and Structural Failures

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Pepsi Center, Denver

- Roof ideal for structural efficiency
- Ends are half-domes
- Middle has tied arches

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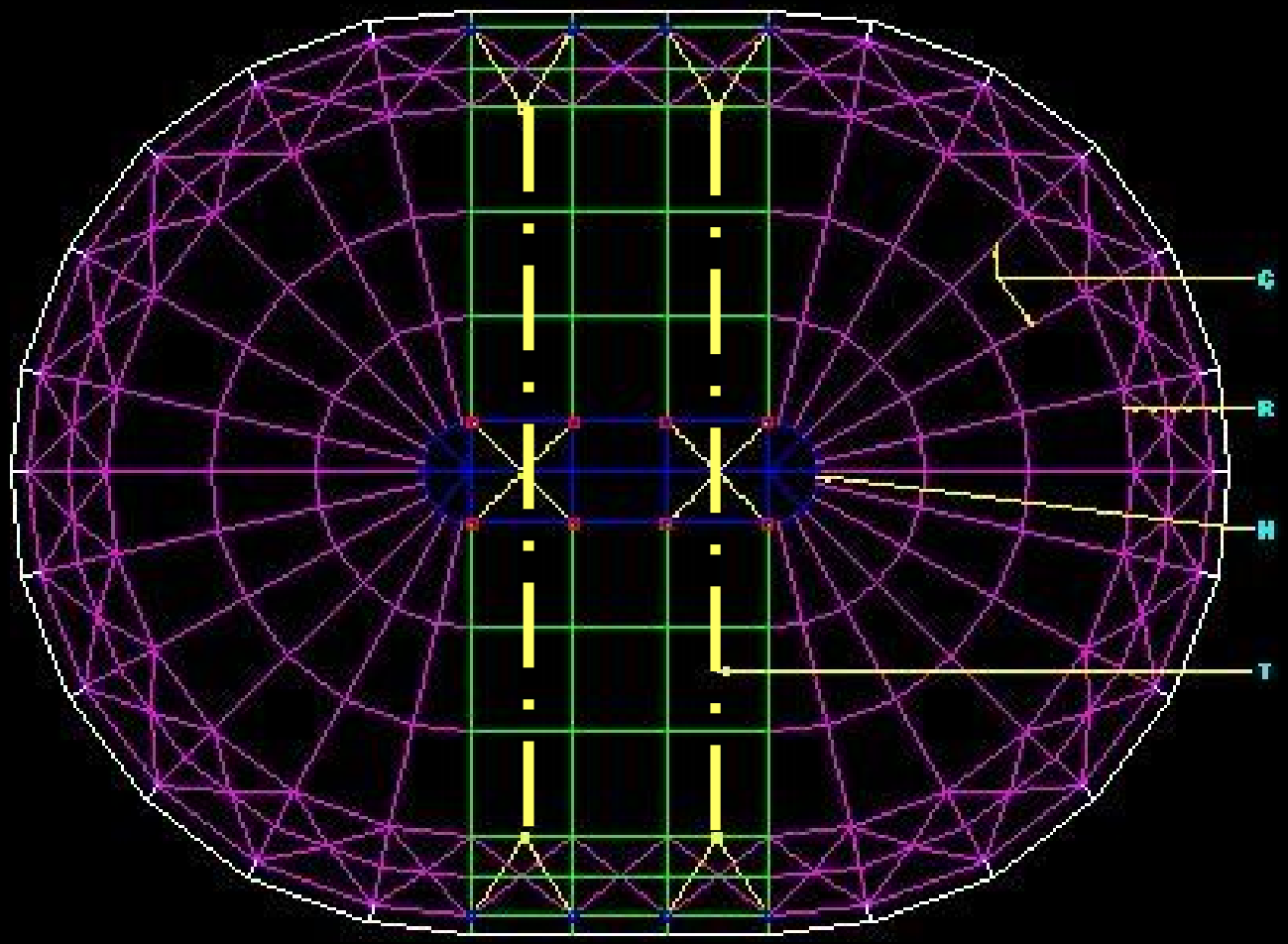
Pepsi Center



- Four trusses share two ties

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Pepsi Center

- Central hub set first on shores

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Pepsi Center

- Radial trusses span edge to hub

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Pepsi Center

- Double W14s cross arena, lift central pyramid

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Pepsi Center

- ‘Y’ at tie end engages two trussed arches

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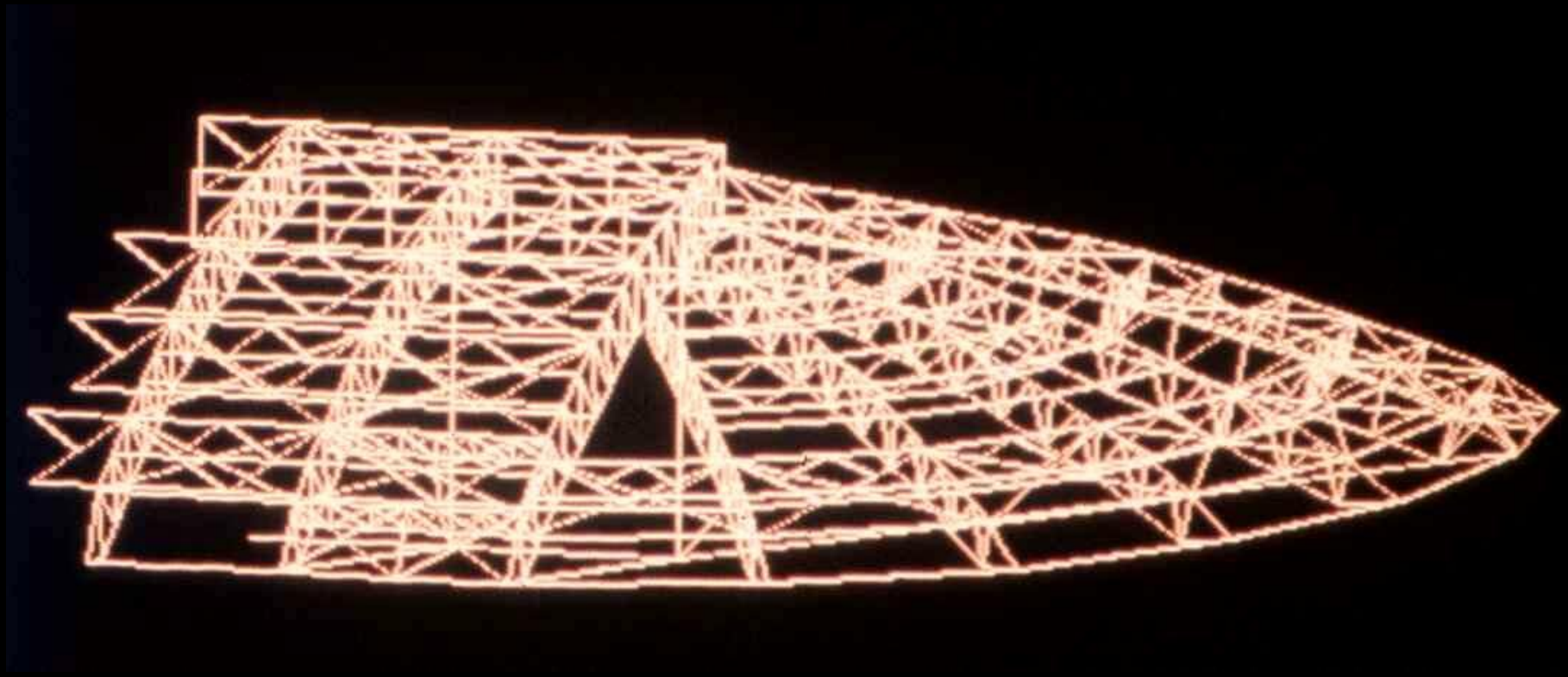
United Center, Chicago – end half-dome



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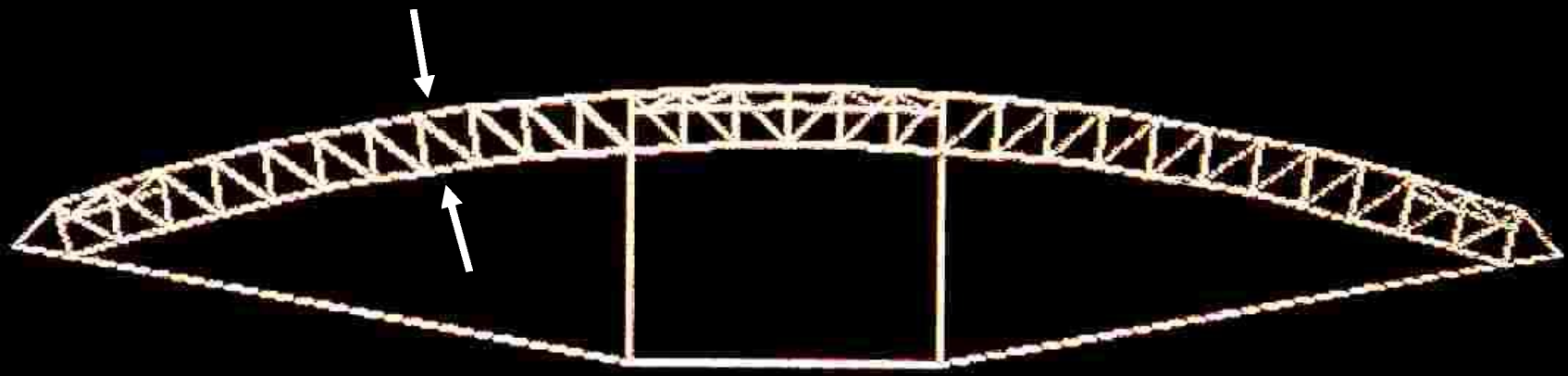
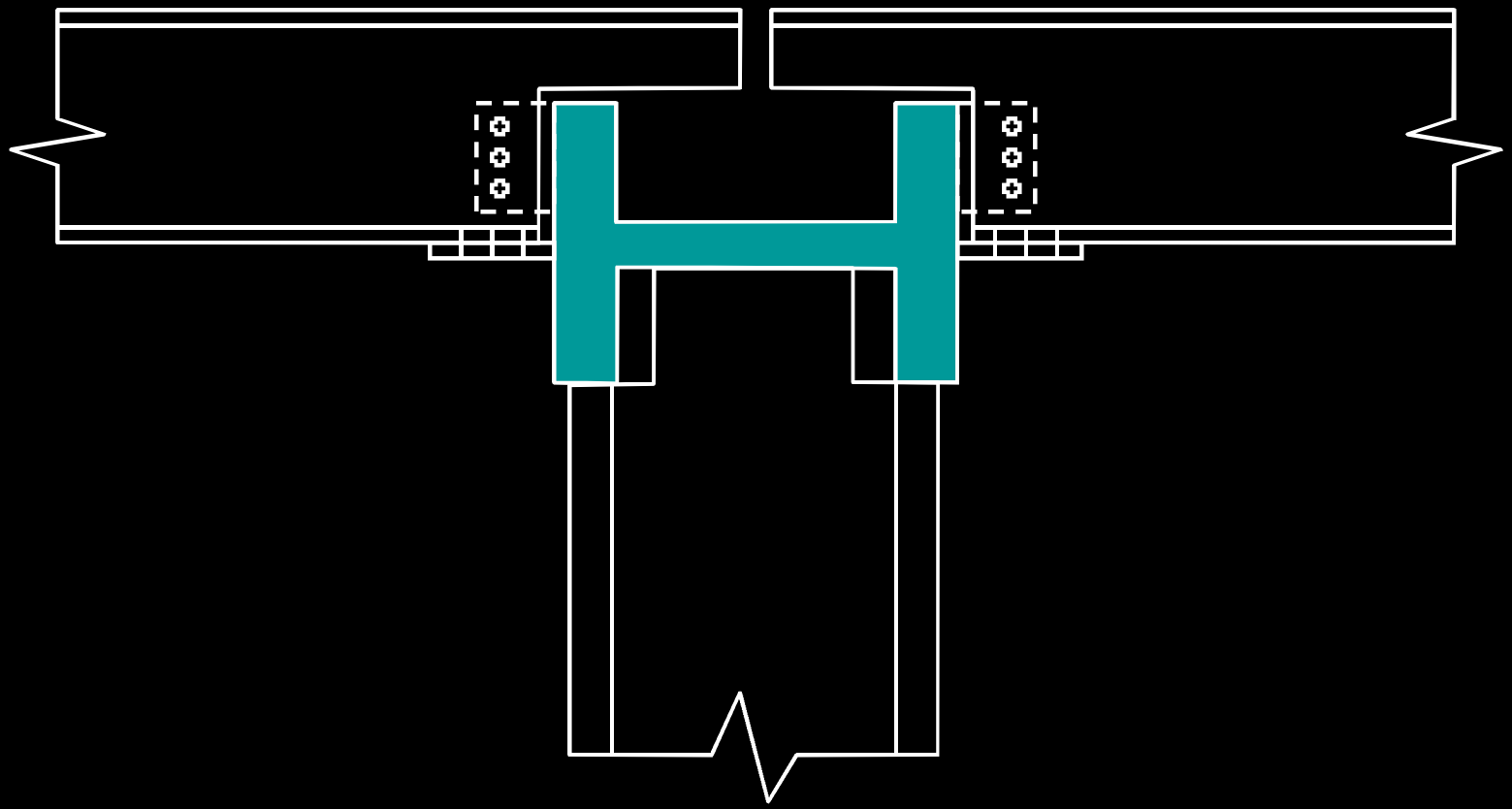
United Center



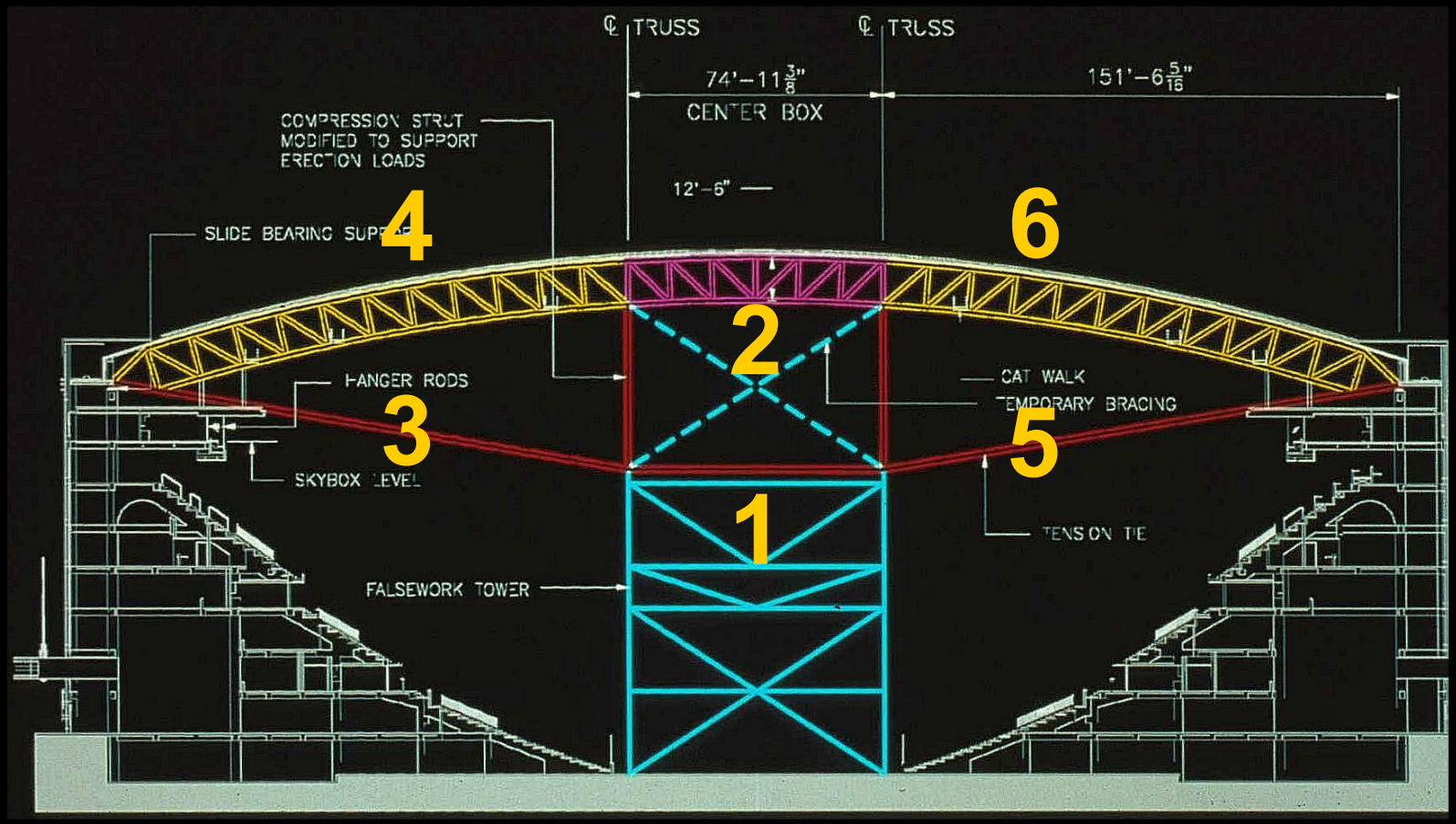
- Trussed top chord shallow enough to truck shop-assembled

Truss/Purlin Configuration



- Truss shop-fabricated, welding economical
- Purlin b.o. steel near top chord centerline
- Bottom flange conn. for bracing, uplift stability

Erection Sequence



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Omaha Arena

- Features
  - Concert seating: 17,000
  - 32 Suites

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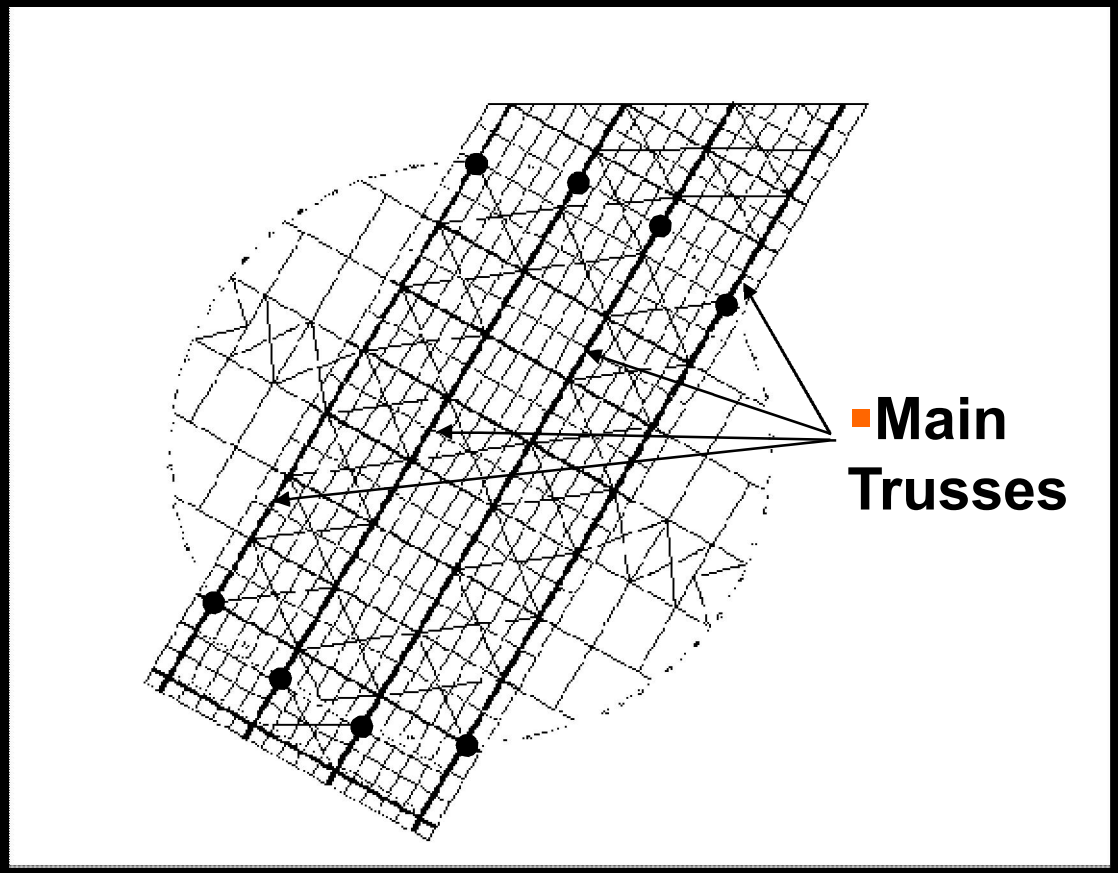
Omaha Arena - Roof Plan



- Truss spans: 350’ main spans
- Longest cantilever: 155’

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Omaha Arena

- Features
  - Large cantilever for “drama”
  - Not typical arena roof condition - special attention required

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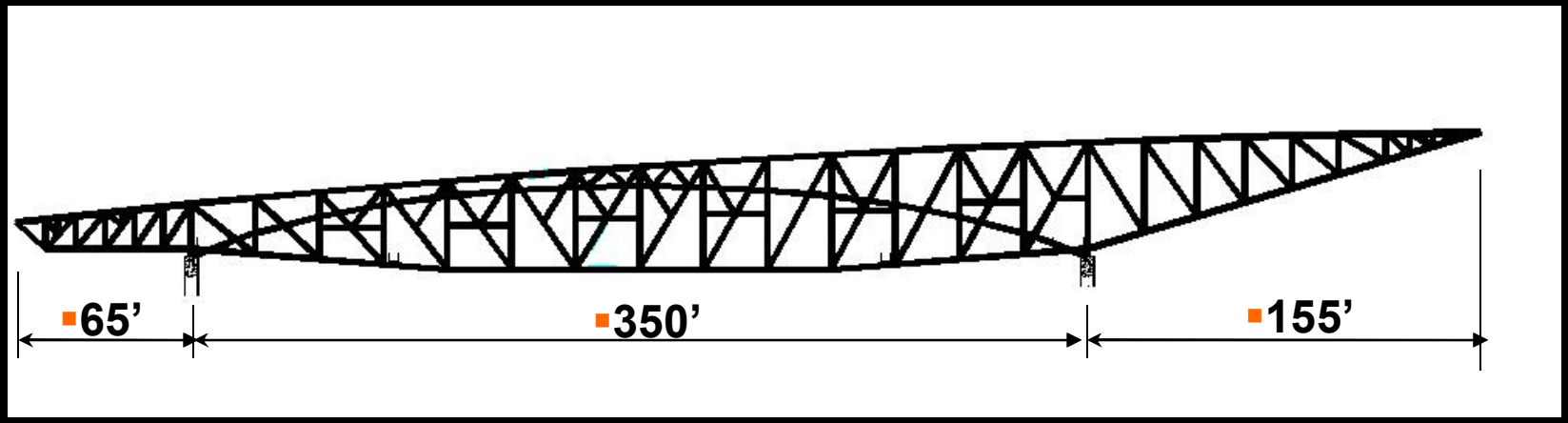
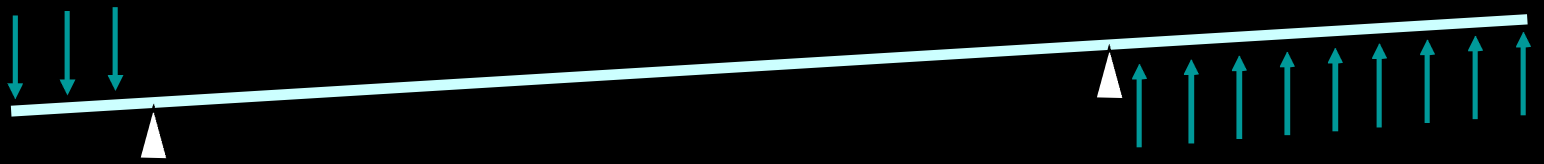
Omaha Arena - Roof Section



- Main Roof Truss



- Challenges:
  - Long Spans
  - Long Cantilever - potential uplift
  - Cranked end moment, induced shear

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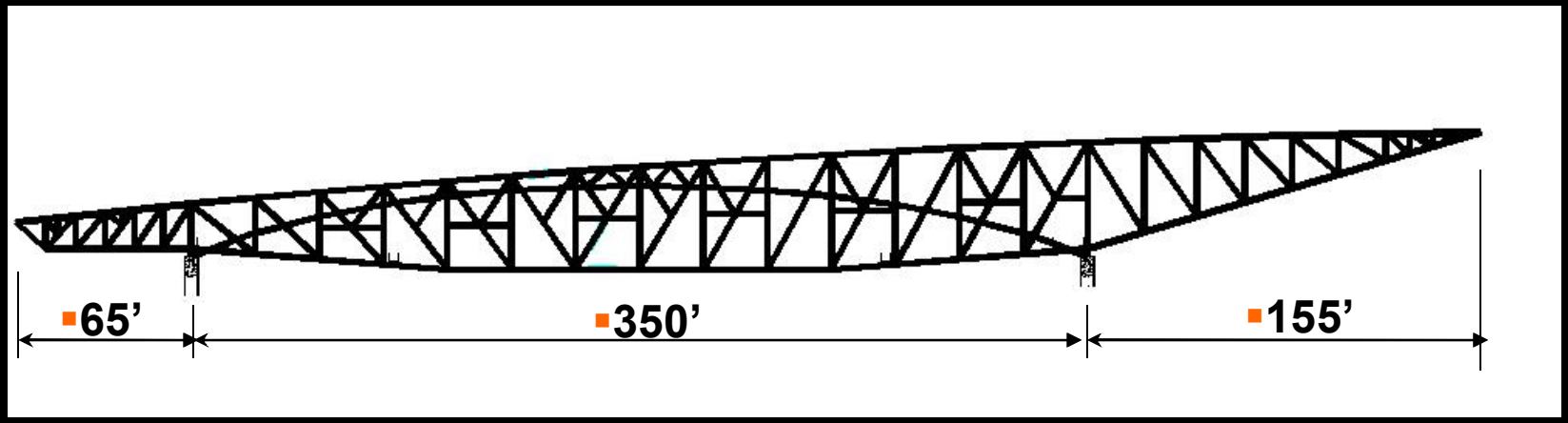
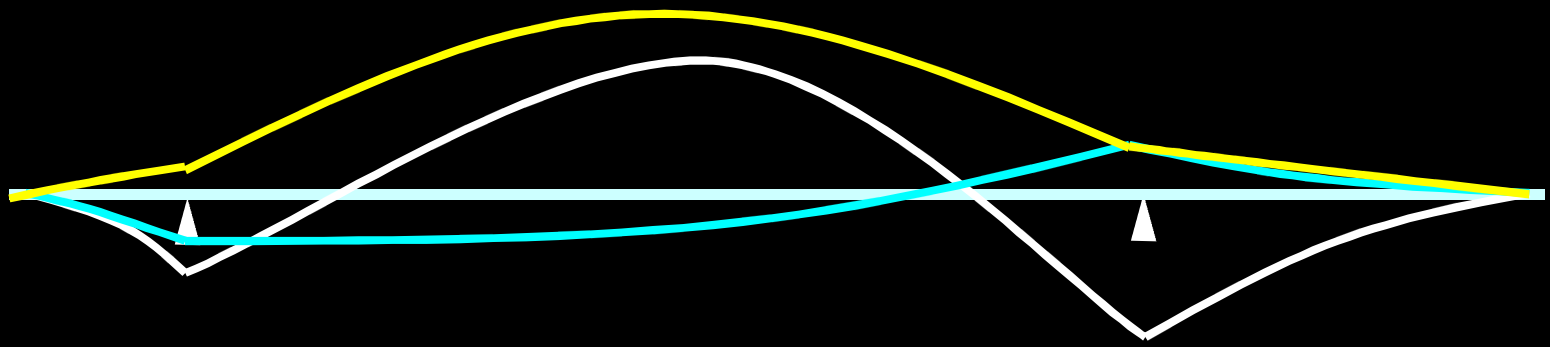
Omaha Arena - Roof Truss Moments





- Unbalanced loads create many moment diagrams
- Shear patterns also vary

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Omaha Arena - Roof Trusses

- Constructed in 2 pieces / spliced mid-air

Omaha, Nebraska Arena

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Gaylord Arena, Nashville TN

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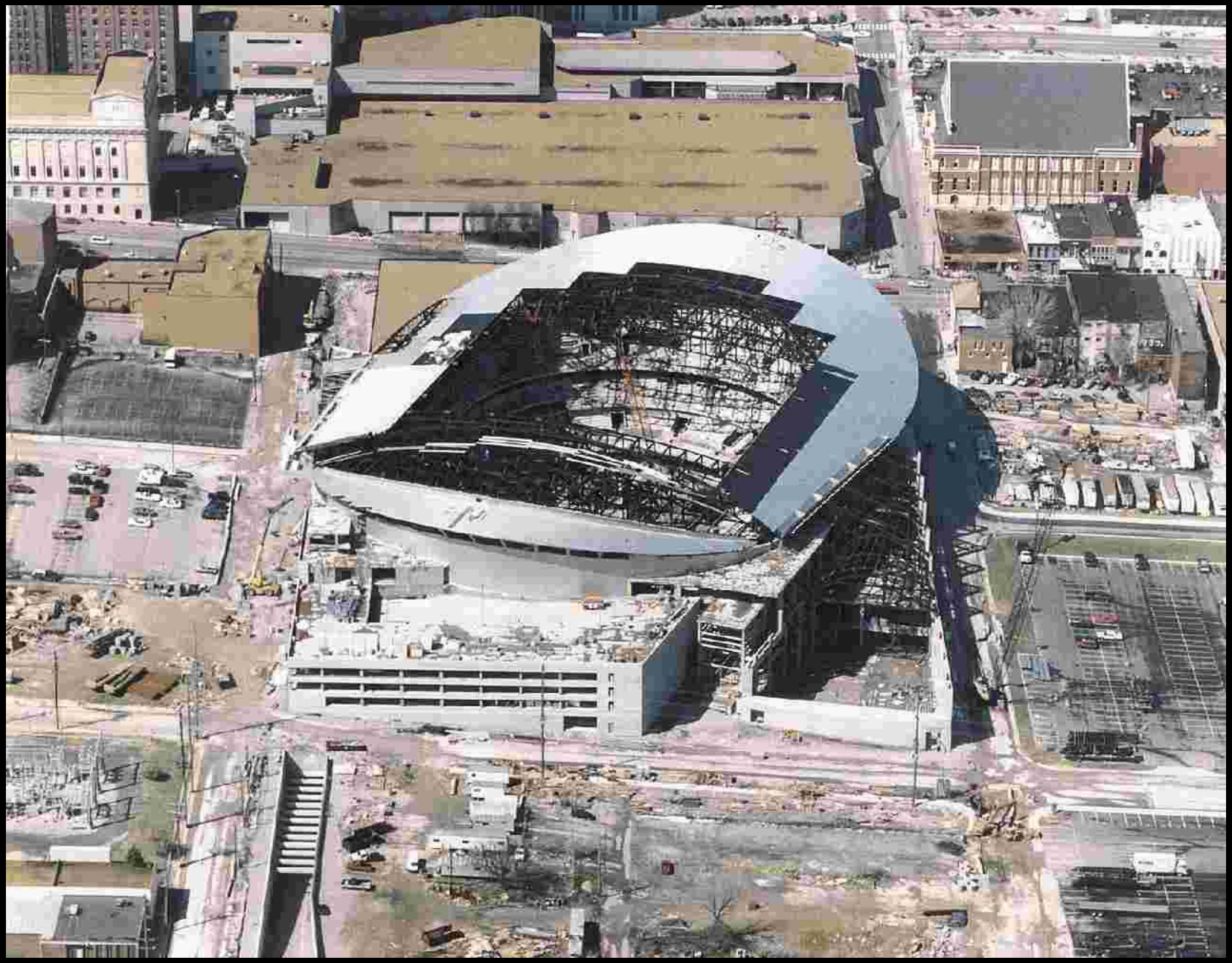

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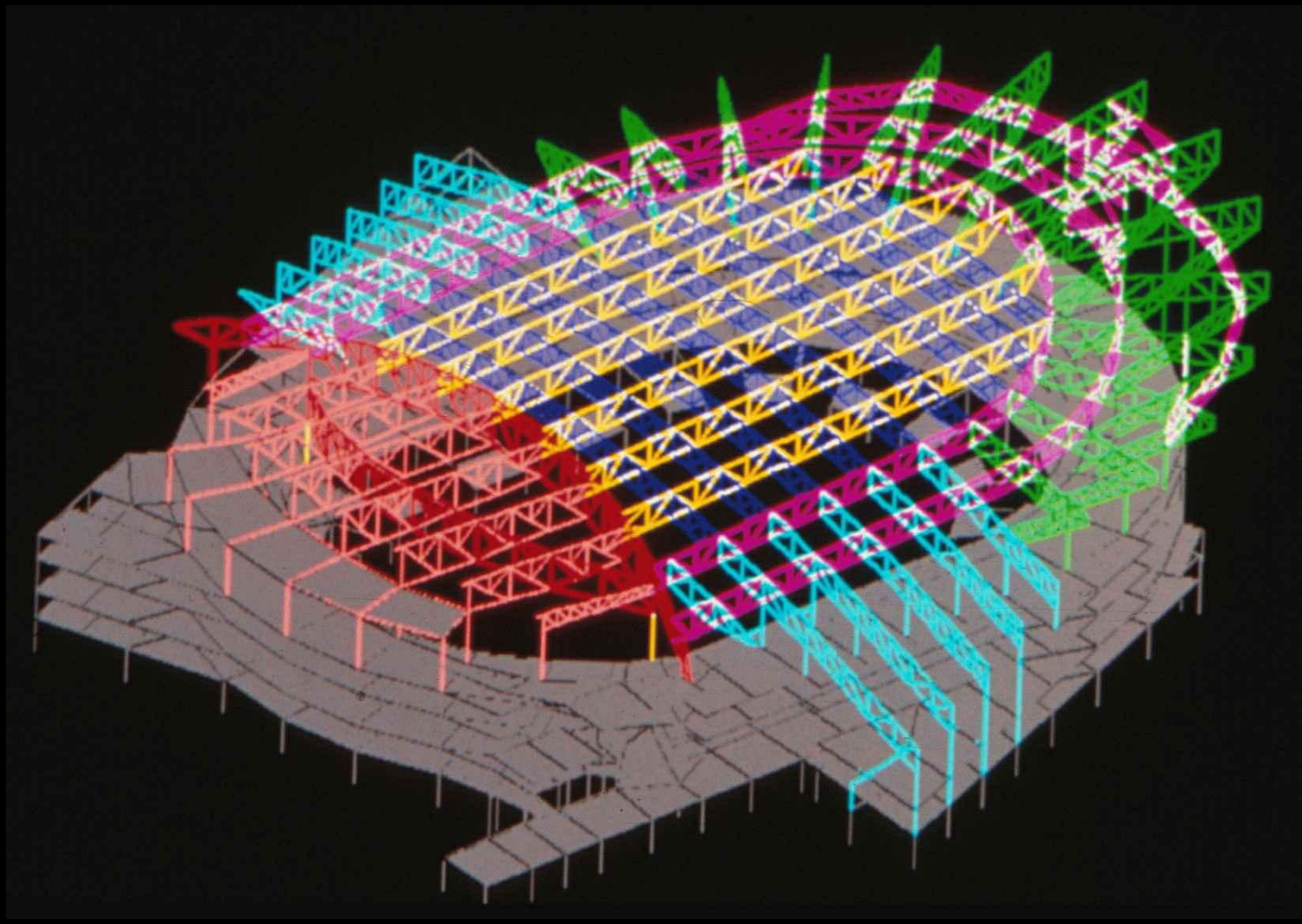
Form set by function as Music Hall



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Banana Trusses and Drop-in Spans

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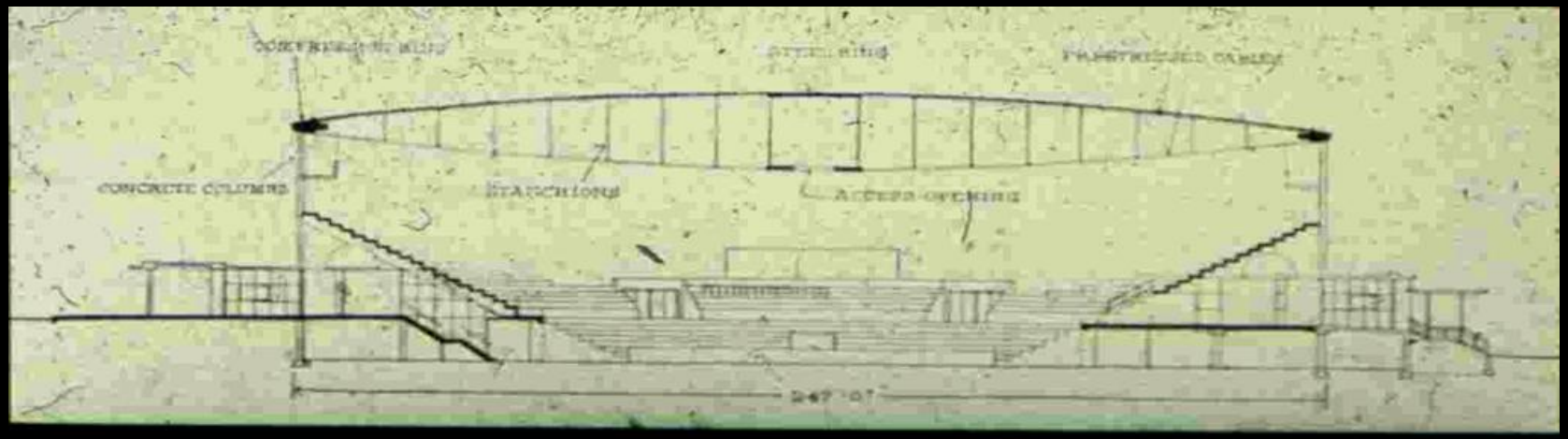
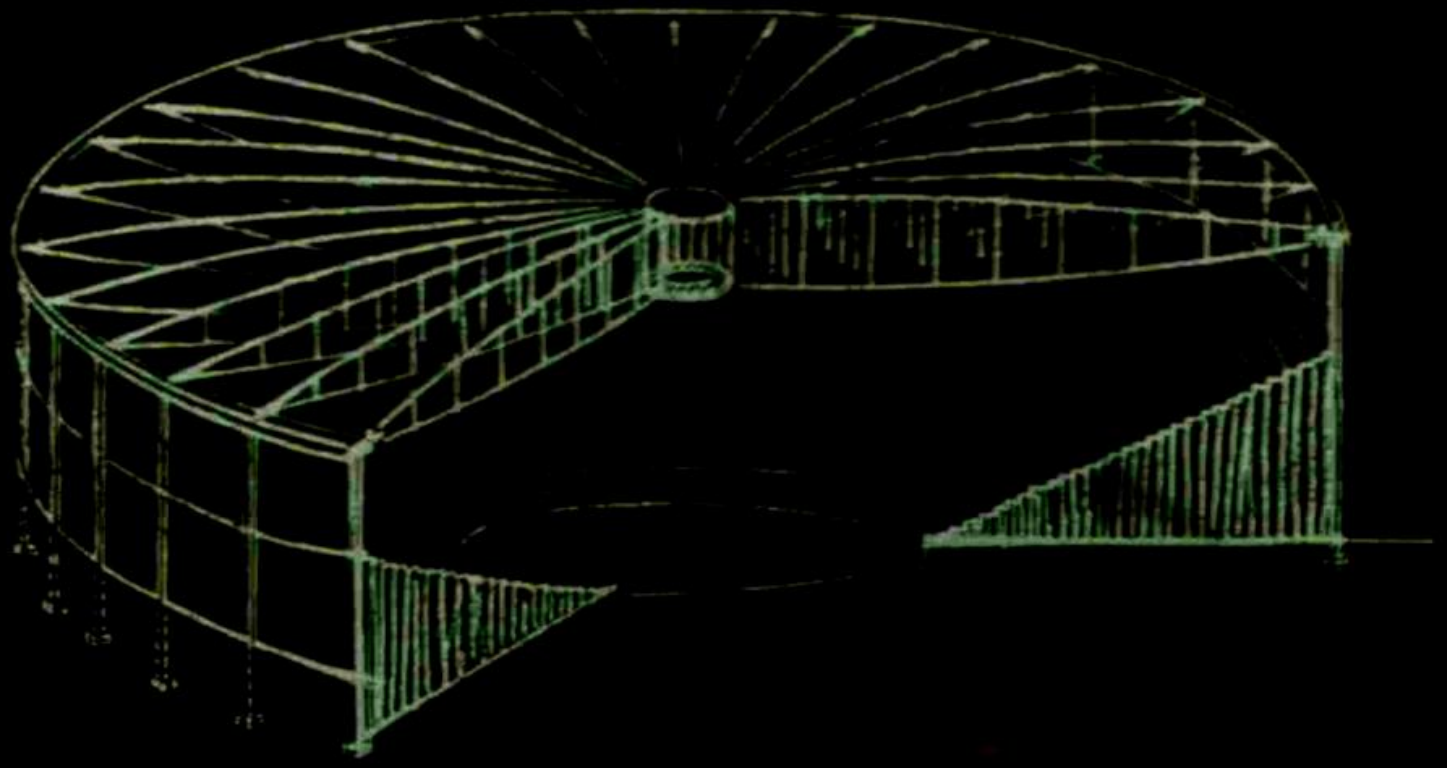
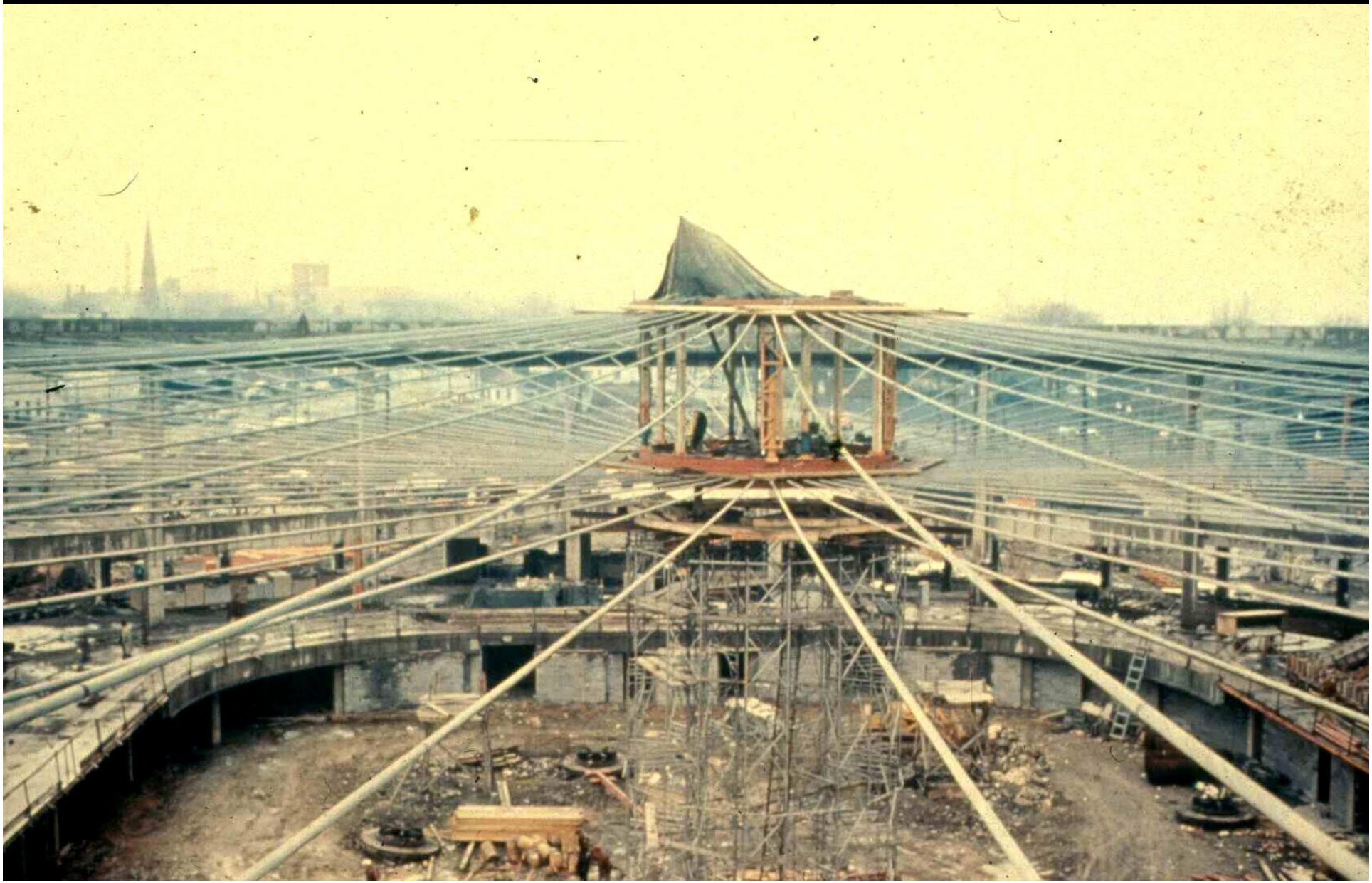
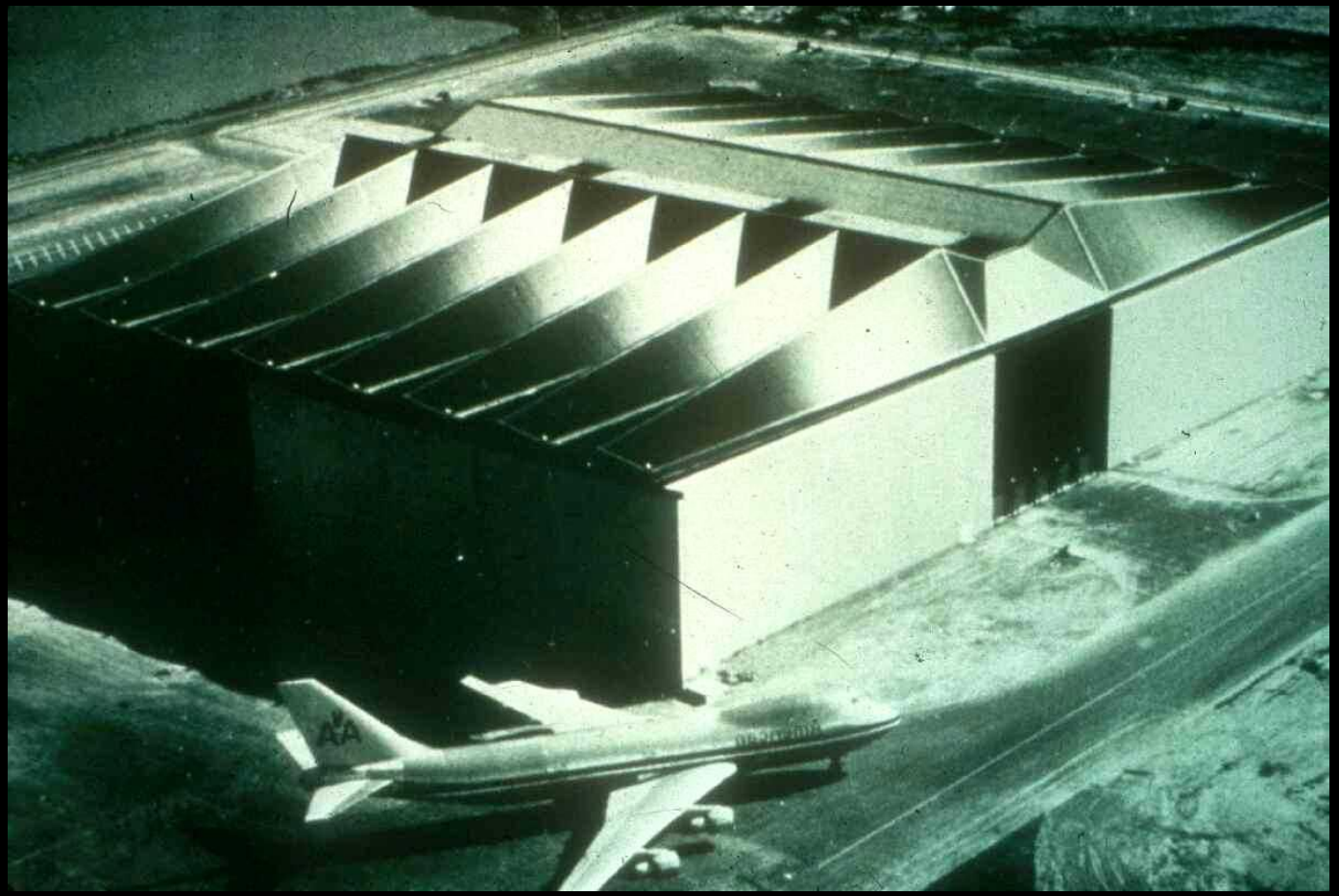

CONCRETE COLUMNS
247'-0"



Bicycle Wheel Truss – prestress cables



AA Hangars at LAX, SFO



- Roof deck in shear links ridges and valleys

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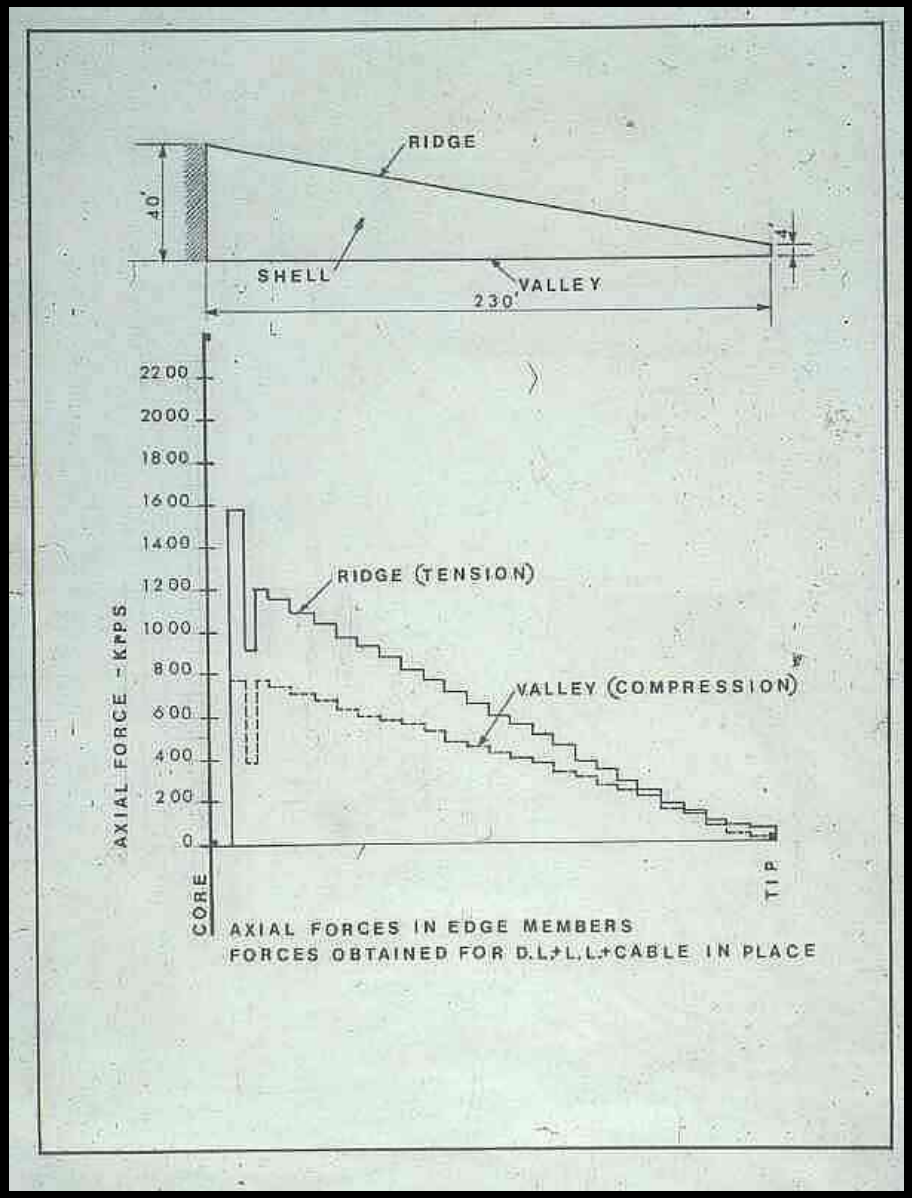
Axial Forces in Edge Members



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AA Hangar Hypars

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AA Hangar Cantilevers

- Tapered gap for live load deflection

Hartford Civic Center – January 18, 1978

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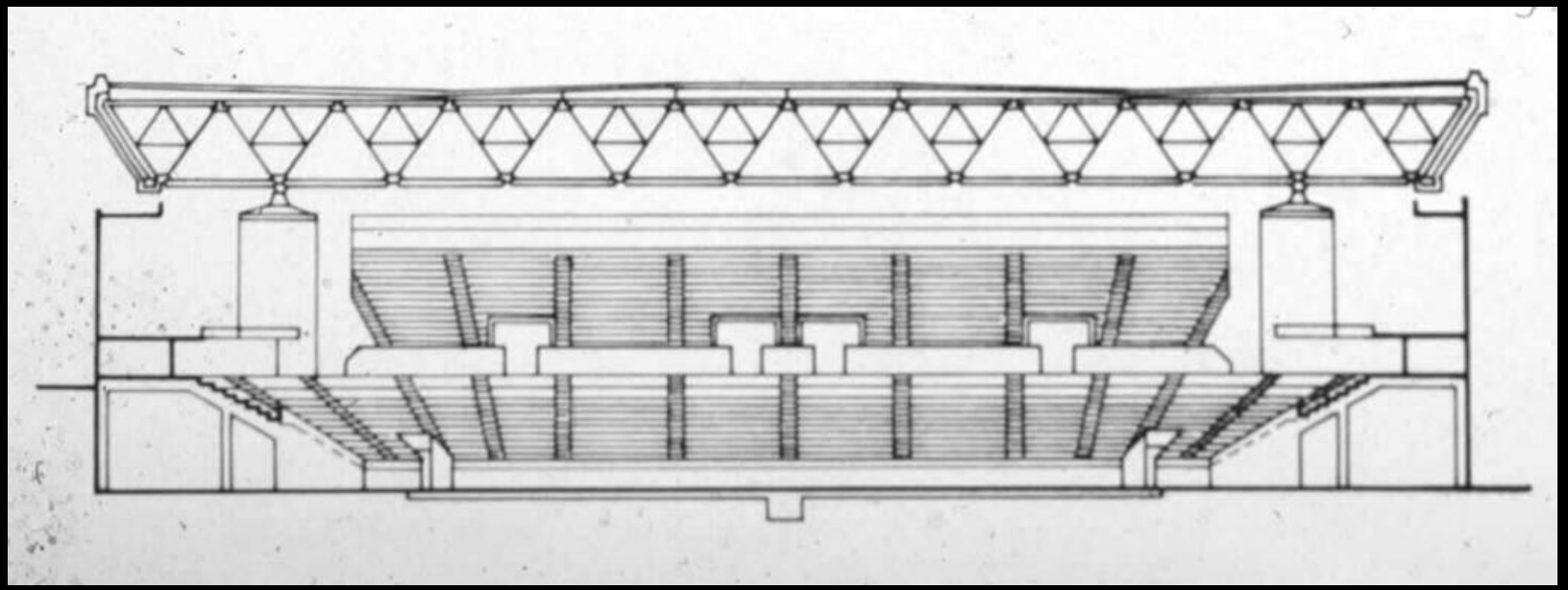
Section



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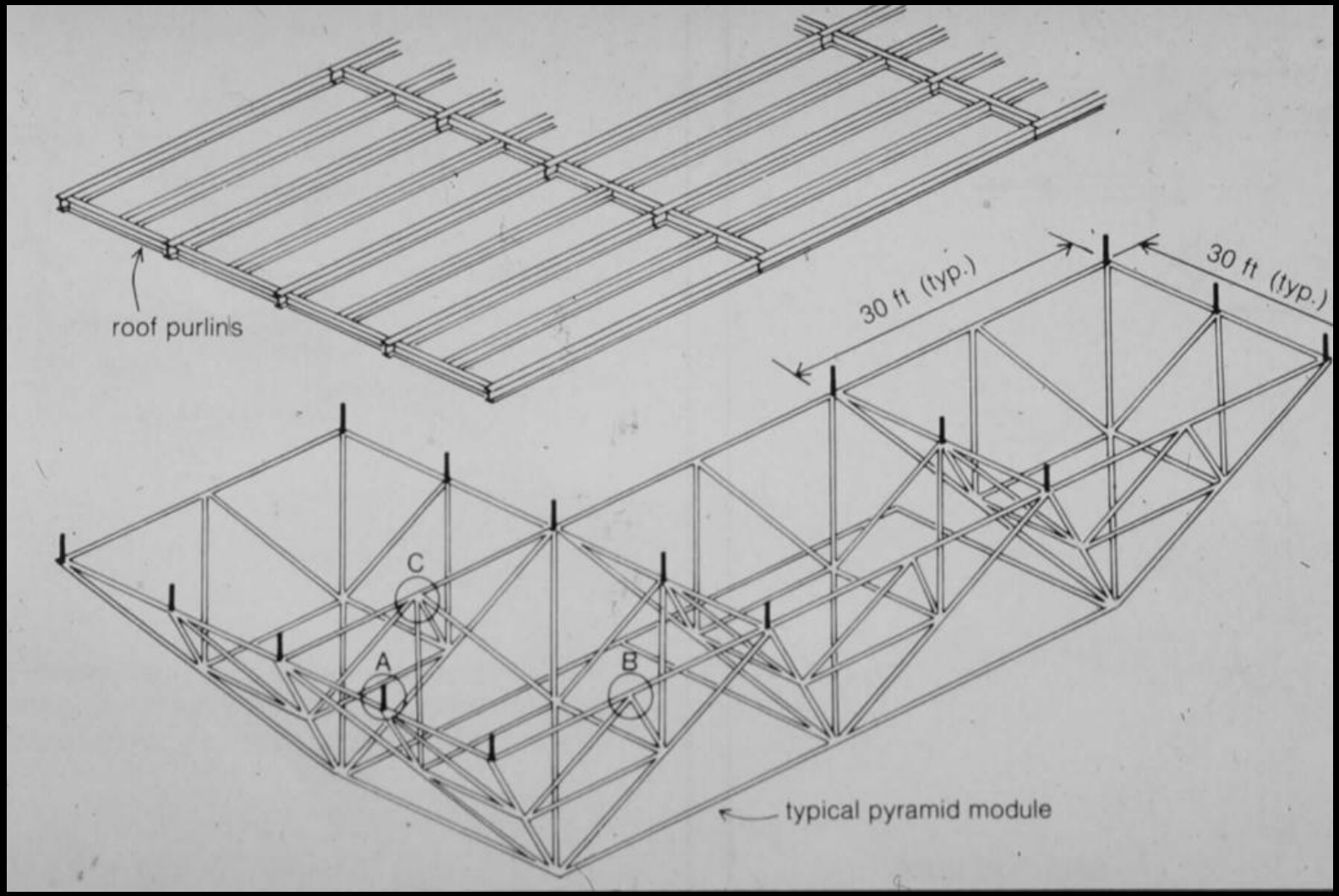
Connection Details



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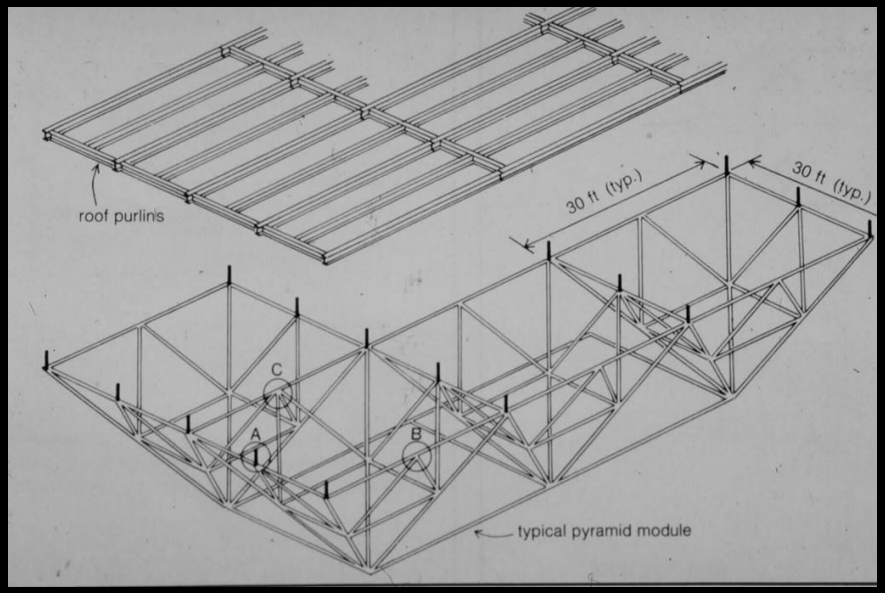
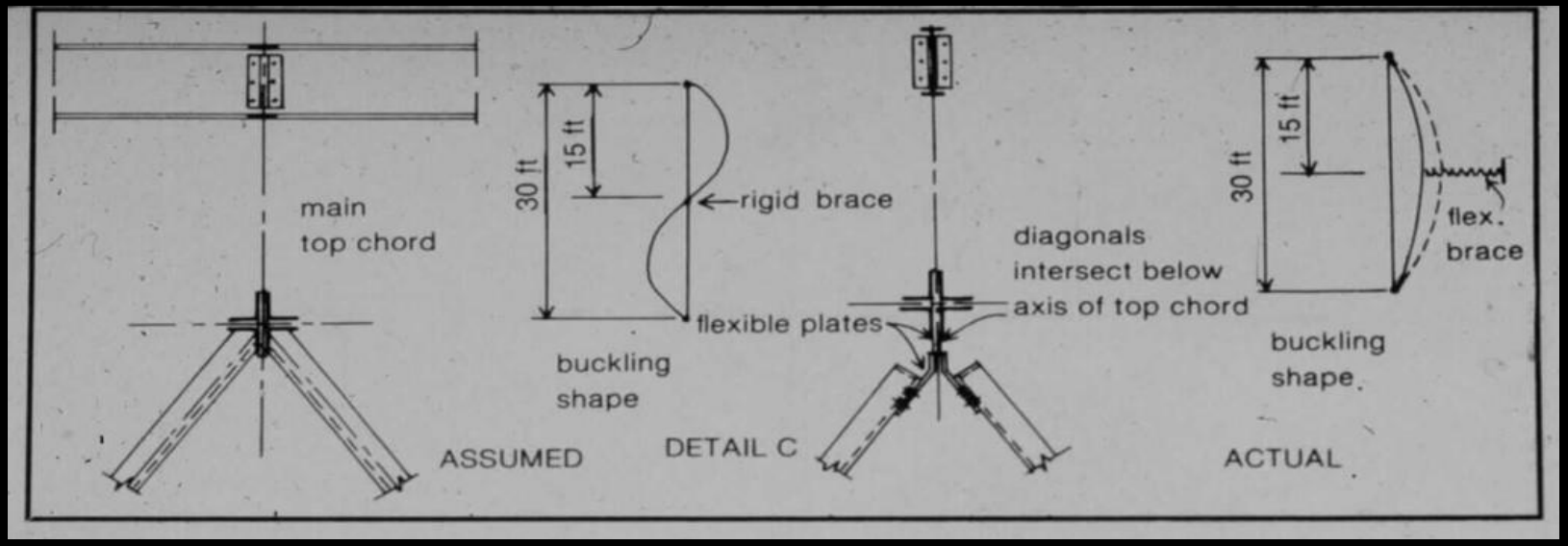
Detail C





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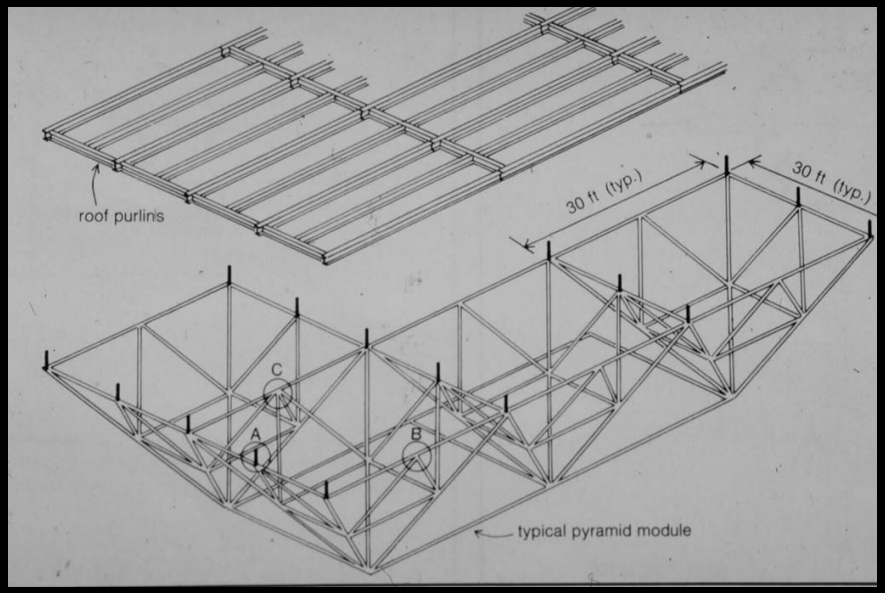
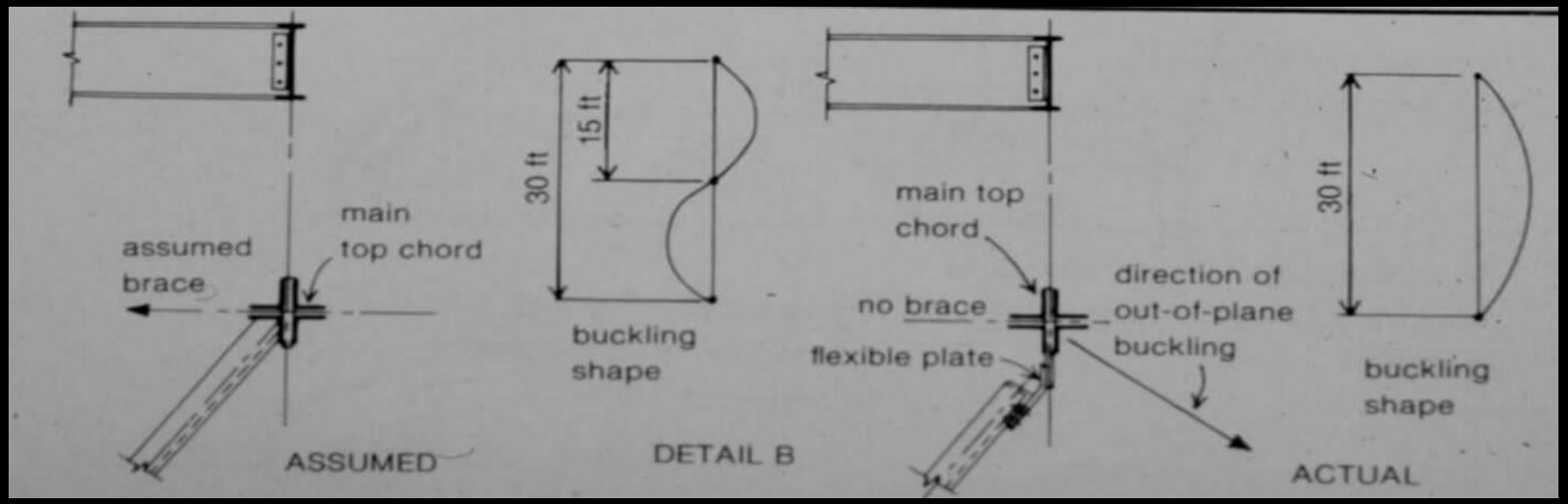
Detail B





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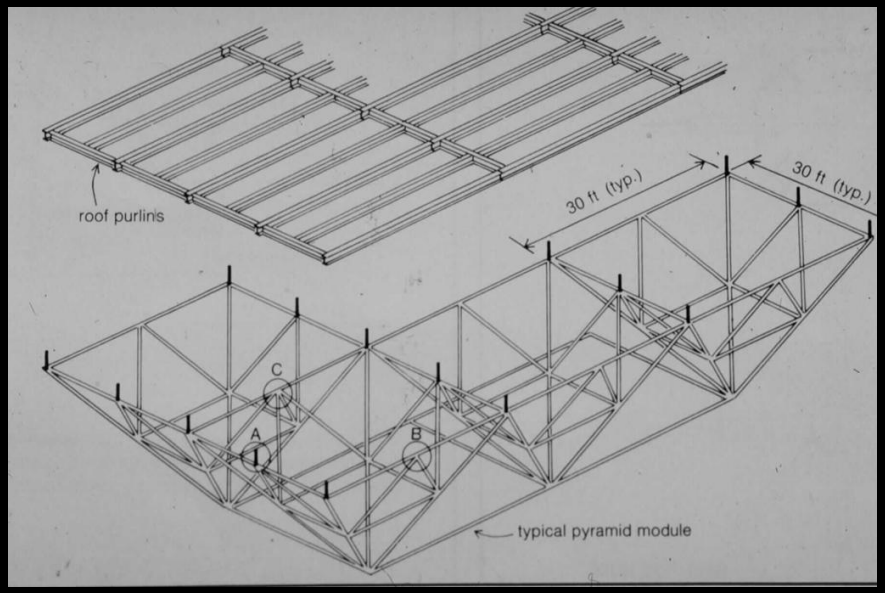
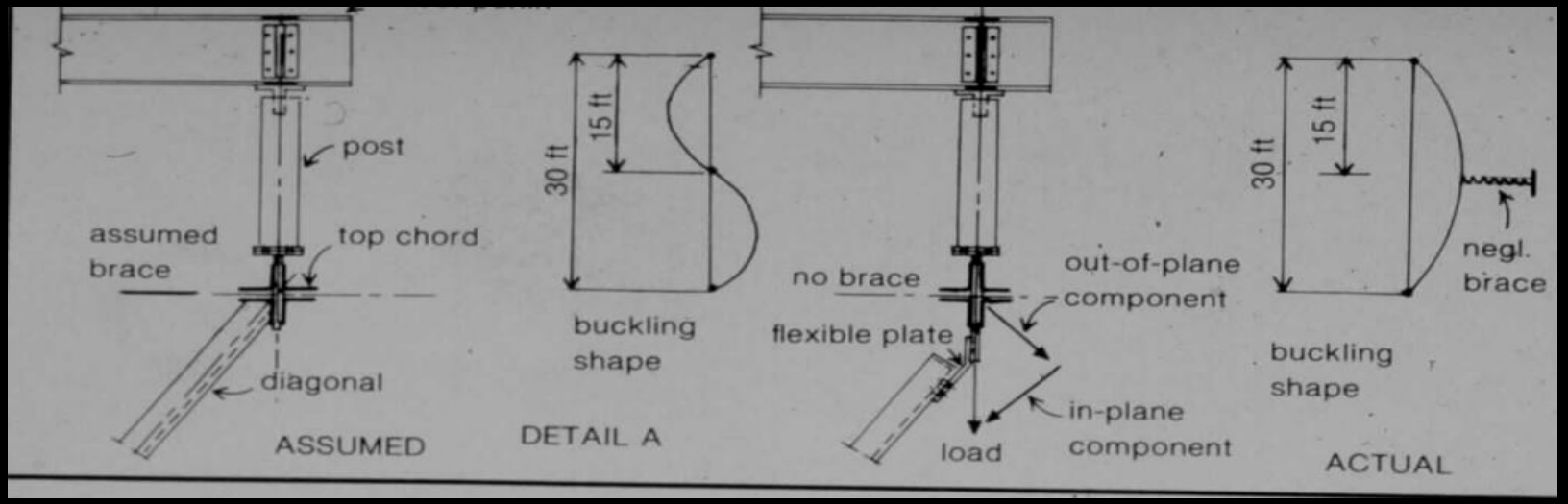
Detail A





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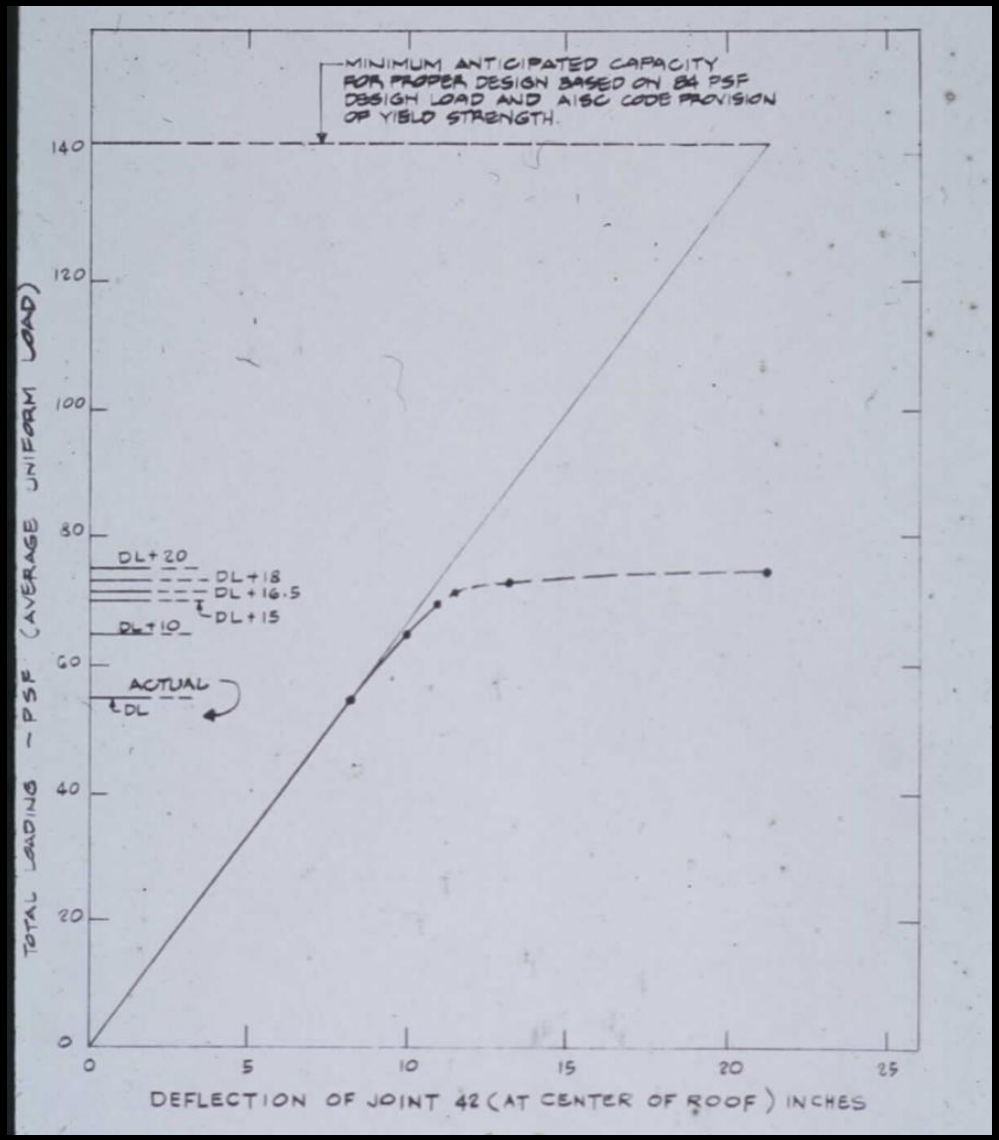
Load-Deflection Curve



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The Result

- Several warning signs during construction
- Computer analysis re-checked and confirmed
- Cause of unusual behavior not determined
- Collapse occurred hours after a basketball game
- No deaths or injuries
- Some snow

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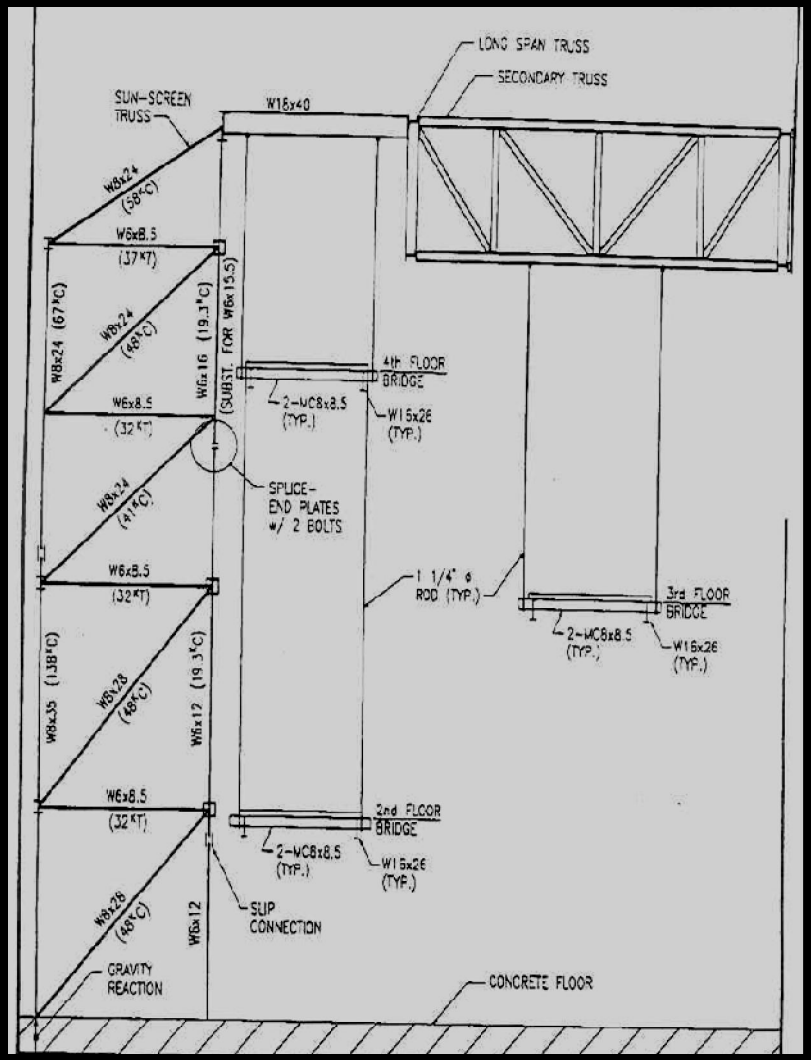
Lessons Learned

- Design details must be consistent with analysis assumptions
- Constantly verify design assumptions
- Avoid over-reliance on computers
- Heed warning signs

Kansas City Hyatt Regency Walkways

- July 17, 1981



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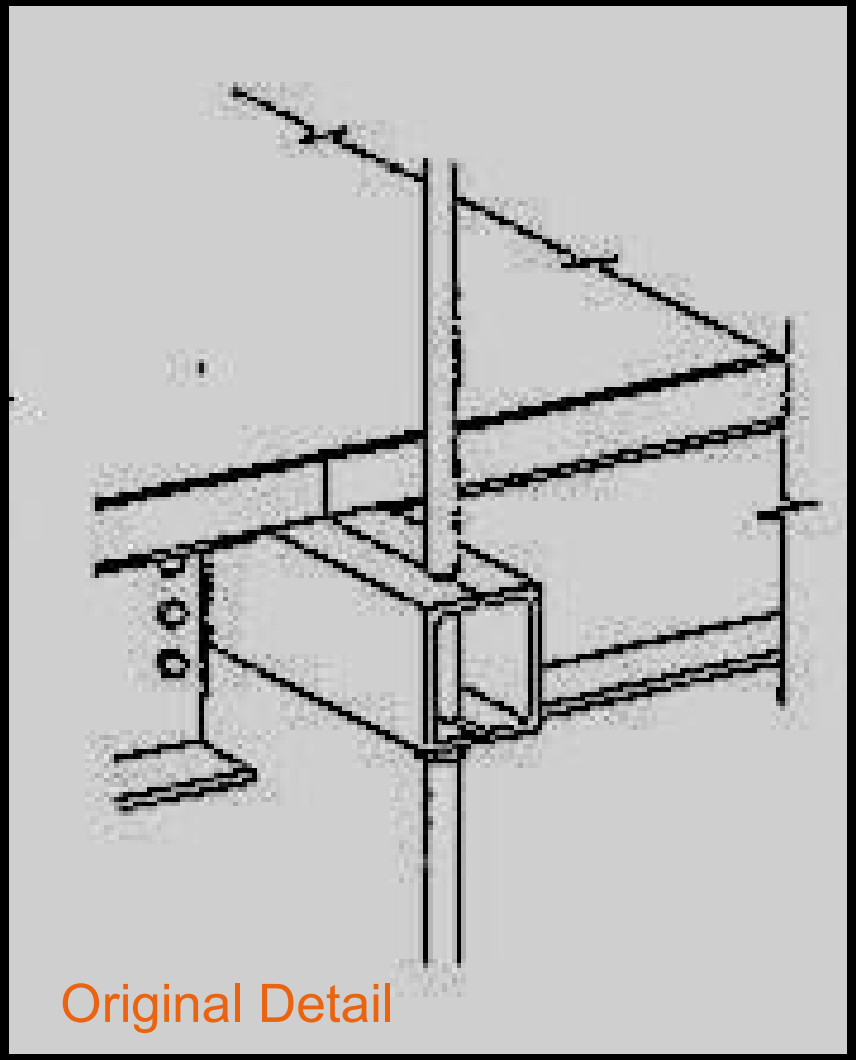
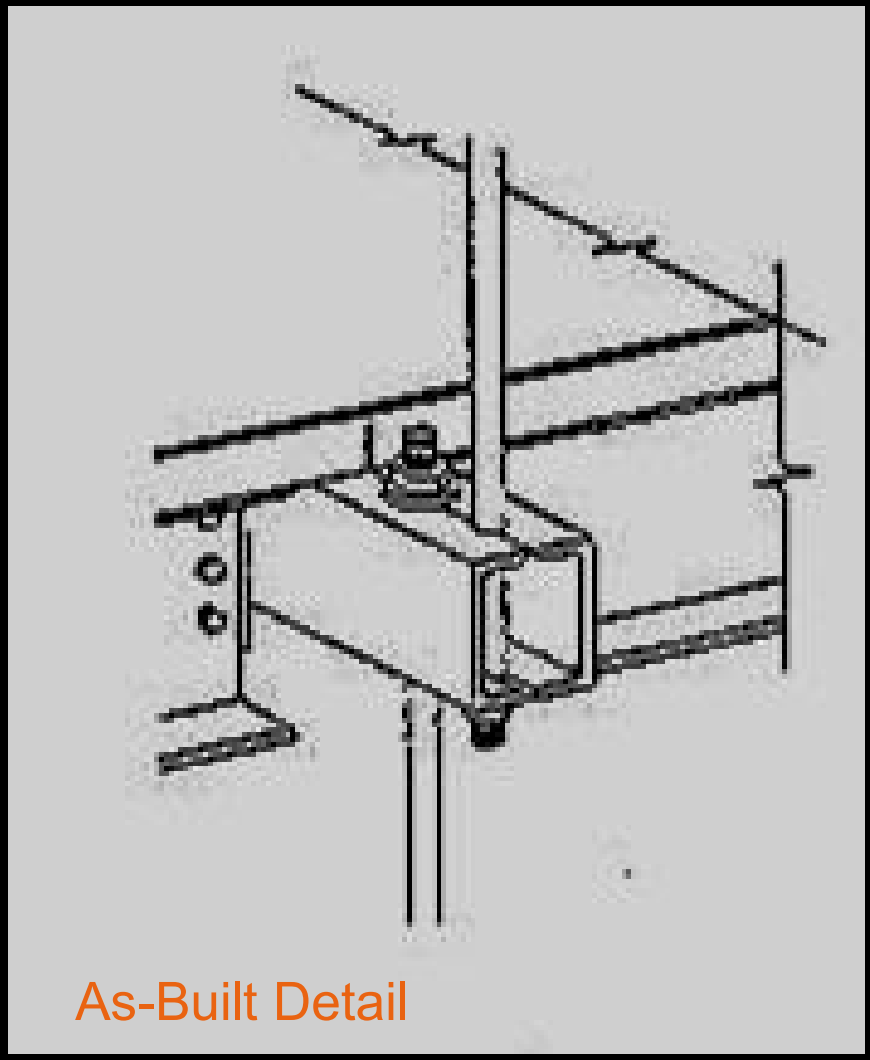
Hanger Connection Detail



Original Detail



As-Built Detail

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Connection Failure

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The Result

- Connection was not engineered
- Original design was inadequate
- Change was not adequately reviewed
- 114 deaths, 185 injuries
- Engineers lost licenses
- Numerous lawsuits
- Claims totaled $3 billion

Lessons Learned

- Engineer has moral obligation to the public to properly carry out design
- If portions of the design are to be delegated to another engineer, must communicate the design criteria and clearly define design responsibilities
- Importance of checking accuracy of drawings
- Review constructability of your design

Airplane Hangar – Boston, MA

- Simple hand calculations can uncover major blunders, even for complex structures

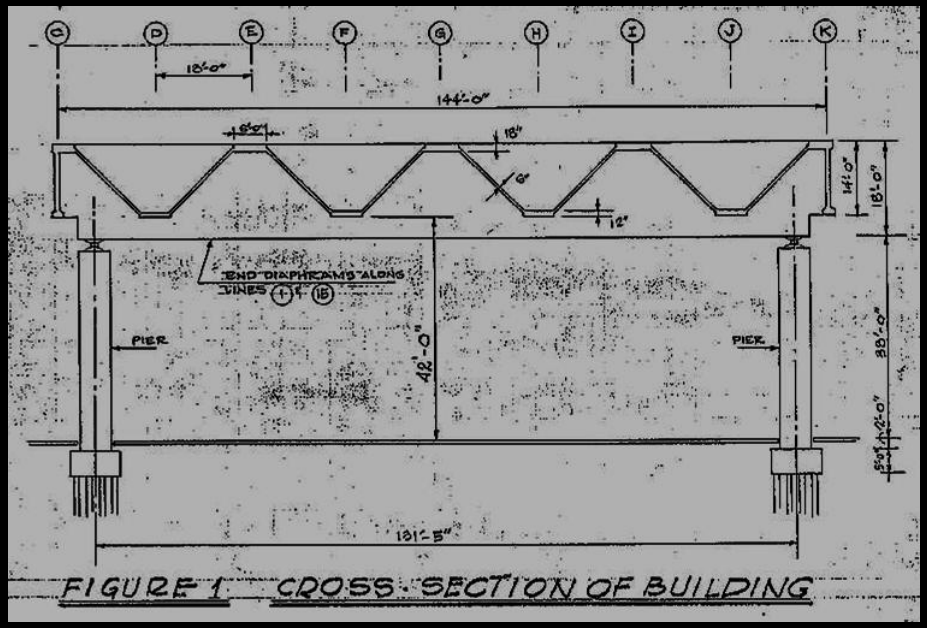

FIGURE 1 CROSS-SECTION OF BUILDING

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Building Information Modeling (BIM)

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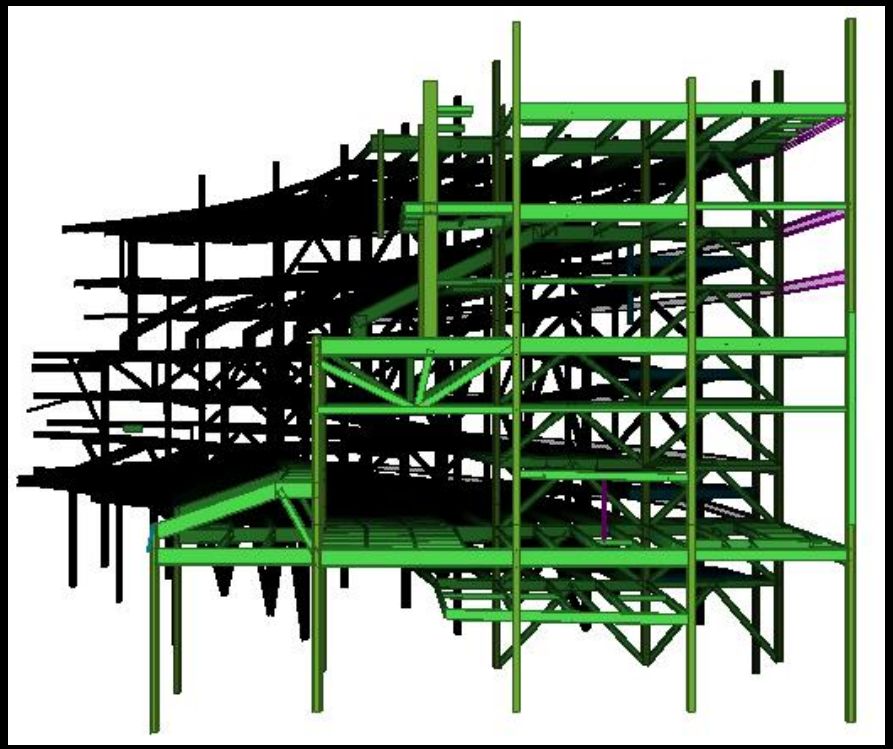
What is a Building Information Model (BIM)?

- What you see…..



- …..is what you get!

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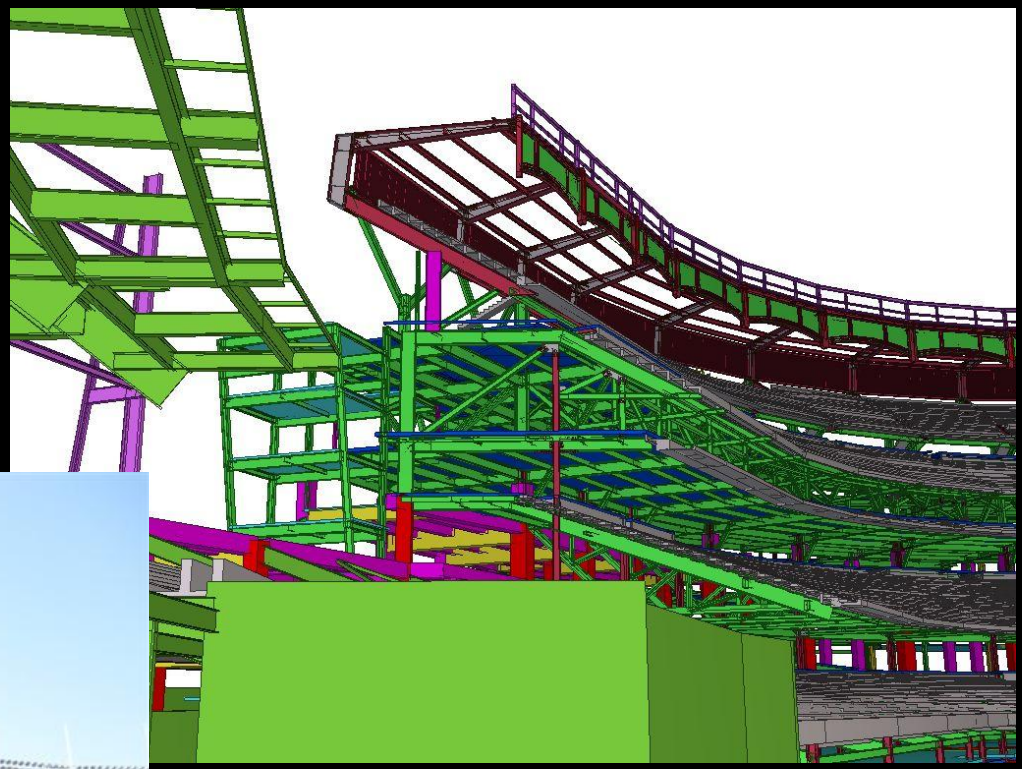
BIM “Building Information Model”



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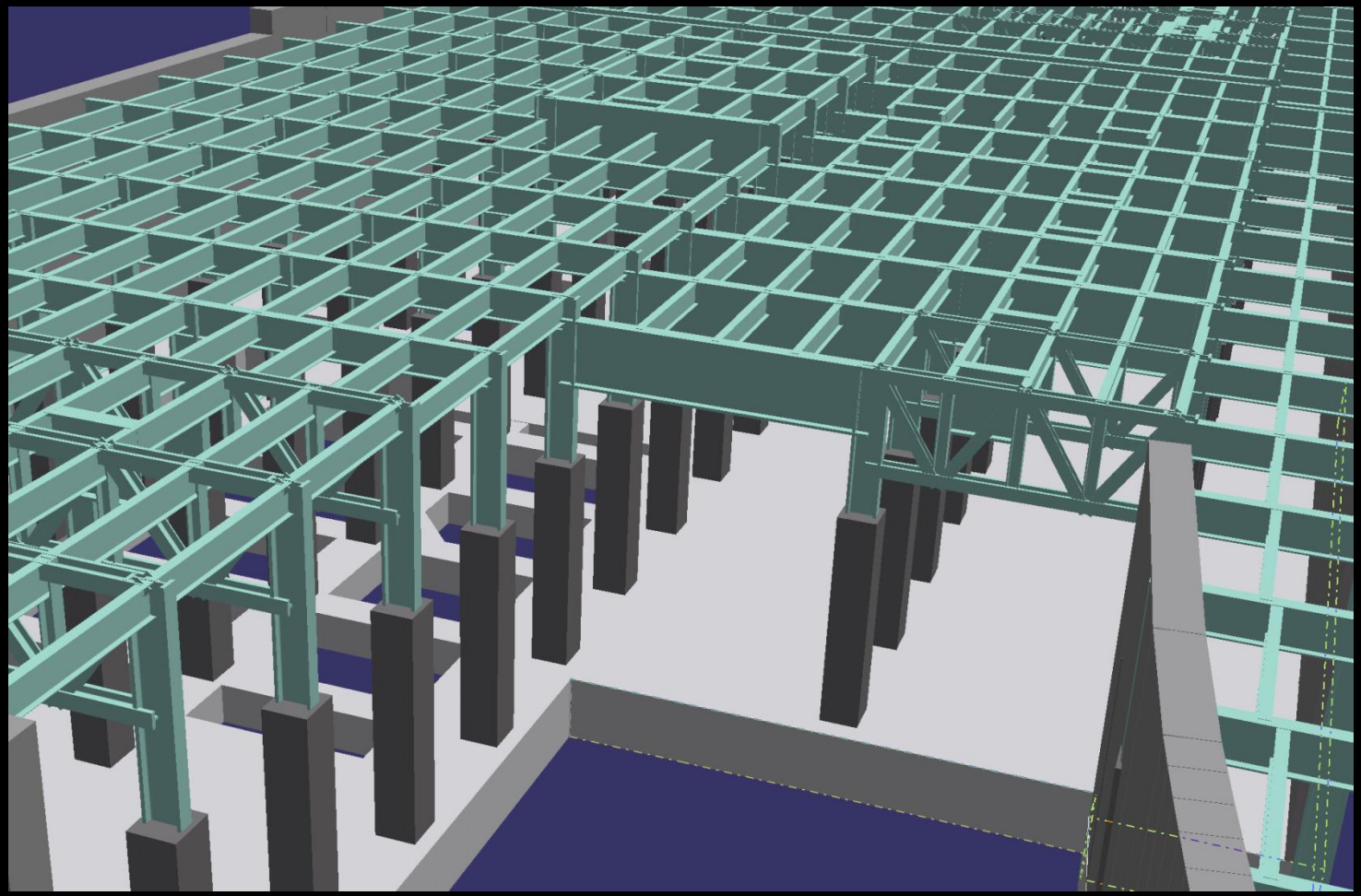
BIM Introduction

- Draw with Objects



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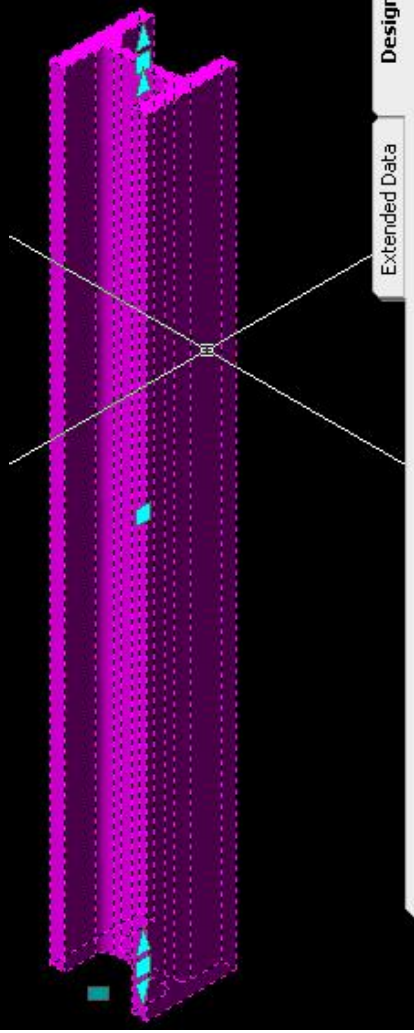
BIM Introduction

- **Smart Objects**
  - **Properties box:**



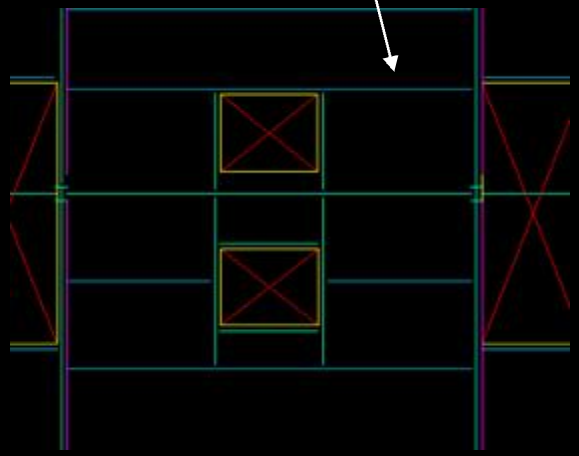
Structural Member

Design | Extended Data

BASIC		
General		
	Description	
	Layer	S-cols-stel
	Style	W14x370
	Member type	Column
Dimensions		
A	Start offset	0"
B	End offset	0"
C	Logical length	12'-0"
E	Roll	90.00
	Justify	Middle Center
	Justify using overall ext...	Yes
Location		
	Start point X	30'-2"
	Start point Y	23'-9 5/16"
	Start point Z	0"
	End point X	30'-2"
	End point Y	23'-9 5/16"
	End point Z	12'-0"
	Rotation	90.00
	Elevation	0"
	Additional information	
ADVANCED		
	Trim planes	(0)

PROPERTIES

- **Old way – just draw** lines, **no information attached**



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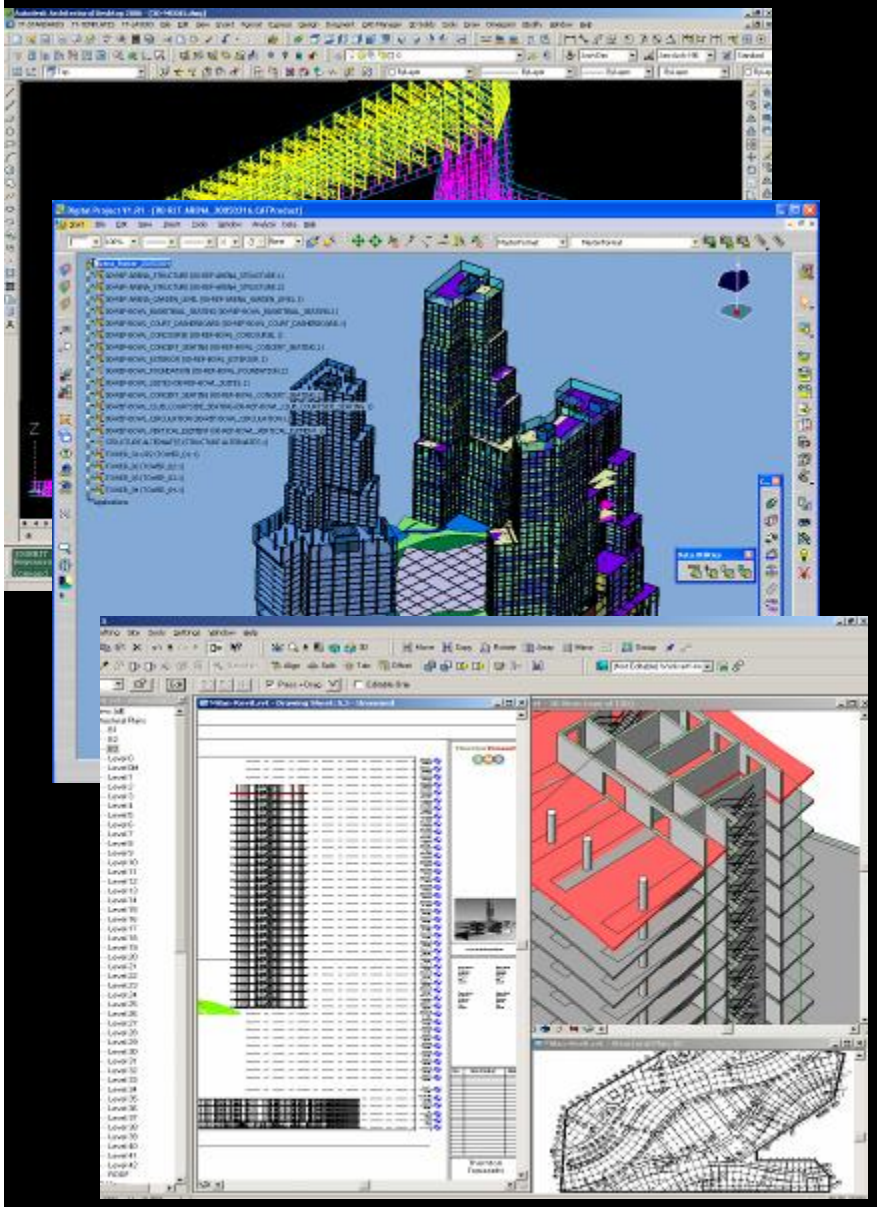
Software used for BIM



- Architectural Desktop
- REVIT Bldg/Str/Systems
- Bentley Microstation
- Digital Project / CATIA
- Rhino Suite
- TEKLA

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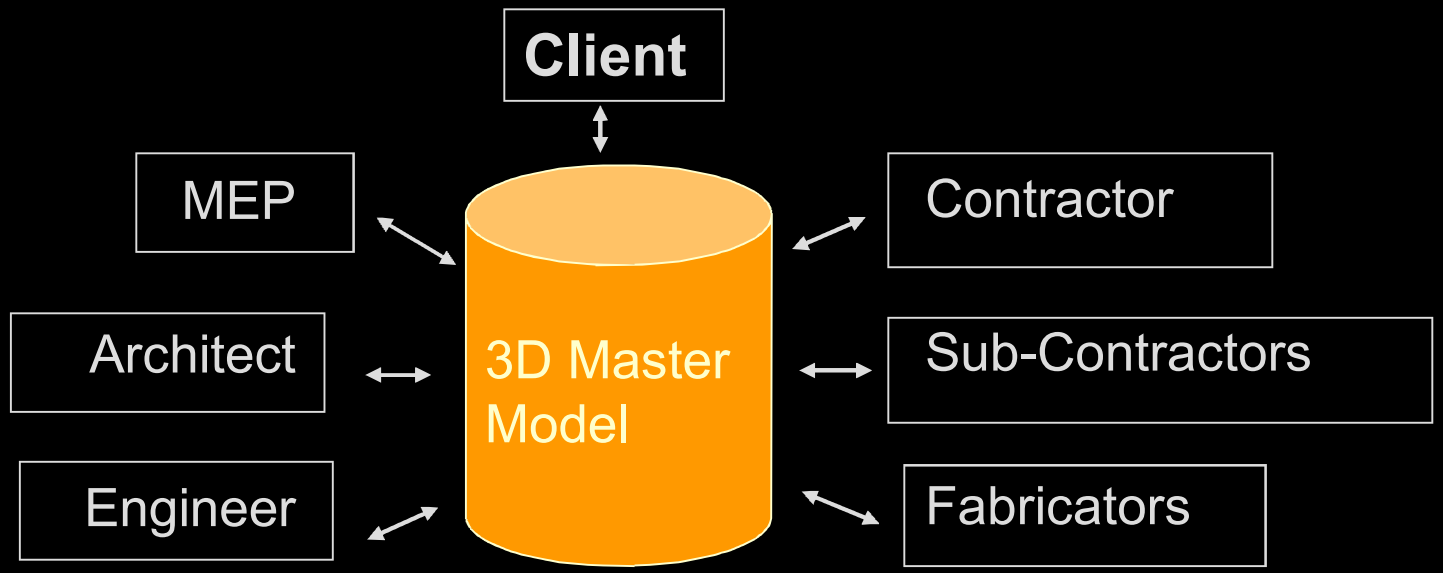
Master Model Concept

- One Master Model
- Typically kept by the Architect or Contractor
- References information from multiple sources
- Used for coordination of design and construction
- Model can be the Construction Documents



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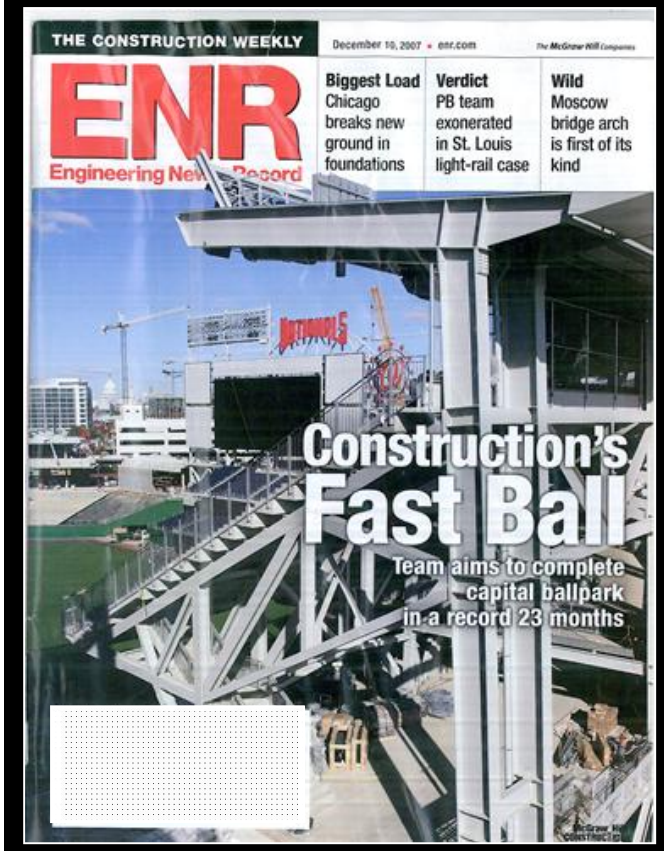
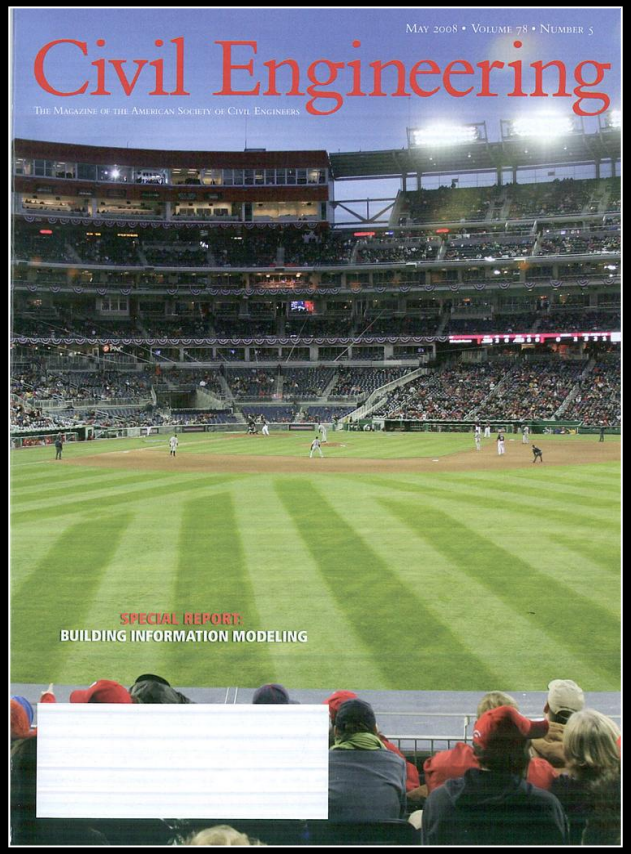
BIM for the A/E/C industry is in the news





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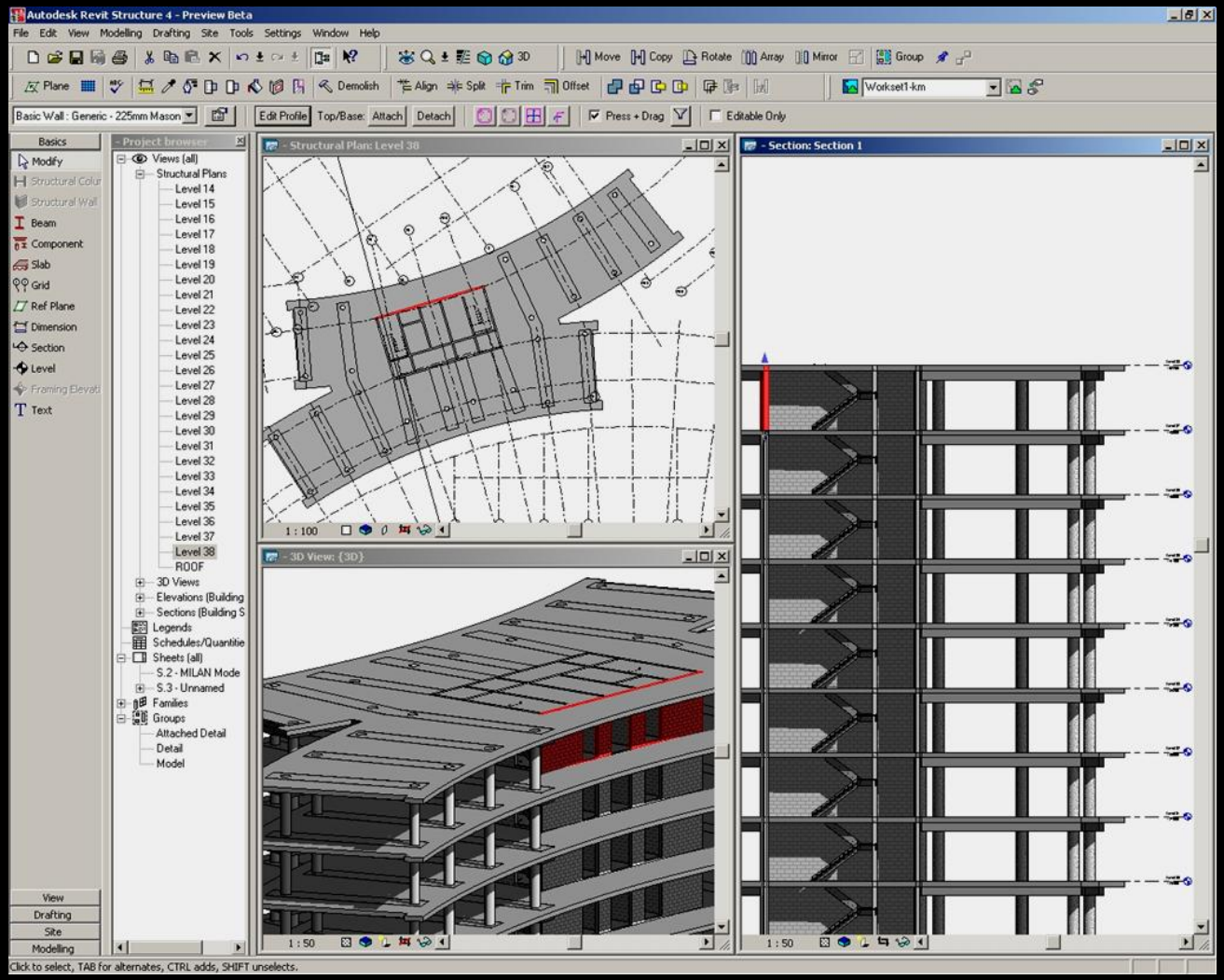
Internal Coordination Benefits



- Change anywhere in a Revit BIM and changes occur everywhere…..

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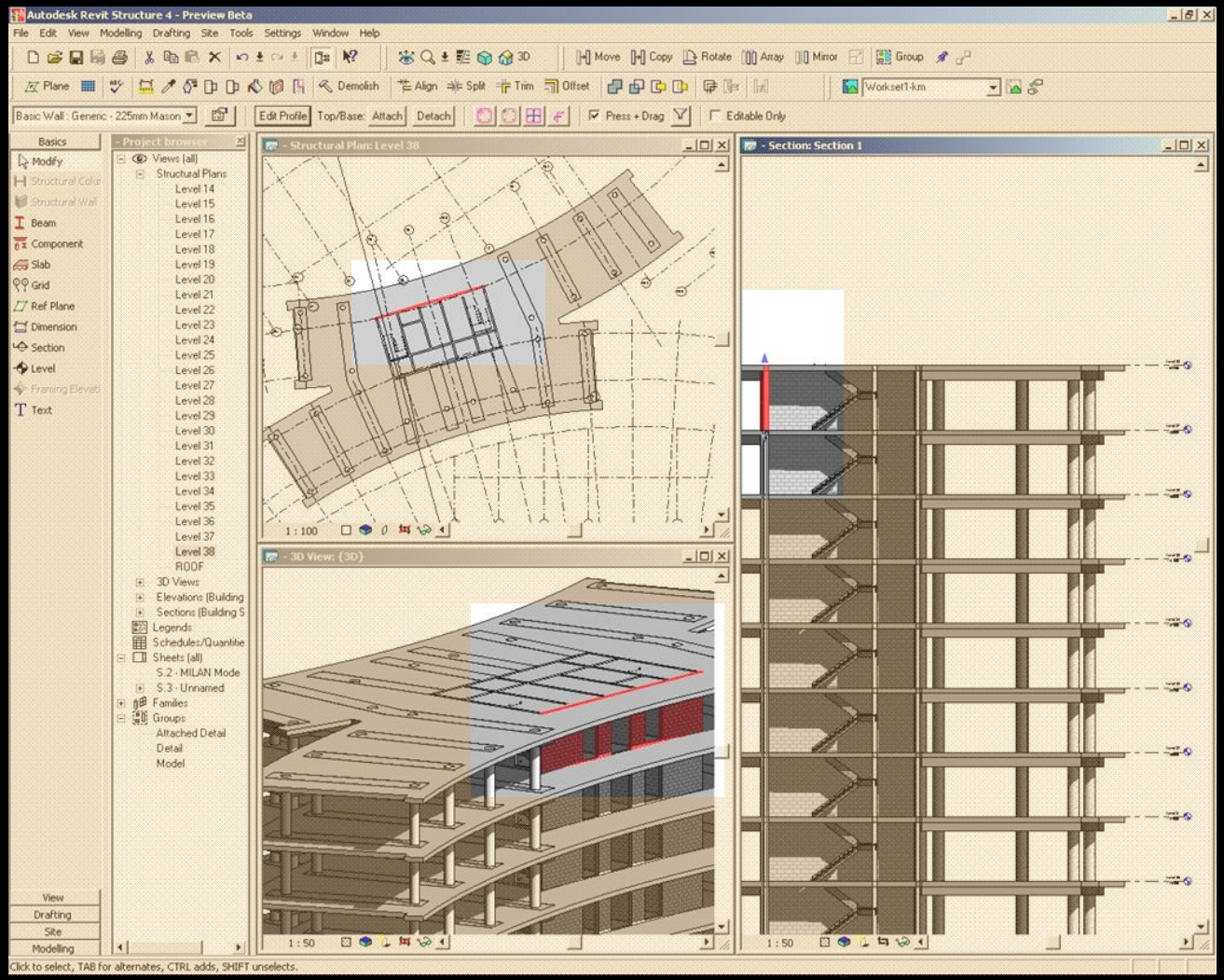
Internal Coordination Benefits



- Change anywhere in a Revit BIM and changes occur everywhere…..

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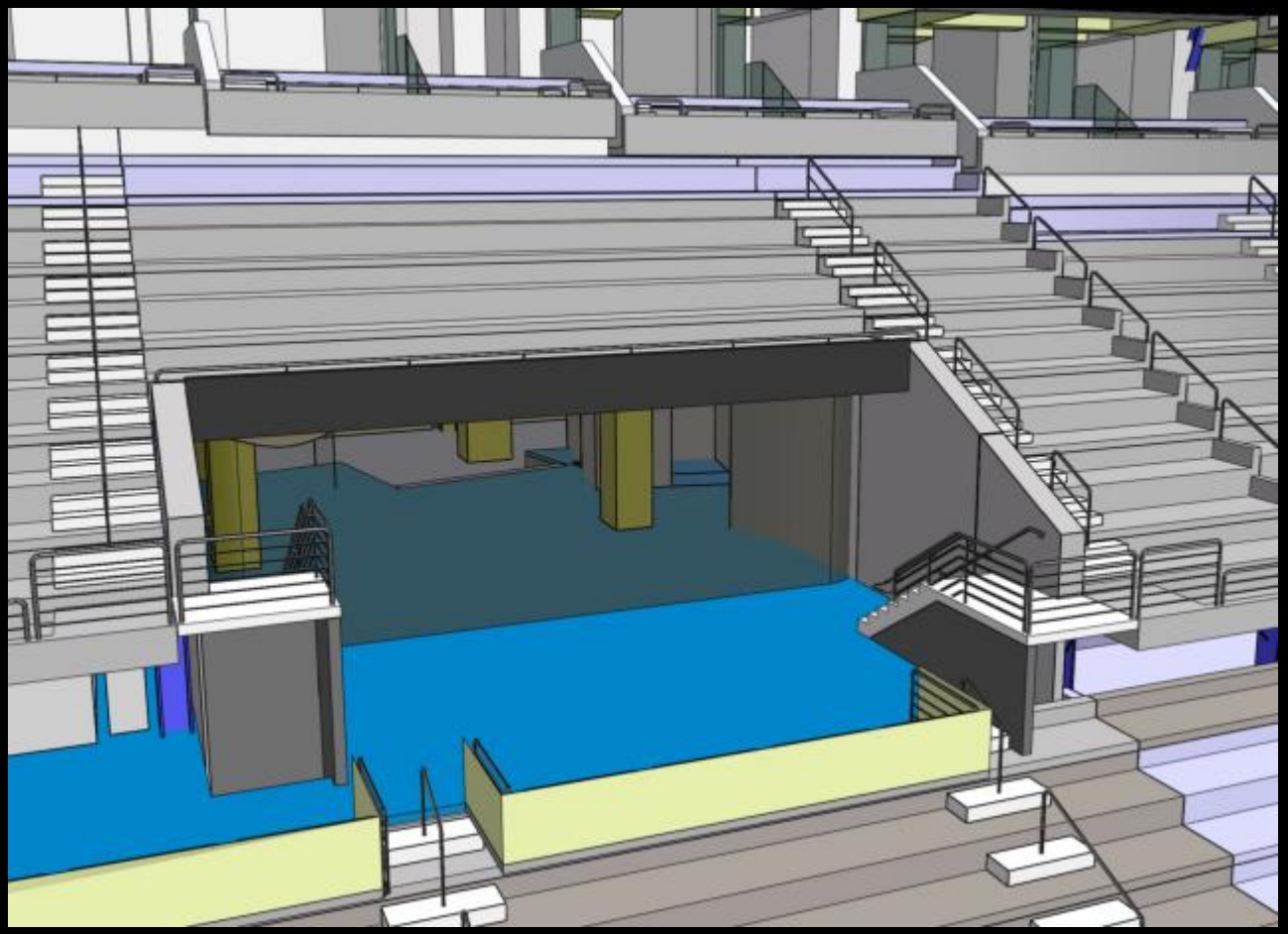
Visualization Benefits



- Quickly create details and render at high detail
- Quickly explore different design options

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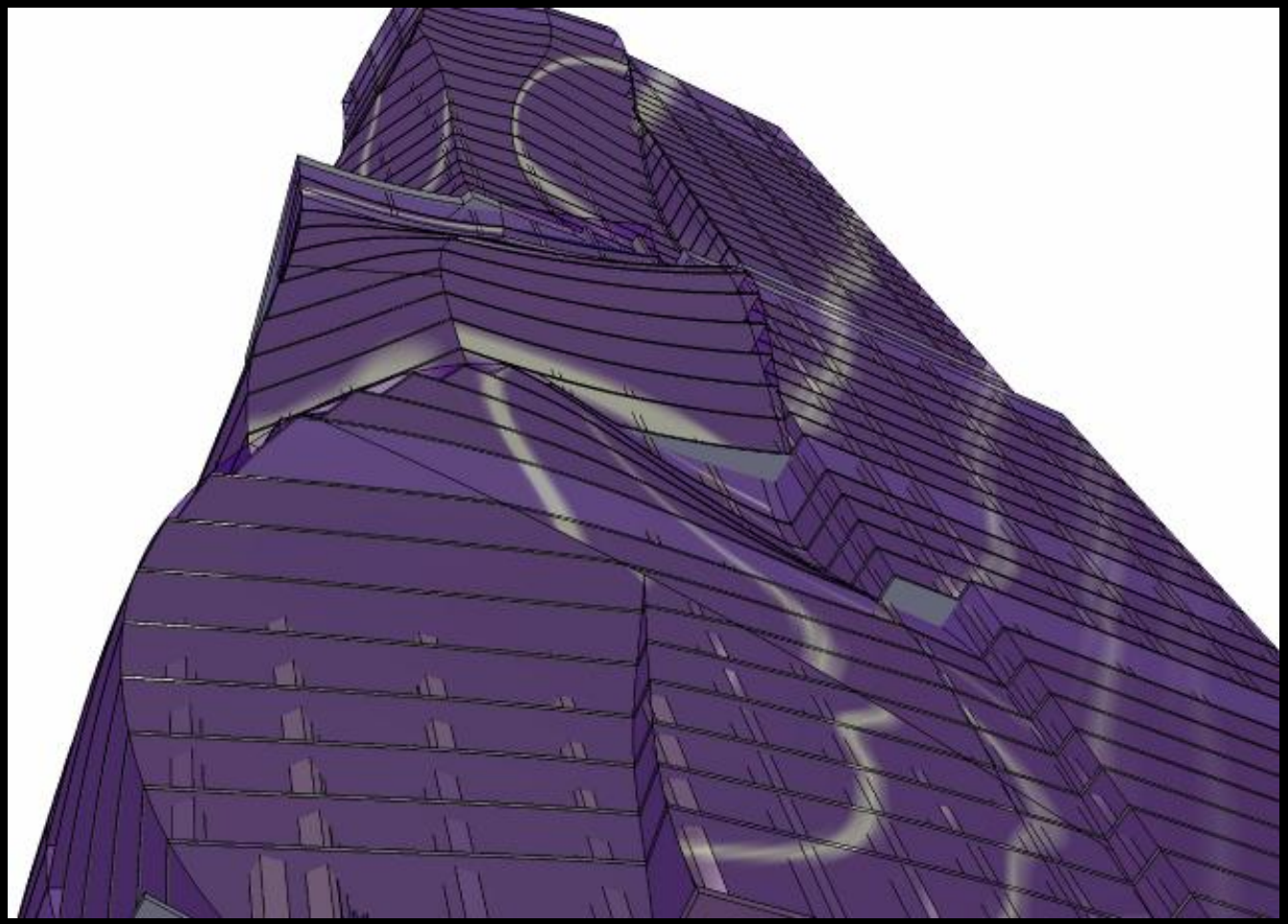
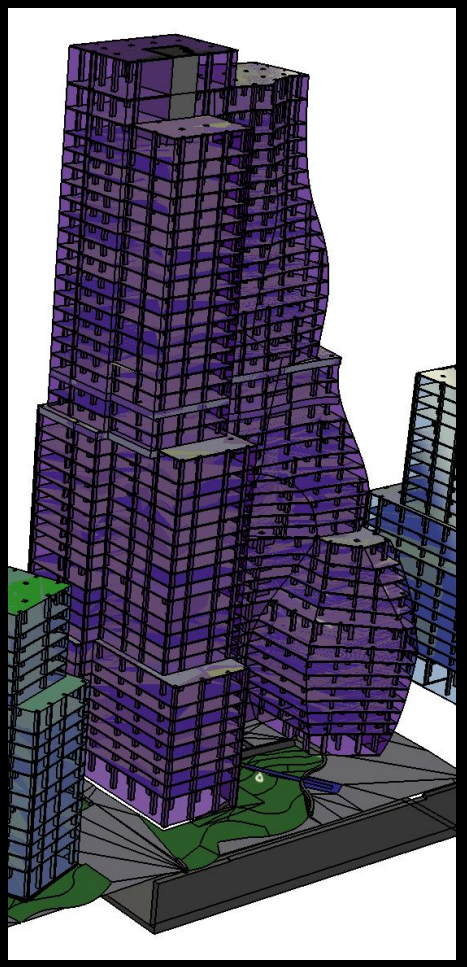
Design Benefits

Easier to create and define complex geometry





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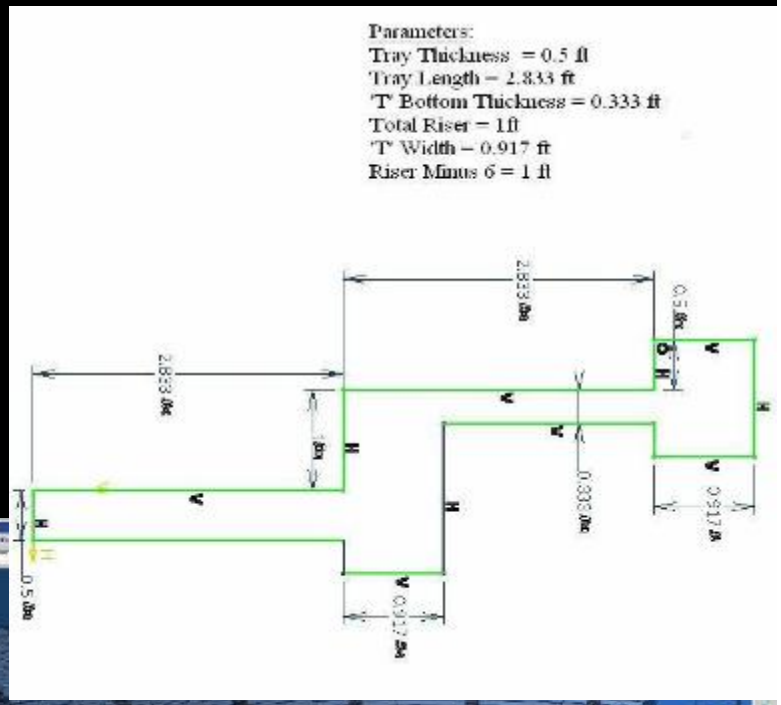
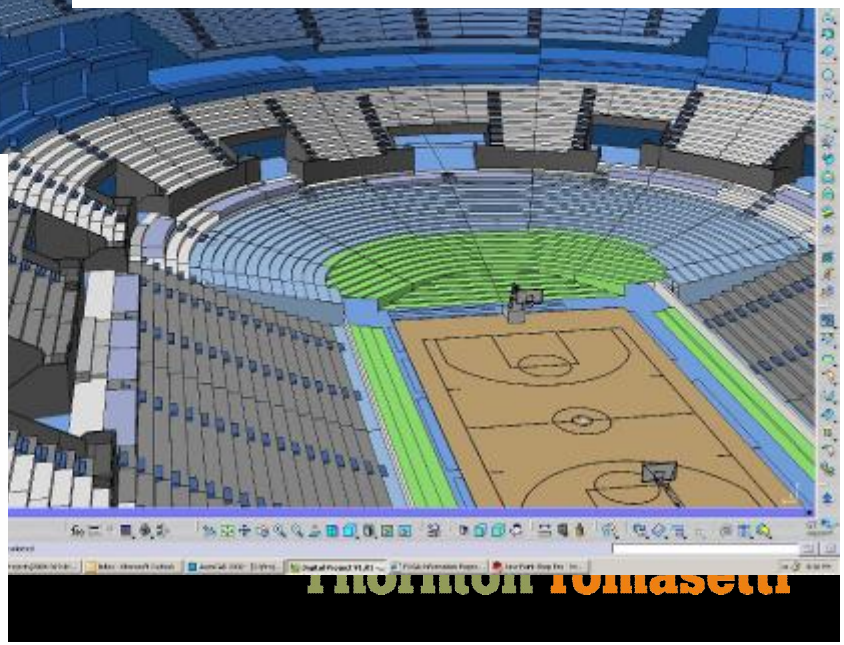
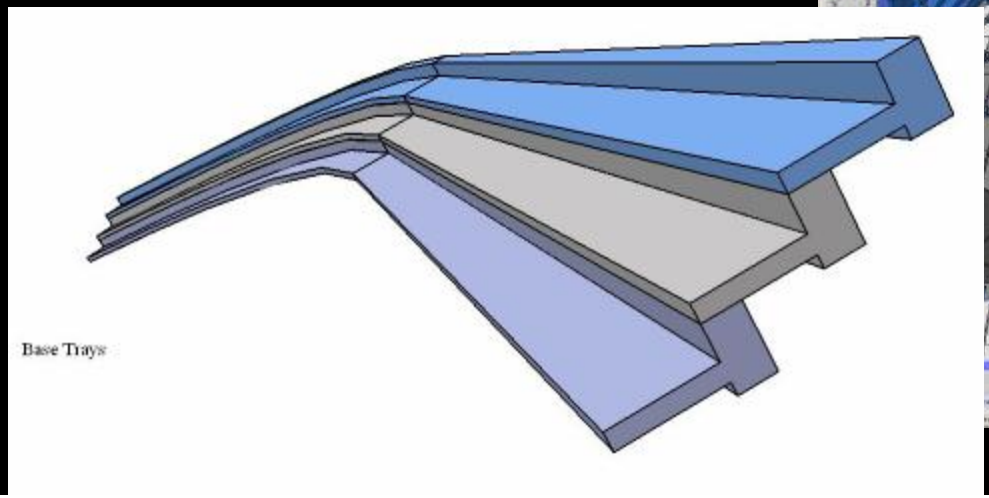
Parametrics

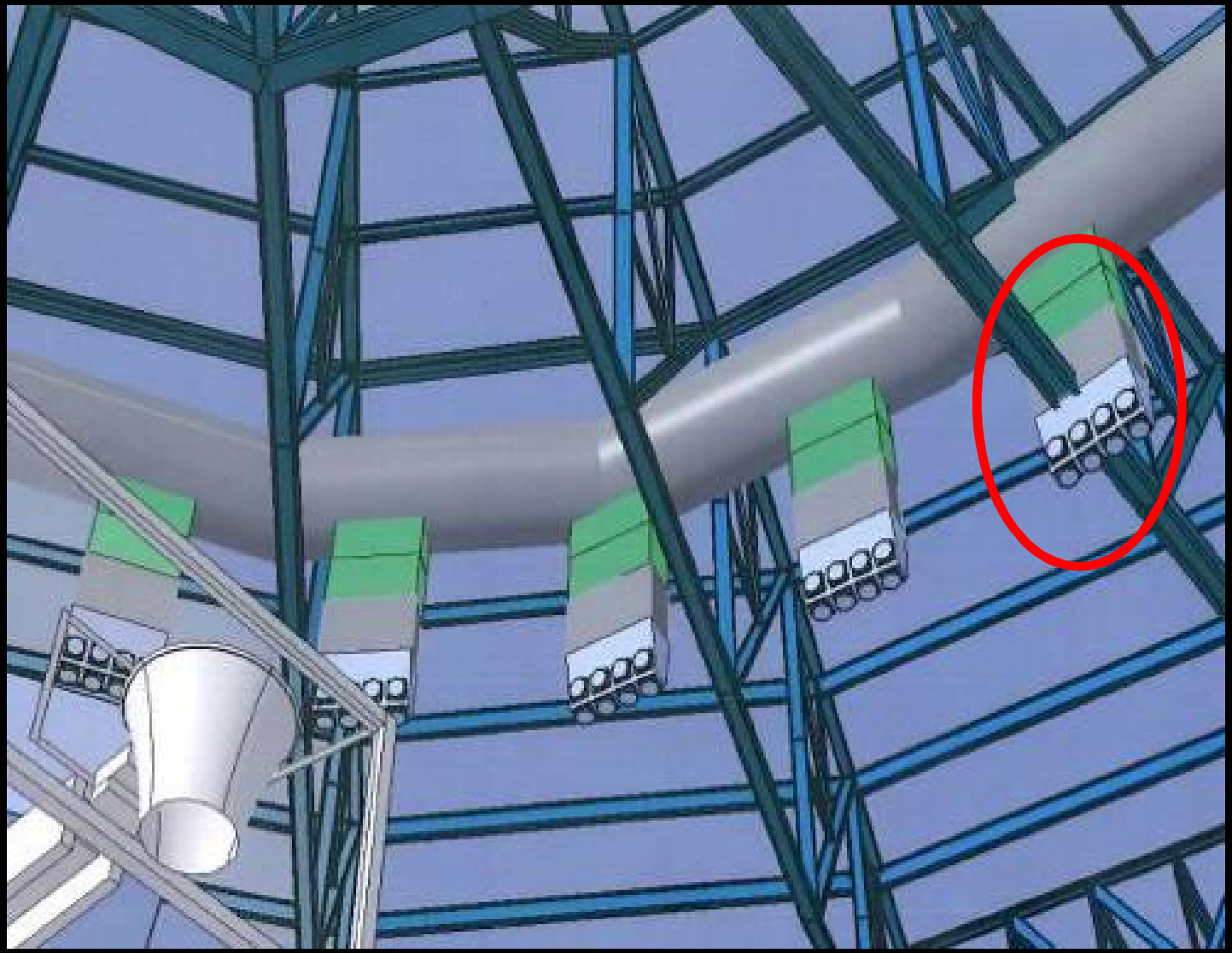
- Reverse of traditional CAD, change the dimension and the object will change
- Powerful feature can change large amounts of data quickly







Coordination and Clash Detection



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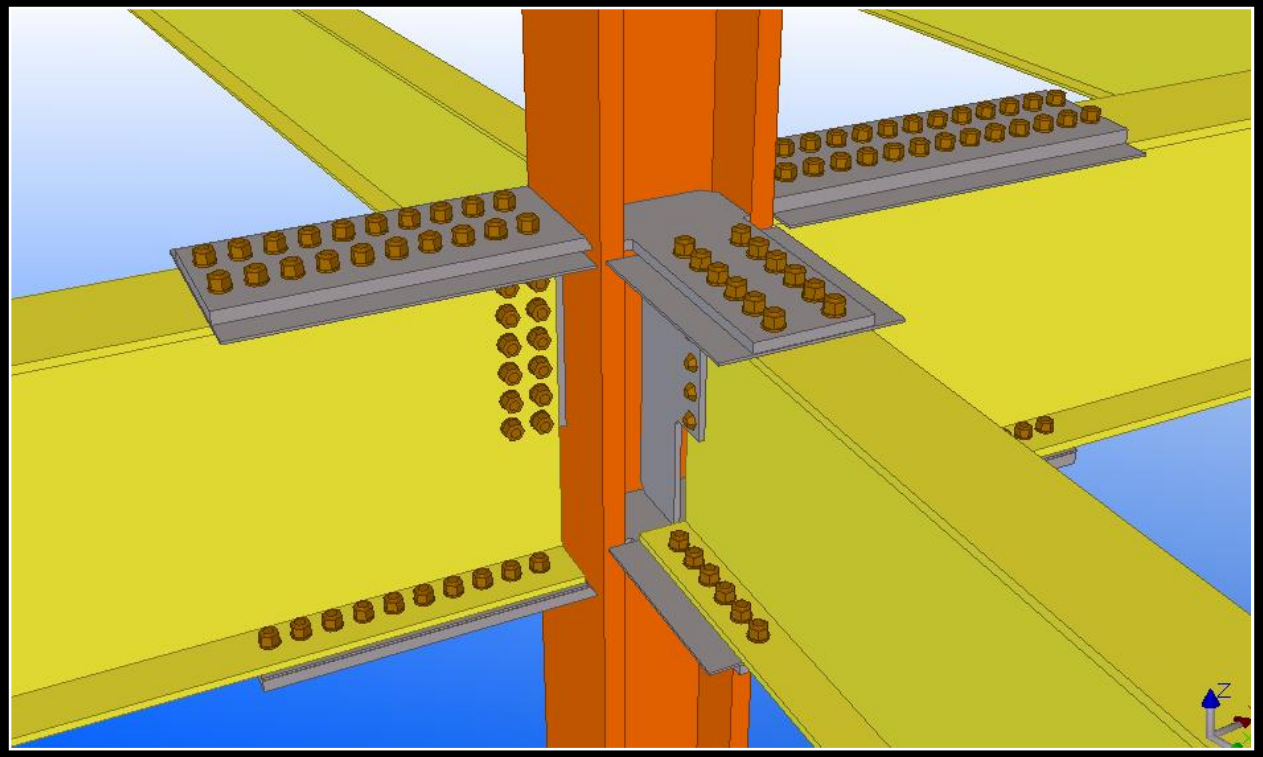
Contractor Deliverable Model

- Identify member properties for mill order
- Design and detail connections
- Create shop drawings



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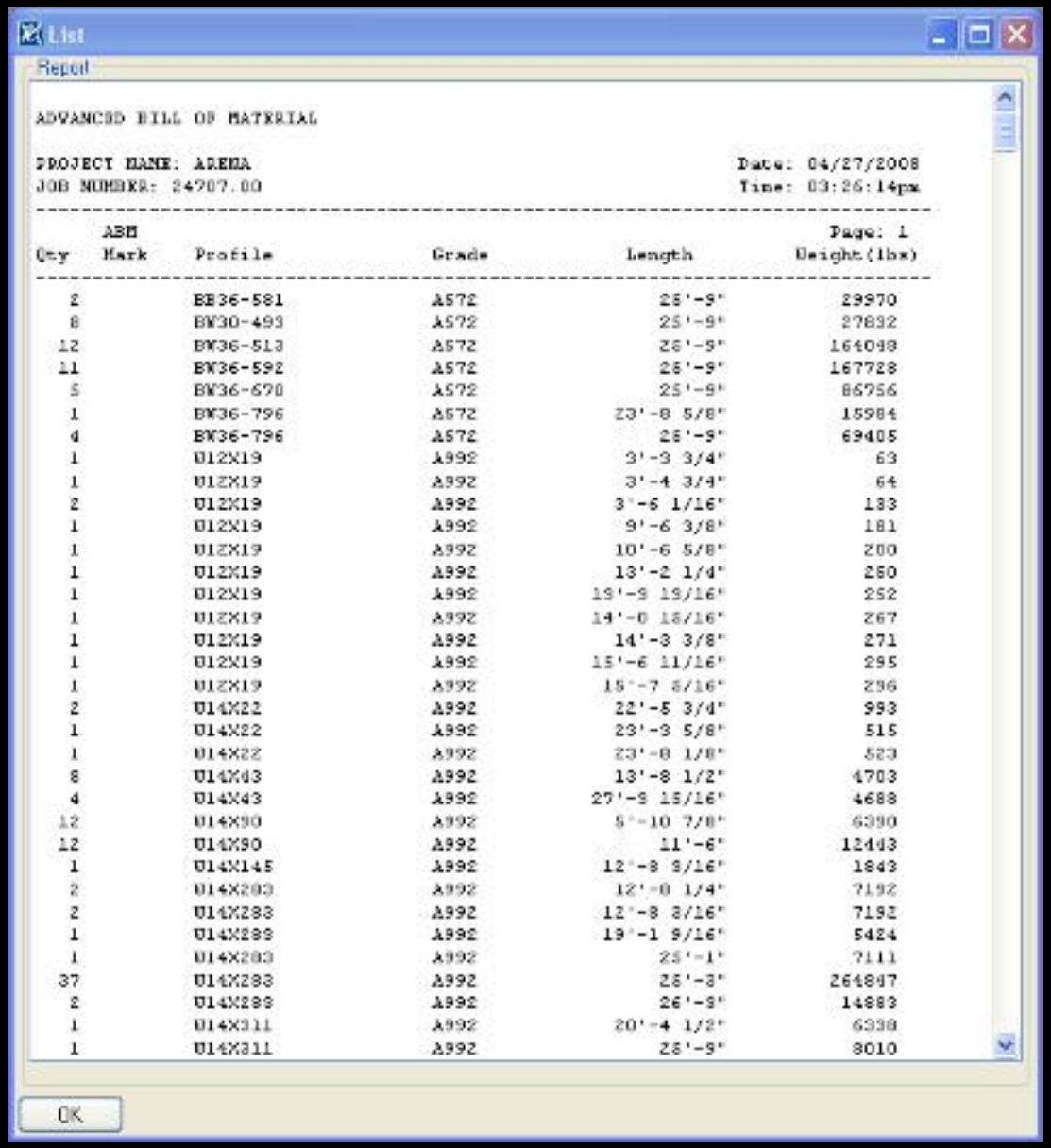
Identify Member Properties for Mill Order



List

Report

ADVANCED BILL OF MATERIAL

PROJECT NAME: ARENA — Date: 04/27/2008
JOB NUMBER: 24707.00 — Time: 03:26:14pm

Page: 1

Qty	ABM Mark	Profile	Grade	Length	Weight(lbs)
2		BB36-581	A572	25'-9"	29970
8		BW30-493	A572	25'-9"	27832
12		BW36-513	A572	28'-9"	164098
11		BW36-592	A572	26'-9"	167728
5		BW36-670	A572	25'-9"	86756
1		BW36-796	A572	23'-8 5/8"	15984
4		BW36-796	A572	26'-9"	69405
1		U12X19	A992	3'-3 3/4"	63
1		U12X19	A992	3'-4 3/4"	64
2		U12X19	A992	3'-6 1/16"	133
1		U12X19	A992	9'-6 3/8"	181
1		U12X19	A992	10'-6 5/8"	200
1		U12X19	A992	13'-2 1/4"	250
1		U12X19	A992	13'-9 15/16"	252
1		U12X19	A992	14'-0 15/16"	267
1		U12X19	A992	14'-3 3/8"	271
1		U12X19	A992	15'-6 11/16"	295
1		U12X19	A992	15'-7 5/16"	296
2		U14X22	A992	22'-5 3/4"	993
1		U14X22	A992	23'-3 5/8"	515
1		U14X22	A992	23'-8 1/8"	523
8		U14X43	A992	13'-8 1/2"	4703
4		U14X43	A992	27'-9 15/16"	4688
12		U14X90	A992	5'-10 7/8"	6390
12		U14X90	A992	11'-6"	12443
1		U14X145	A992	12'-8 9/16"	1843
2		U14X283	A992	12'-0 1/4"	7192
2		U14X283	A992	12'-8 9/16"	7192
1		U14X283	A992	19'-1 9/16"	5424
1		U14X283	A992	25'-1"	7111
37		U14X283	A992	25'-8"	264847
2		U14X283	A992	26'-9"	14883
1		U14X311	A992	20'-4 1/2"	6338
1		U14X311	A992	25'-9"	8010

OK

- Quantity
- Preliminary Mark
- Member Size
- Material Grade
- Special Rqmts
- Material Length
- Material Weight

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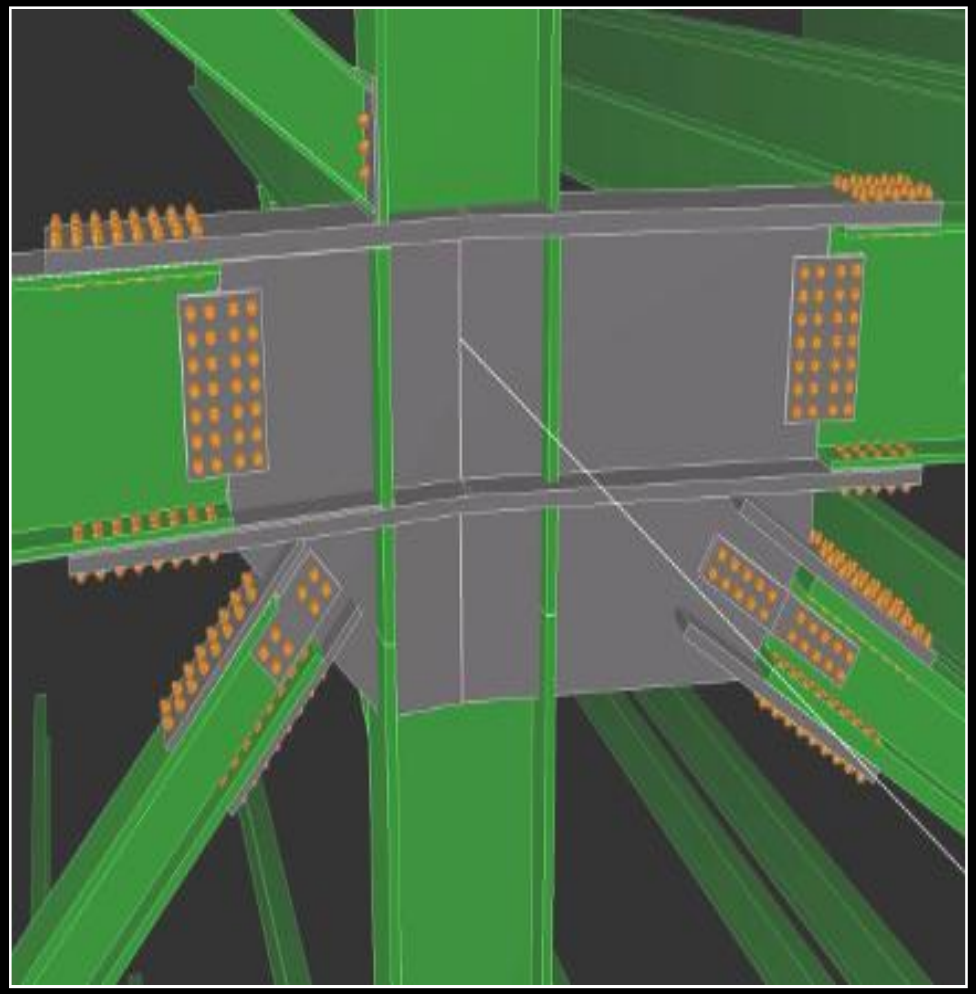
Design and Detail Connections



- True Member Size
- Connection Plates
- Bolts
- Welds
- Special Requirements
- Clearly defines connection scope

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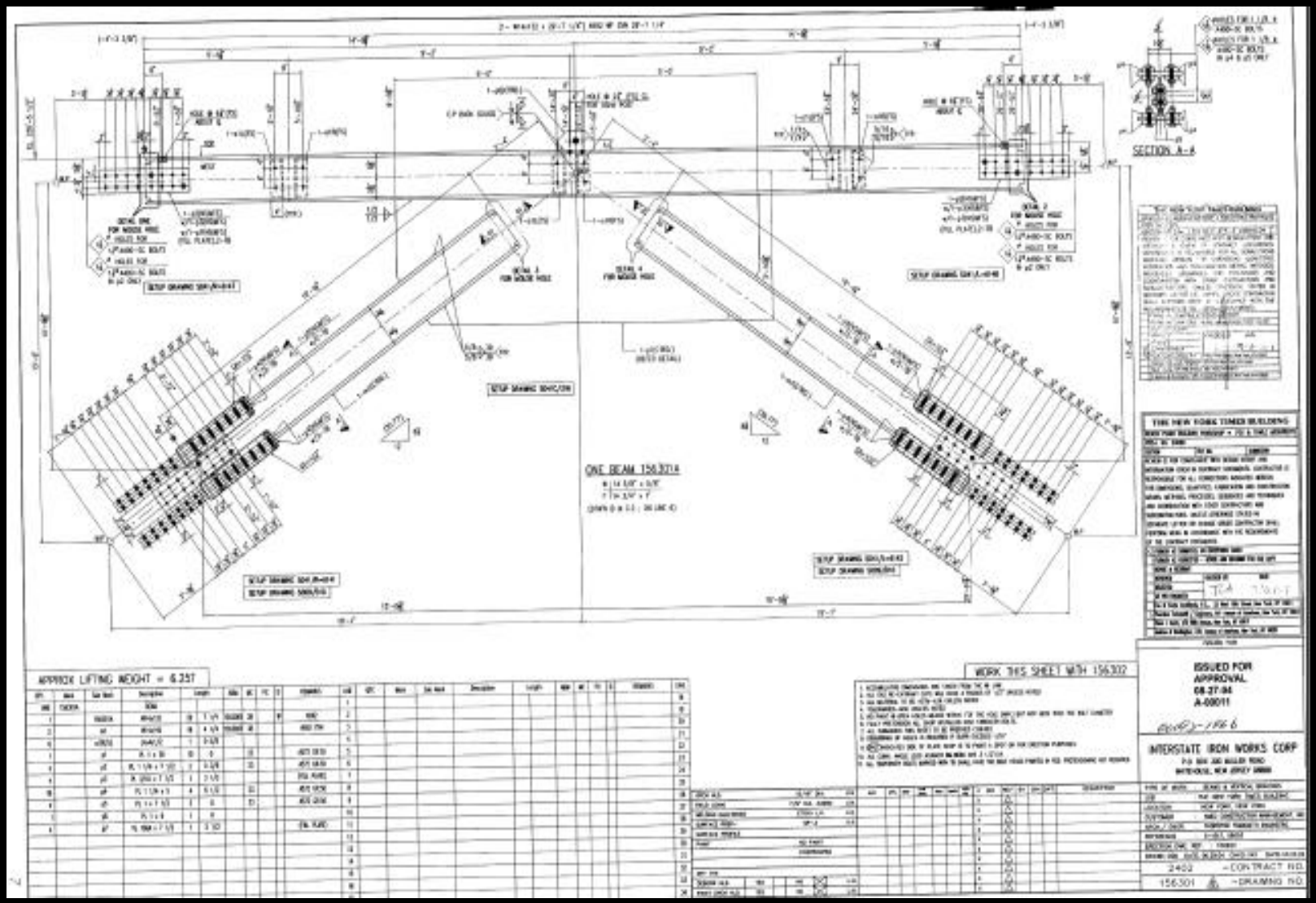
Create Shop Drawings



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CNC Fabrication Equipment

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Project Delivery Benefits

Complexity is better documented

- Reduces contractor's
- claims that complexit
- was not shown on the
- drawings

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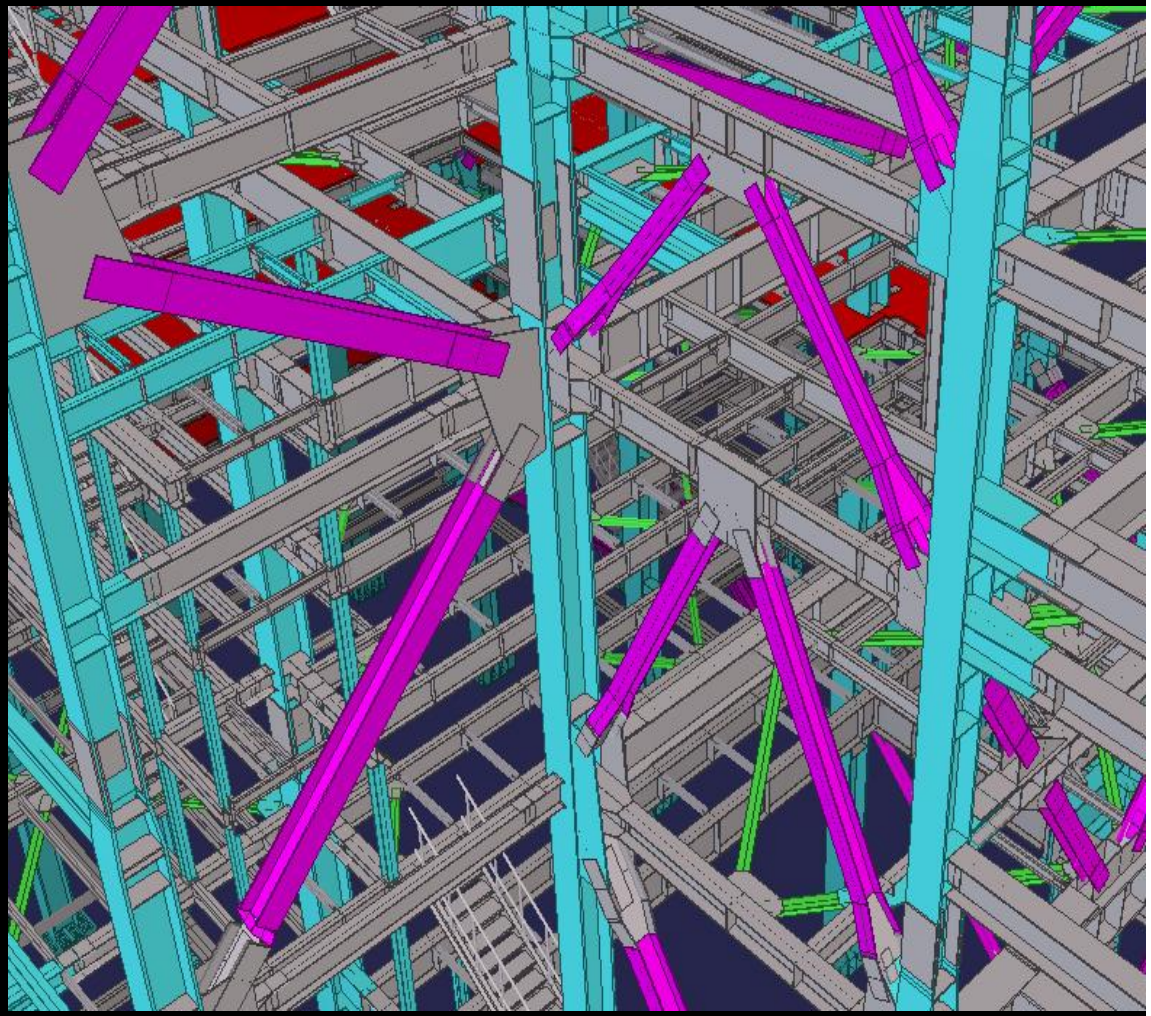
Project Delivery Benefits

Scope is better defined

- **Eliminates estimators extrapolating typical details**



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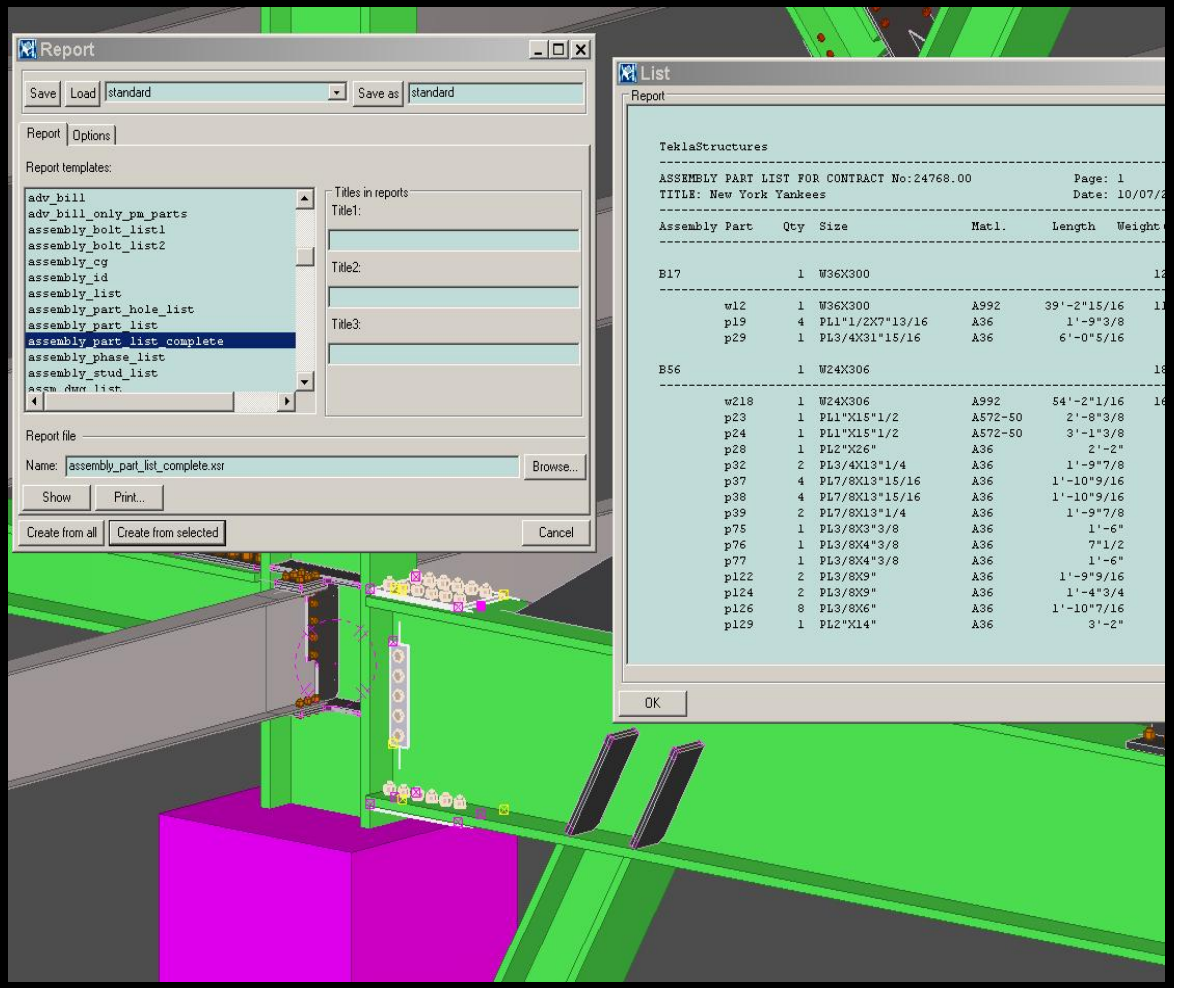
Project Delivery Benefits

Accurate tonnage known at bid time

- **Minimizes claims from incorrect interpretation of traditional documentation**



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Project Schedule Benefits

- Detailing overlaps with design
- Mill order and other estimation information available at bid time
- Compresses overall schedule (detailing work is front-loaded)
- Reduced schedule risk
- More collaborative work process

Green Building Design and LEED

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Environmental Impact of Buildings in the US*

IMPACTS OF U.S. BUILDINGS ON RESOURCES

40% primary energy use*

72% electricity consumption*

39% CO_2 emissions*

13.6% potable water consumption**

Sources:
*Environmental Information Administration (2008). EIA Annual Energy Outlook.
** U.S. Geological Survey (2000). 2000 data.

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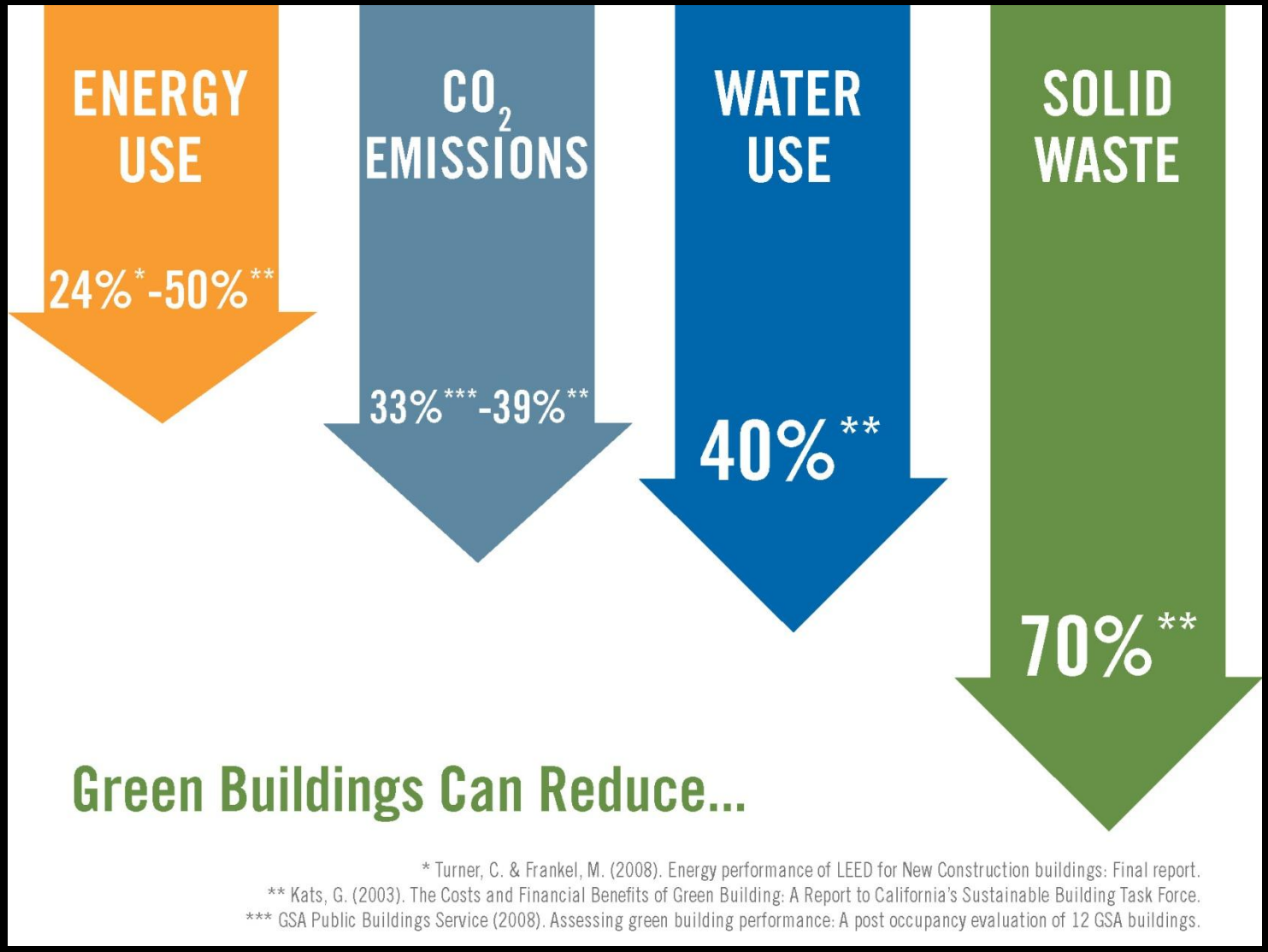
Green Building Benefits



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What is a Green building?

- Green is not a scientific term
- Typical goals of Green Buildings:
  - Minimize impact on environment
  - Minimize energy / water consumption
  - Use of building materials that are not harmful to occupants
  - Use of building materials and methods to minimize Carbon Footprint
- Many technologies and strategies are available to achieve these goals that can be combined in infinite ways
- From low-tech to high-tech, small to large

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The USGBC

United States Green Building Council

- The USGBC is the main “cheerleader” for Green Buildings
- More than 17,000 member organizations
- Website: www.usgbc.org

Mission: Work towards a sustainable Built Environment

LEED Rating Systems

Leadership in Energy and Environmental Design

- USGBC's certification program for designing, constructing and operating high performance Green Buildings
- Certifies existing and new buildings, and neighborhoods, but not individual products or materials
- Uses a point system
- Buildings: LEED certified
- Individuals: LEED accredited (LEED AP)
- Dominant green building certification system in the US
- LEED is used internationally, currently in more than 90 countries

Sustainability at Thornton Tomasetti

- Member of the USGBC since 2004

- Currently 183 LEED APs:
  - Structural Engineers, Architects, MEP

- Involved in more than 70 LEED Projects to date

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LEED Rating Systems Structure

- Six main credit categories (all systems)
  - Sustainable Sites – SS
  - Water Efficiency – WE
  - Energy & Atmosphere – EA
  - Materials & Resources – MR
  - Indoor Environmental Quality – EQ
  - Innovation & Design Process - ID

- Certification levels
  - Platinum
  - Gold
  - Silver
  - Certified

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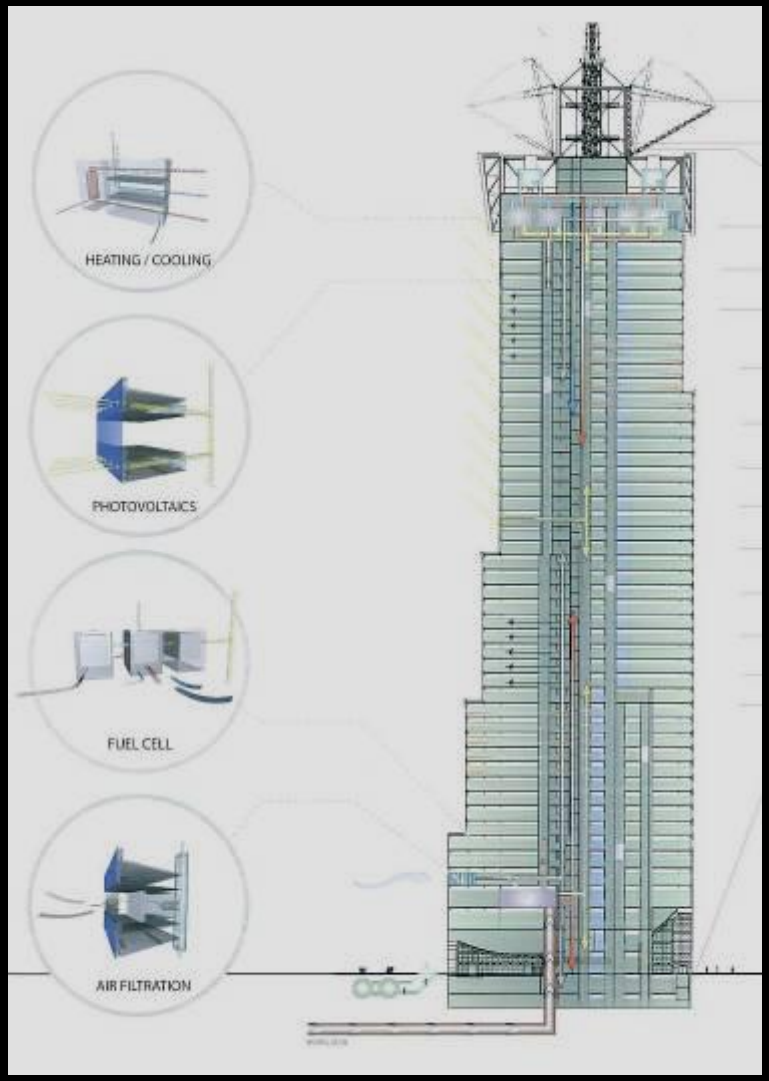
What parts of a building are affected by LEED?

- Potentially all, but varies from building to building
- Most significant contributing components:
  - Energy-consuming systems (HVAC, lighting, hot water, equipment)
  - Water-consuming systems
  - Building Envelope (resistance to heat loss)
- But: All materials can contribute by virtue of being recycled or local



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Green Technologies & Strategies: Site

- Goal: Minimize environmental impact from site selection

- Strategies:
- Limit encroachment on natural areas
- Preference for previously developed areas
- Limit disruption to stormwater flows
- Proximity to basic amenities
- Proximity to public transportation
- Building orientation / massing

- Urban

- Suburban

- Natural

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Green Technologies & Strategies: Materials

- Goal: Minimize environmental impact from material extraction/harvest, manufacture & transport

- Strategies:
- Use of recycled materials
- Use of salvaged, reused, refurbished
- Use of local materials
- Use of certified wood
- Use of rapidly renewable materials

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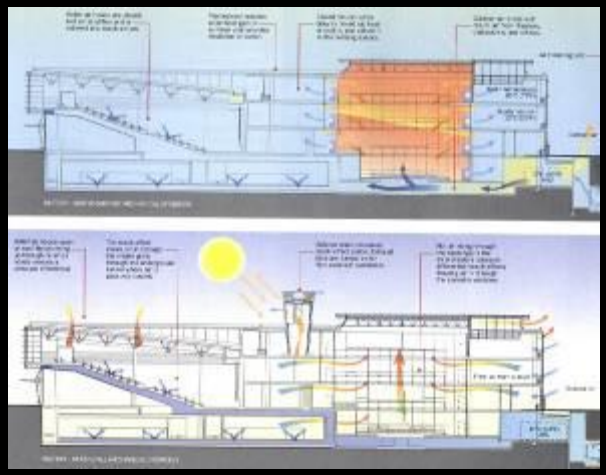
Green Technologies & Strategies: Energy

- Goal: Minimize Energy Use
- HVAC, Refrigeration, Lighting, Domestic hot water, Elevators, Equipment, Machinery

- Strategies:
- High-efficiency MEP equipment
- Smart controls / BMS
- Thermal properties of building envelope
- High-efficiency curtain walls
- Passive solar heat gain
- Natural ventilation
- Renewable energy (on-site or off-site)



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Green Technologies & Strategies: Water

- Goal: Minimize potable water use
- Toilets, Urinals, Faucets, Showers, Laundry, Irrigation, Cleaning, Manufacturing, Industrial processes

- Strategies
- High-efficiency fixtures
- Rainwater capture & reuse
- Waste water treatment
- Non-potable water for flushing toilets, irrigation
- Vegetated roofs
- Natural retention ponds

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Green Technologies & Strategies: Comfort

- Goal: Increase human comfort and well-being

- Areas:
- Thermal comfort
  - Air temperature
  - Radiant temperature
  - Air speed
  - Relative humidity
- Daylighting & Views
- Indoor Air Quality (IAQ)
  - Toxicity of materials
  - VOC emissions
  - Ventilation rate

- Affects well-being, productivity, absenteeism

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Thank you!

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