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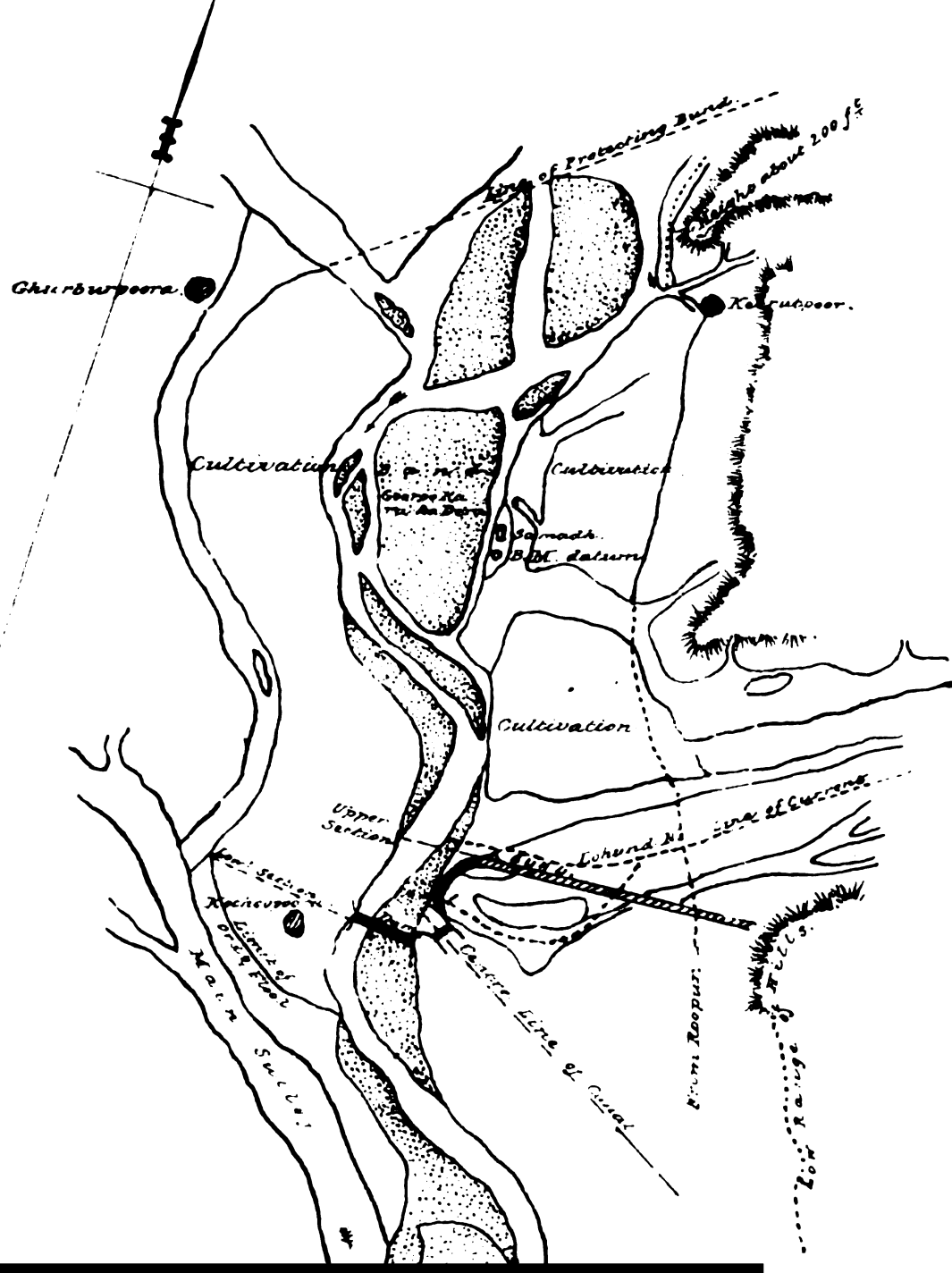


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Thomason Civil Engineering College

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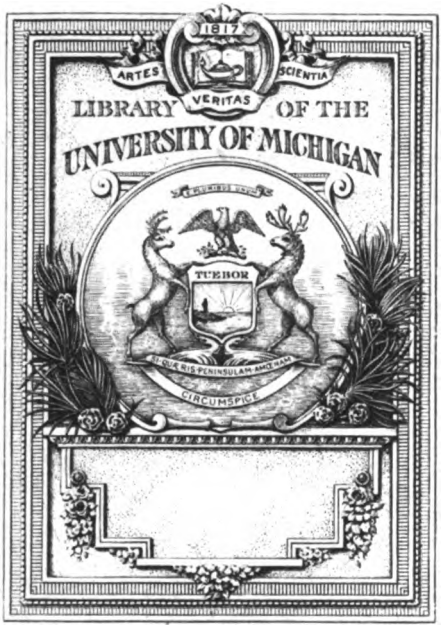


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# PROFESSIONAL PAPERS

ON

# INDIAN ENGINEERING.

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VOL. II.—1865.

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EDITED BY

MAJOR J. G. MEDLEY, R.E., Assoc. Inst. C.E.,

PRINCIPAL, THOMASON C. E. COLLEGE, ROORKEE.

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ROORKEE:

PRINTED AND PUBLISHED AT THE THOMASON COLLEGE PRESS.

CALCUTTA: THACKER, SPINK & Co. BOMBAY: THACKER, VINING & Co.

MADRAS: GANTZ, BROTHERS. LONDON: SMITH, ELDER & Co.

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# PREFACE TO VOL. II.

I HAVE to congratulate the Subscribers to these Papers on the successful completion of the Second Volume, and to thank the Contributors who have so willingly and gratuitously aided me. Without being over sanguine, there is I think a fair promise of the series being creditably carried on, at least for the present. Any suggestions for improvement from Subscribers will be gladly welcomed.

The number of original contributions received has been quite as many as I could reasonably expect. The other Papers have been chiefly abridged or adapted from Government Reports, or from books not generally accessible; and I have been guided by my own judgment of their probable utility and interest to the majority of Subscribers. To the P. W. Secretariats of India, the N. W. Provinces and the Punjab, I am indebted for assistance in this matter. From the Madras, Bombay, and Calcutta offices, I regret to say I have as yet received nothing, though many works of great interest are in active progress under those Governments. It is, however, to individual Officers, Civil and Military, of the P. W. Department, and other members of the Profession, especially the Railway Engineers, that I look for aid; and judging from the past two years, I am sure I shall not look in vain.

Several enquiries having been made for particular Papers, an extra number of copies will in future be printed, so that any Paper can be had separately (price 8 As.), and the more interesting of those already issued will be re-printed. Each Contributor will in future be supplied with six copies of his own paper *gratis*, and can have more if desired.

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No. X. being the first Quarterly Number of Vol. III., will be issued on 1st February next.

The price for Vol. III. for 1866, will be as before, Rs. 14, if paid by 1st January next; *after* that date, Rs. 16, or Rs. 4 for each Quarterly Number.

Orders and Subscriptions received by the Editor at Roorkee; by Messrs. Thacker and Co., Calcutta or Bombay; or Messrs. Gantz, Brothers, Madras.

English Subscribers will receive their copies through Messrs. Smith, Elder & Co., for 32*s.* the Volume, including postage.

J. G. M.

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# INDEX TO VOL. II.


PAGE

Alguada Light-house, The. Built by Lieut.-Col. Alex. Fraser, R.E., ... ... ... ... ... 304

Attock Church, Punjab. By W. B. Harington, Esq., Exec. Engineer, ... ... ... ... ... 278

Barra Bridge, Lahore and Peshawur Road. Built by Lieut.-Col. Taylor, R.E., ... ... ... ... ... 95

Barracks and Jails, Ventilation of. By Major De Budé, R.A., ... 174

Bombay Police Courts, Designs for, By Captain Fuller, R.E., ... 324

Brickmaking in India, ... ... ... ... 137

Brickwork in India. By the Editor, ... ... ... 301

Bridges, Railway Suspension. By Archdeadon Pratt, ... 183

Canal Falls, a Suggestion for. By Lieut.-Col. Fife, R.E., ... 195

Cavour Canal, Memo. on the. By Lieut.-Col. Dyas, R.E., ... 369

Civil Engineering Colleges, of India. By the Editor, ... 1

Clock Tower, Umritsur. Designed and built by J. Gordon, Esq., C.E., ... ... ... ... ... 113

Dharwar Bridges. By J. Hart, Esq., C.E., ... ... 270

Expansion of Masonry by Heat. By A. Hughes, Esq., Assistant Engineer, ... ... ... ... ... 198

Flood discharge of Rivers. By Lieut.-Col. C. H. Dickens, R.A., 133

Ganges Canal Controversy, The. By the Editor, ... ... 203

Ghaut Tracing in North Canara. By a Madras Engineer, ... 315

Indian Barracks. By the Editor, ... ... ... 107


Digitized by Google

PAGE

Indus Silt Experiments. By Colonel Tremenheere, R.E., Chief Engineer in Sind, ... ... ... 18 and 308

Indus Tunnel, The. Projected and partly executed by Lieut.-Col. Alaric Robertson, ... ... ... 34 and 117

Iron Tie-bars for Roofs, ... ... ... ... 365

Jubbulpore Railway Specification. By H. P. Le Mesurier, Esq., Chief Engineer, ... ... ... ... 9

Jumna Floods' Diagram. By George Sibley, Esq., C.E., ... 242

Laying out Curves. By R. McKennie, Esq., Assistant Engineer, Mysore, ... ... ... ... ... 245

Military Bridges. By Lieut.-Col. A. Cowper, R.E., ... 57

Oil Mills for the East Indian Railway, ... ... ... 31

Out-post, Koorum Frontier. By Lieut. J. Browne, R.E., ... 276

Rates of Work in Bengal. By P. H. Trotter, Esq, Dy. Controller, P. W. Accounts, ... ... ... ... 90

Rates of Work in Hyderabad. By Chas. Nuttall, Esq., Dy. Contoller, P. W. Accounts, ... ... ... ... 178

Rates of Work in the N. W. Provinces. By Harry Marten, Esq., Controller, P. W. Accounts, N. W. Provinces, ... ... 281

Rates of Work in the Punjab. By Major McLeod Innes, R.E., V.C., Controller, P. W. Accounts, Punjab, ... ... 393

Railway Institute, Punjab. Designed and built by Edwin Baines, Esq., District Engineer, ... ... ... ... 244

Rawul Pindee and Murree Hill Road. By Major H. Rose, Exec. Engineer, ... ... ... ... ... 128

River Works, Cuttack, ... ... ... ... 352

Road Metalling, Notes on. By Lieut.-Col. Cowper, R.E., ... 382

Roads and Railways in India. By Colonel Sir William Denison, K.C.B., R.E., ... ... ... ... 250

Sealdah Railway Station. Designed and built by Walter Granville, Esq., C.E., ... ... ... ... ... 212

Digitized by Google

PAGE

Sind Railway, The. By J. Brunton, Esq., C.E., ... ... 327

St. Mary Magdalene's Church, Meean Meer, Punjab. Designed and built by the late Captain J. N. Sharp, Bengal Engineers, ... 7

Stone Quarries. By T. E. Owen, Esq., Assist. Engineer, ... 81

Survey of India, The Great Trigonometrical, ... 285 and 398

Sutlej Canal, Project for the. By Captain J. Crofton, R.E., 145 and 214

## LIST OF PLATES.

### Photographs.

Sealdah Railway Station, ... ... ... ... 212

Thomason Civil Engineering College—Roorkee (Frontispiece). 1

### Engravings.

Alguada Light-house, ... ... ... ... 304

Umritsur Clock Tower, ... ... ... ... 113

### Lithographs.

Civil Engineering Colleges—Roorkee (2)—Madras, ... ... 4

Meean Meer Church—Plan, Side and End Elevations, ... 8

Indus Silt Experiments—Instruments used in (18), Plan and Sections of river (24), Bottle for taking Water, ... ... 308

Oil Mills, Plan and Elevation of, and Shed for, ... ... 32

Indus Tunnel, Plan of River (34)—Section of River, showing proposed Tunnel (44)—Section of Tunnel showing Lifts and Roadway (118)—Lift Machinery, ... ... ... 120

Military Bridges—Austrian Pontoons (60)—Proposed Pontoons, 72

Barra Bridge—Half Section and Elevation (96)—Plan, ... 100

Design for a Barrack in Upper India, ... ... ... 108

Umritsur Clock Tower—Plan and Section of Foundations, ... 114

Digitized by Google

PAGE

Rawul Pindee and Murree Road, Plan and Section of (128)—Plans and Elevations of Barrakow, Phoolgram, and Salgram Bridges,... 130

Brick-making in India—Mould and Pug Mill (138)—Shed and Kiln, ... ... ... ... ... 140

Sutlej Canal—Map of Country (146)—Longitudinal Sections (152) Site of Head Works (154)—Head Works (156)—Sursa and Kalee Koondwalee Nuddees (160)—Roopur Aqueduct (168)—Seesooan Superpassage (170)—Cross Sections (172)—Kotlah Branch Head (220)—Overfalls at Barah (222)—Inlet and Outlet for Sursootee, ... ... ... ... 230

Apparatus for Measuring the Expansion of Masonry by Heat, ... 198

Plan of Ganges Canal, ... ... ... ... 210

Diagram of Jumna Floods—Allahabad, ... ... ... 243

Punjab Railway Institute, ... ... ... ... 244

Railway Curves, ... ... ... 246 and 248

Dharwar Bridges—Yangul Bridge (270)—Pile Engine, ... 272

Koorum Frontier Outpost, ... ... ... ... 276

Attock Church, Punjab. Plan and North Elevation (278)—East and West Elevation, ... ... ... ... 280

Trigonometrical Survey—Map of India (286)—Measurement of Barrackpore Base (294), The Great Three-feet Theodolite, ... 401

Brickwork Designs, ... ... ... ... 302

Alguada Light-house, ... ... ... ... 306

Ghaut Tracing in North Canara—Map of District, ... ... 316

Bombay Police Courts—Front Elevation and Plan (324)—End Elevation and Plan of Second Floor, ... ... ... 326

Sind Railway—General Plan of the Line, ... ... 328

Cuttack River Works—Plan and Sections of River, 353, 362 and 364

Cavour Canal—Bird's Eye View of Head Works and Map, 369 and 370

Rollers for Road Metalling, ... ... ... ... 390

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THOMASON CIVIL ENGINEERING COLLEGE—ROORKEE.

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# THE CIVIL ENGINEERING COLLEGES OF INDIA.

THAT several of the earliest and most distinguished Civil Engineers in England were men of little or no education, was for a long time alleged as a proof of the inutility of a scholastic training for the young Civil Engineer. It can scarcely, however, be necessary to refute such an argument now-a-days, nor would it ever have been put forth if the distinction between the theory and practice of any profession had been attended to. A theoretical Engineer is neither more nor less valuable than a theoretical Doctor or Lawyer, and in all three cases the value of a scientific training in the principles of each profession is justly regarded as an indispensable preliminary to the actual practice of it. It is often, however, alleged with a greater show of truth that this preliminary education can be acquired better in Workshops than in a College. Each doubtless has its advantages; the information acquired in the former is more practical, but is necessarily more special; in the latter it covers more ground and is likely to be more generally useful. In England, where the sub-division of labor has been carried to an almost indefinite extent, a man rarely attains eminence in any calling who does not confine himself to some special branch of it, and for the generality of men, even the early training must be special if only from economical considerations. But in a country like India, where the Engineer may have to do the work of half a dozen different men at once, or may constantly have to exchange one kind of work for another, the education required is altogether different, and it may safely be said that, at any rate for the wants of Government, it will best be supplied by a Civil Engineering College.



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It is thought, therefore, that some account of those now existing in India will be generally interesting, especially as they are, I believe, the only ones at work in any part of the British Empire.

*The Thomason Civil Engineering College, Roorkee,* is the oldest in point of date, having been founded in 1847, under the auspices of the Honorable James Thomason, Lieut.-Governor N. W. Provinces. Designed at first chiefly to supply the want of European Overseers and Native Subordinates on the Ganges Canal Works, it was established at Roorkee, in the vicinity of which the most important of those works were then in active progress. Its operations were subsequently much extended and the Course of Study from time to time carefully revised as experience showed what changes were necessary. The general scheme, however, has been little altered from that originally drawn out by Lieut. (now Lieut.-Col. Maclagan) the first Principal, who filled that Office for more than ten years, and to whom the College is mainly indebted for the success it has attained.

The College is divided into the Senior, First, Second, and Third Departments. The Senior consists of Officers of the Army, the First of young Civilians; both of these Departments pursuing the same Course of Study to qualify them for the Public Works or Survey Departments. The Students remain two years, and on the successful completion of their studies receive Certificates and appointments as Assistant Engineers, or Surveyors in the Government service.

The Second Department chiefly consists of English Soldiers, (though there is also a Civilian and Native Class attached,) who remain for one year, and on passing out are appointed Assistant Overseers in the Public Works Department.

The Third Department is entirely for Natives, (the instruction being in the Vernacular,) who remain two years, and are passed out as Sub-Overseers or Sub-Surveyors of the First or Second Class.

All Students have to pass an Entrance Examination: the instruction is gratuitous, and there are certain Scholarships attached to

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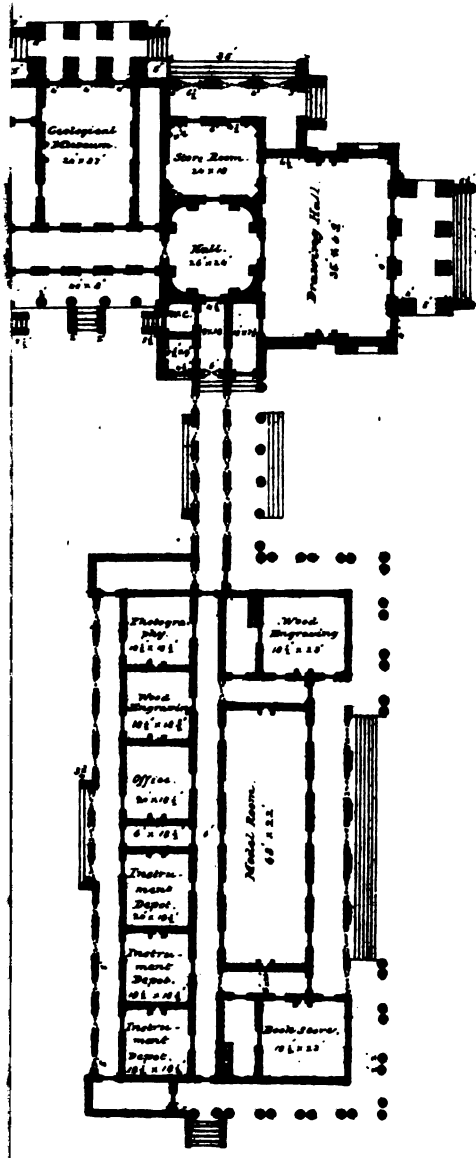


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all three Departments, as well as several handsome prizes—such as The Council's Prize of 1,000 Rs.—The Thomason and Cautley Gold Medals, &c.

The Course of Study varies of course in the different Departments, but includes Mathematics, Civil Engineering, Surveying, and Drawing for all—besides instruction for the higher Departments in Chemistry, Mineralogy, and Photography.

The following is the detail of the four principal subjects for the two higher Departments.

*Mathematics.*—Arithmetic, Algebra, Geometry, Trigonometry, Statics, Dynamics, Hydro-statics and Hydro-dynamics, Conic Sections, Differential and Integral Calculus, Spherical Trigonometry.

*Civil Engineering.*—Building Materials, their nature, uses and strength—Principles of General Construction, including Earthwork, Masonry and Carpentry—Special Constructions, such as Roads, Bridges, Buildings, Irrigation Works and Railways—Applied Mechanics—Machinery—Designing—Estimating—Laying out Work.

*Surveying.*—Use and Adjustment of Instruments, viz.:—Chain, Compass, Sextant, Level and Theodolite, taught practically in the Field—Execution of Surveys with the Chain and Compass, Theodolite and Plane Table—Trigonometrical Surveying—Levelling—Contouring—Practical Astronomy.

*Drawing.*—Construction of Scales—Making Plans and Sections from actual measurements—Mapping—and a regular course of Engineering, Architectural, Mechanical and Perspective Drawing.

The subjects taught to the two Lower Departments are of course both fewer and are more restricted.

The number of Students now in the College is 114, viz.:—6 Officers, 10 Civilians, 36 Soldiers, and 62 Natives. Since the commencement more than 700 have been qualified for the Public Service in the various Departments, and it may be confidently asserted that they have generally given satisfaction. Indeed, Students bearing the College Certificate are sought after by the Railway Companies and others, having no connexion with the Public Works or Survey Departments, and this extraneous demand

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is now so large that Government is obliged to protect its own interests by a guarantee binding the Student not to quit its service within a certain time.

The Staff of the College consists of a Principal and two Assistants (all Engineer Officers), Professors of Experimental Science and of Drawing, Head and Second Masters for the Soldiers, and six Native Masters for the Third Department, besides the Office and Press Establishments, &c.

A view of the College is given in the Frontispiece. The Architect was Capt. Price, now Chief Engineer at Hyderabad. Besides the various Class and Lecture Rooms, the building contains a Library of some 7000 volumes on subjects of general as well as scientific and professional interest, a Drawing Hall, Museums of Geology and of Natural Produce, and a Model Room. To the College are also attached a Press, where Printing, Binding, and Lithography are executed—a Wood Engraving Department—a Depôt for Surveying and Mathematical Instruments—and a Meteorological Observatory.

*The Calcutta Civil Engineering College* was founded in 1856. Officers and Soldiers do not study here, and there is no Vernacular Department, the majority of the Students being Bengalees, whose instruction is conducted in English. The Course of Study is much the same as that of the First Department of the Thomason College. The general results, however, have not been so good, certainly not from any fault of the instructors, but because the material is inferior, the Bengalee being more fitted for sedentary pursuits than for the active out-door life of a practical Engineer.

*The Madras Civil Engineering College** was formed in 1859, under Captain Winscom, R.E., as Principal, with twenty Military and twenty-six Civil Students.

The nucleus for its formation was the Government Survey School, which was established in 1834, for the purpose of training men as Surveyors under the Revenue Department.

In order to supply the wants of the Department Public Works,

* Communicated by Capt. Edgcome, R.E.

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# MADRAS CIVIL ENGINEERING COLLEGE.

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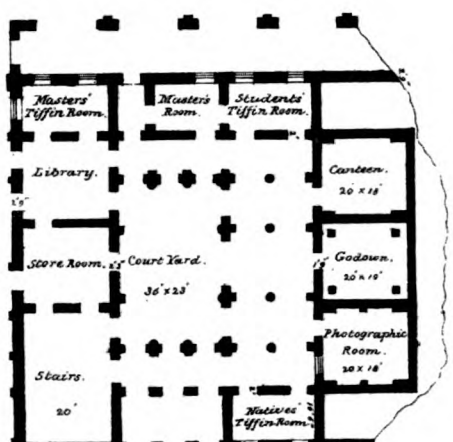
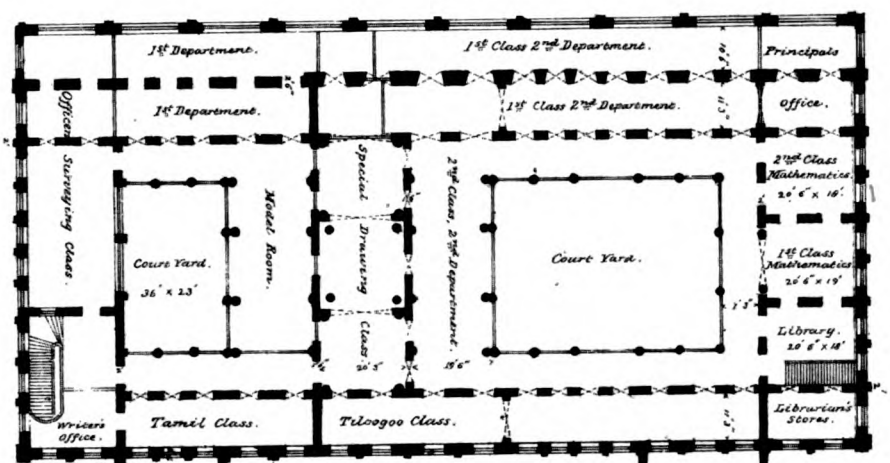



## UPPER PLAN

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the curriculum of instruction was extended, and the Survey School gradually merged into the Civil Engineering College.

As at first established, the College had for its object the training of men as Subordinates only, *i. e.*, Overseers and Sub-Overseers in the Department of Public Works. But in 1861, a special Class for Drawing and Estimating was formed; and in March 1862, a *First Department* was established, for the purpose of training Military Officers and Matriculated Students of the University of Madras for the position of Assistant Engineers. In December 1862, an *Officers' Surveying Class* was attached to the College. So that the Civil Engineering College now consists of a First Department—Officers' Surveying Class—Second Department—Special Survey and Drawing Class.

With an educational Staff of—Principal—Two Assistant Masters for Mathematics—Three Assistant Masters for Surveying, Drawing, and Estimating—Two Assistant Masters for Vernacular Language.

The number of Students has risen from 46 to 103 at close of past Session.

The Course of Instruction, which is similar to that of the Thomason College, extends to about two years, and the average annual out-turn is—Five in First Department—Twenty in Second Department—Fifteen in Draughtsmen, Surveyors, and Estimators.

The building was formerly the Palace of the Nawab of the Carnatic, and though rather an imposing edifice, is not well adapted for a College, as so much space is taken up by the large open courts in the centre of the building.

Captain Winscom, R.E., who was Superintendent of the Government Survey School, was the First Principal of the College.

He was succeeded by Capt. (now Lieut.-Col.) Carpendale, R.E., in 1860, and in November 1863, Capt. Edgcome, R.E., was appointed Principal, and now retains the appointment.

There is also a *Civil Engineering School at Poona*, in the Bombay Presidency, which hitherto has been employed in training Native and European Subordinates only, but is now to be expanded

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into a College, towards which a lakh of Rupees has been contributed by Sir Jamsetjee Jeejeebhoy, and for which a very handsome building has been designed, and is now being erected by Capt. H. St. Clair Wilkins, R.E., who is to be the first Principal.

J. G. M.

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## No. LI.

## ST. MARY MAGDALENE'S CHURCH, MEEAN MEER—PUNJAB.

*Designed and Built by the late* CAPTAIN J. N. SHARP, *Bengal Engineers.*

THIS handsome Church, designed in the early English style, was built in 1854-56. It is entirely of brick, and the workmanship throughout is of first-rate excellence, and beautifully finished.

The *Outside* is finely plastered with mortar, containing a small admixture of soorkhee, so as to be of a faint reddish tinge, which, with a slate roof, gives a very clean finished look to the exterior. The work is lined in imitation of stone joints. The verandah floors are laid with square blocks of reddish stone, placed diagonally, alternate light and dark stones being used. Stone benches are also provided on the inner side.

*Inside*, the walls are plastered with mortar made from marble out of the city, from old buildings. This is polished exceedingly smooth and is of a pure white. It is also jointed in imitation of stone. The band running round the chancel and side aisles, shown in the drawings, is made of the same, beautifully finished. The roof trusses are 42 feet span, and are of stained deodar with wrought iron ties; the purlins being covered with boarding of the same wood, on which the slates are laid. The floor is of the same description as the verandahs as a grounding, but the whole of the chancel, and a path 7 feet wide down the centre of the main and side aisles, is of alternate blocks of white marble and a dark agate-like looking stone, which, as well as the marble, is highly polished. These paths are finished off with a neat border inlaid of the same stones. The stones

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inside the altar rails have each a *fleur de lis* of the opposite color let into their centre. The steps to the chancel and to the altar are of white marble.

*Windows.*—The whole of these are filled with stained glass. The ends of the chancel and centre and side aisles have figures in medallion, set in a very rich colored ground, and the side windows are of a black and white diamond and *fleur de lis* pattern, with a colored border, and centres to arched heads.

*Font, Altar, &c.*—The font is of white marble. The Ten Commandments and Lord's Prayer are cut in old English letters, on marble slabs, behind the Communion Table, and colored black and red. The cloth for the table and cushions, &c., is dark green, the former being covered with gilt *fleur de lis.*

*Furniture.*—Is of stained wood, of a handsome and substantial pattern. The pulpit and reading desk are low, and rather plain.

*Gallery.*—There is a wooden gallery supported on wooden pillars at the west end.

*Lighting.*—Consists of bronze brackets with shades for candles, and a bright brass corona over the font.

*Punkahs.*—Are of green painted sheet iron framed with dark wood, suspended by iron rods from horizontal ones built into the walls. The arrangement is as neat and as little offensive as possible.

*Number of Sittings.*—There are 32 benches down each side of the centre aisles, with 9 sittings in each; total, 576. The side aisles have 115 each, and the gallery 100, making a total of 906 sittings, but they are too small, and the Church cannot be said to have room for more than 800, or comfortable room for 700 persons.

*Cost.*—The precise cost is not known, but it is believed to have been about Rs. 90,000, of which Government paid Rs. 43,000, the rest being raised by private subscription.

A. M. B.

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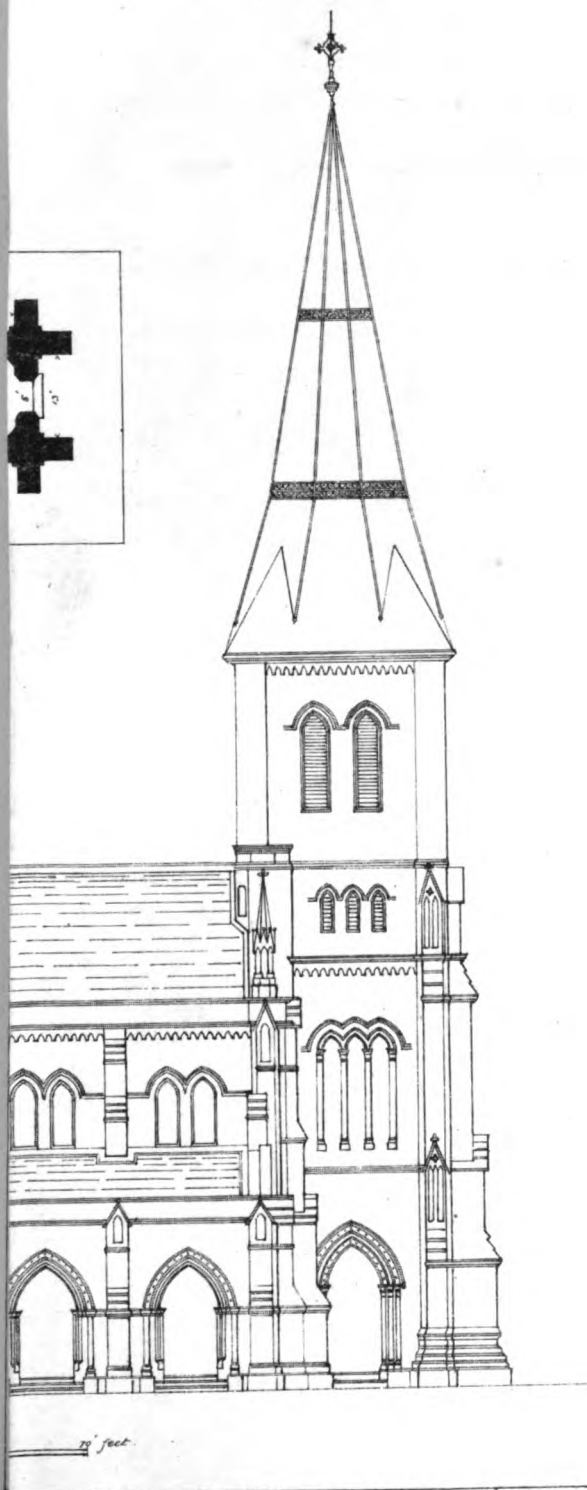


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# No. LII.

## JUBBULPORE RAILWAY SPECIFICATIONS.

[*The following extracts are from the Specifications for the works on the E. I. Railway Branch Line, from Allahabad to Jubbulpore, 221 miles, now being executed by* MESSRS. WARING AND HUNT, *Contractors; communicated by* H. P. LE MESURIER, ESQ., *Chief Engineer.*]

*Earthwork in Embankments and Cuttings.*—The embankments will be principally made from side cuttings, either in tanks or trenches, on each side of the line of Railway. It will, however, be necessary in some few places to form the banks from line cuttings, owing to the scarcity of soil alongside of the line. The embanked approaches to level crossings and road diversions to be formed in like manner.

In forming the embankments the earth is to be deposited in layers of such thickness, not less than 2 feet, as the Engineer shall approve, concave in the centre of the embankment; and the embankments are to be raised to such a height above the formation level as may in each case sufficiently allow for subsidence.

To avoid misunderstandings a deduction of one-sixth of the height of all banks will be made, in taking measurements for monthly certificates on account of work executed.

At the discretion of the Engineer, small longitudinal and transverse bunds may be made on the top of banks, to prevent cutting during the rains; these bunds are generally from 9 to 12 inches in height.

*Ballast and Road Metalling.*—It will consist of hard broken stone, clean gravel, clean kunkur, or hard well-burnt clay, or well-burnt broken bricks, or other approved material of equally good quality.



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The ballast is to be broken to such a size as will pass in all directions through a ring 2½ inches in diameter.

The portion of ballast immediately on the formation, at the discretion of the Engineer, may consist of coarsely broken stone or other specified material.

There will be about 158,400 cubic feet of ballast required per mile for a single line, with an additional allowance for sidings and metalling.

*Permanent Way.*—A single line of railway is to be laid from end to end, with sidings at stations and such other points as the Engineer may direct. The gauge or distance between the rails to be 5 feet 6 inches.

The weight of the permanent way is estimated to be as follows, per mile:—

115 tons rail, of 73 lbs. to the yard.
Maximum length of a rail, 24 feet.
35 tons chairs, 24·5 lbs. each.
5 tons fishes.
3 tons spikes, in cases of about 5 cwts.
1¼ tons bolts and nuts, in cases of about 5 cwts.
1½ tons of keys, in casks.

The sleepers generally will be of Indian woods, 10 feet long and 12 inches by 6 inches in section, not exceeding 1,700 to the mile, and averaging about 240 tons weight to the mile; but should it be found impossible to obtain a sufficient supply of native sleepers for the line between Allahabad and Myhere, creosoted fir sleepers weighing 142 tons, or Greave's bowl sleepers, weighing 142 tons per mile, will be provided.

The centre line of the railway will be marked out by the Engineers, and stakes driven at proper intervals, giving both the line and level of the rails.

The sleepers are to be prepared for the reception of the chairs by planing the seats for the chairs for the whole breadth of the sleepers, and not less than 18 inches in length for each chair. The surface to be dressed smooth, level, and brought out of winding by means of gauges prepared for that purpose.

The joint sleepers and their chairs are to be first laid down, and the rails fished and laid in their places exactly parallel and level, and to the right gauge. The intermediate chairs having been previously slipped on to the rails, the intermediate sleepers are then to be brought into their proper position, the chairs keyed on to the rails at the exact distance re-

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quired, holes bored in the sleepers with the self-adjusting guard auger, and the spikes carefully and firmly driven and fixed.

There will be an average of about 1,700 sleepers laid in every mile of the railway, but plans will be furnished to the contractor shewing their exact distance apart from centre to centre, and other necessary details.

The sleepers and rails are to be laid to the proper height at first, and no raising or lifting through the ballast will be permitted.

In curves such a height is to be given to the outside rail as may be directed by the Engineer, but on the straight parts of the line the rails are to be exactly level across.

All twisted or bent rails must be straightened or brought out of winding by hammering, or by the straightening machine usually employed for that purpose, at the contractor's expense, whether the rails were bent previously to their delivery to him or afterwards.

The price named in the tender for laying the Permanent Way must include the laying of six sets of points and crossings at each station.

If necessary the ends of the rails are to be cut or filed true and square; and, in laying, all the joints must be left wide enough to allow for expansion.

The contractor will be furnished in England with a standard gauge for the width between the rails, and from this all the others required by him are to be made. These will, before being used, be compared with a standard gauge in the possession of the Chief Engineer of the Jubbulpore Railway in India.

The linking-in is not to proceed more in advance of the permanent laying than the Engineer may deem expedient.

*Electric Telegraph.*—The wire is to be No. 5 gauge of the "best best" annealed galvanized description. The binding and connecting wires are to be of charcoal galvanized iron. The joints of the wires are to be on Ryland's or the best known principle, to be approved by the Company's Consulting Engineer.

There are to be 24 standards to the mile, one of which is to be a straining standard. All are to be made from stout sál spars of the kind known as bullies. Ordinary standards must be 20 feet long, and not less than 5 inches in diameter in any part. The straining standards and those used at stations and road crossings must be not less than 26 feet long, and 6 inches in diameter in the smallest part. The lower ends of all must be charred and buried in the ground not less than 5 feet.

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The insulators are to be of the best brown ware, and with their fittings all according to pattern.

The instruments are to be according to pattern; not less than thirty single needle and six Morse printing ones are to be supplied with the usual duplicates.

STONE-WORK. *Ashlar.*—Will be of two kinds—1st, Smooth-faced or tooled ashlar; and 2nd, Fair broached and Rock-faced ashlar, with or without a chisel draft round the edges; the rock-facing where used, not to project more than 2 inches beyond the face of the chisel draft or arris.

It is proposed to use but a limited proportion of this class of work, which will be principally confined to imposts, bed plates for girders, springers, string courses and copings, and occasionally in quoins and walling, and large arches, but power is reserved to use it whenever it may be deemed necessary.

*Thickness of Ashlar Courses, and general arrangement.*—No course of ashlar to be less than 8 inches thick. One-third of the entire length of each course to be headers. No stone to be less than 2 feet long, and when the thickness of the course does not exceed 10 inches, the stones must not be less than 15 inches on the bed. Where the thickness of the ashlar courses *exceeds* 10 inches, the breadth of the beds will not be less than a third more than the thickness of the course.

No header to be of less length than 18 inches in excess of the breadth of the course of ashlar to which it belongs. In walls up to 3 feet thick all headers to be through stones. The beds and joints of all ashlar stones to be dressed perfectly true, square and full. No hollow beds will be allowed.

The vertical joints in all cases to be dressed true and square for at least two-thirds of the breadths of the beds in from the face of the work.

No joint to exceed three-sixteenths of an inch in thickness.

The courses to be arranged with as much uniformity as possible, and laid perfectly horizontal, the lighter courses being kept towards the top of the structure.

The vertical joints of each course not to have less than 6 inches lap over the joints of the course next below. The work to be thoroughly well grouted after every course.

*Ashlar in Copings.*—The coping stone will as a rule be dowelled, but the Engineer may dispense with this system in such cases as he may deem expedient.

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No stones in the ashlar copings to be less than 2 feet 6 inches long, and the exposed surfaces to be dressed to a smooth face.

*Ashlar Arch Stones.*—Ashlar arch stones, which are in all cases to be of the entire thickness of the arch, are to be carefully and accurately wrought, giving the proper radiating, or summering joints.

The intrados to be fair broached; the beds and joints fairly wrought and left full; the last or keying course is to be very accurately fitted, and driven into its place with heavy wooden beaters.

The face stones of ashlar arches may be tooled or rock-faced, and with or without a chamfer, as may be directed.

Exact uniformity will be required in the thickness of each course of arch stones, and in the oblique arches great care is to be taken to dress the beds to the wind required by the obliquity of the arch.

*Large Rough Stone Blocks.*—It may be necessary to use one or more courses of rough stone blocks in the foundations of bridges; such blocks to be only quarry scabbled, and none less than 8 inches thick or less than 8 square feet in area. These blocks to be measured half as ashlar, half as rubble; they are to be laid in mortar, and great care is to be taken that they rest evenly on their beds.

*Coursed Rubble Facing.*—This class of work will be extensively used. In bridges up to 20 feet span no course to be less than 8 inches in thickness. When the span exceeds 20 feet the minimum thickness of a course to be 4 inches.

In structures other than bridges the minimum thickness may be 3 or 4 inches, at the discretion of the Engineer. No stone to be less than 9 inches along upon the face, or less than 6 inches on the bed.

In courses of 6 inches and upwards, no stone to have a bed less than one-third more than the thickness of the course in which it occurs.

One-fifth of the whole length of each course to be headers.

No header to be less than 2 feet long. All rubble quoins to be formed of header-stones laid alternately along each face.

The vertical joints of each course not to have less than 3 inches lap over the joints of the course next below.

The joints in all cases to be dressed as far back from the face of the work as the thickness of the course in which they occur.

The beds are to be dressed level so as to rest evenly on the mortar without any hollows or projections.

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The faces of the stones to be left rough, but no part to project more than 1 inch beyond the face arrises, which are to be in all cases chipped off square.

The joints to be dressed square, true, and full, and no mortar joint to exceed half an inch in thickness; and the average of the joints to be under half an inch.

Face-work of this nature will be measured one-fifth more than the breadth of the courses, to compensate for the headers, on the same principle as is noted in the specification of ashlar.

*Arrangement of Courses.*—All the courses are to be kept perfectly horizontal, but uniformity in the thickness of each course throughout its entire length will not be insisted on. Every care must be taken to ensure proper skill in the arrangement of the work generally, and especially where changes in thickness of the courses occur; and where ashlar quoins or courses are used *with* the rubble, the latter must be brought up to the ashlar with a perfectly level bed.

The thicker courses are to be used in the lower portions of the work, and are also to be selected for the building of the piers and abutments or other important walls.

At every 2 feet in height it will be necessary to bring the masonry to a perfectly horizontal bed throughout the entire length of each particular wall, and to thoroughly well grout the whole.

In all stone-work the stones are to be laid on their natural beds.

In all cases where battering walls are required the beds of the stones are to be at right angles to the batter.

The face joints in all stone-work are to be raked clean and neatly pointed, and the whole work carried on and completed to the entire satisfaction of the Engineer.

*Rubble Backing.*—Is to be of the best materials and workmanship, built of good sound stones. No stone to be of smaller size than one quarter of a cubic foot.

The stones of the rubble backing to be carefully set and well bonded with themselves and with the face-work. The whole to be laid flush in mortar so as to leave no spaces.

The interstices between the stones to be filled in with spauls or quarry chips. The larger stones to be roughly picked when necessary, so that they may rest evenly on their beds without hollows.

The rubble backing to be brought up flush with the face-work for every

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2 feet in height of the walls, and well grouted; and in no case will the building of the backing be allowed to proceed in advance of the face-work.

The joints in the back of all rubble walling to be raked and completely rough pointed.

*Coursed Rubble Arching.*—This work will be composed of stone similar to the headers required for coursed rubble face-work; no stone to be less in length than the thickness of the arch, or less than 1 foot in breadth.

In arches up to 20 feet span, no course to be less than 3 inches in thickness, and in arches over 20 feet span, no course to be less than 4 inches in thickness.

The arches will be built in alternate courses of headers and stretchers, or otherwise as may be from time to time directed by the Engineer.

The headers in all cases must extend right through from the intrados to the extrados of the arch unless otherwise ordered, and be not less than 12 inches wide.

The stones in the face rings must in all cases extend right through from intrados to extrados, and in bridges of 20 feet span and upwards, these face stones must be alternately not less than 15 inches, and not less than 21 inches long upon the intrados face.

The stones to be dressed and summered true and out of winding, so that no joint shall with its mortar exceed three-eighths of an inch in thickness, and the joints throughout must average less than three-eighths of an inch.

The face ring and intrados in this class of arching may be fair broached or rock-faced at the discretion of the Engineer.

All joints on the face-work and intrados to be raked and properly pointed, and the whole work made clean and neat.

*Stone Pitching.*—To be of the same class of stone as the rubble face-work; the face to be kept roughly dressed, and the stone to be as nearly as possible of an uniform depth. This pitching will be set on a layer of concrete or rubble, not less than 6 inches thick as described for backing, and the whole must be thoroughly well grouted.

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## Schedule of Prices.

The prices in the following schedule are intended to be for work finished complete in every respect as shown in the drawings, described in the specification, or ordered during the continuance of the contract. They must

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therefore include all charges for superintendence, labor, materials, patterns, moulds, fittings, painting, and erecting; for temporary works and buildings; for machinery, tackle, plant, and tools of every kind, and for all lighting and watching.

The net measurement or weight of the work in place will always be taken; but no deductions will be made in masonry for grout nicks, or joggle holes, or in timber for mortices and tenons, or sinkages for fitting iron-work. No allowance will be made for scarfs.

The excavations for foundations, road or river diversions, drains and line cuttings as distinguished from side cuttings, will be measured in the cutting. All banks made from side cuttings will be measured from the sections.

The prices for the banks and cuttings must include clearing ground as specified. The ground is covered with dense jungle for about 25 miles in all; the remainder of the line is more or less open or cultivated.

| Works. | R. | A. | P. |
|---|---|---|---|
| Earthwork, including trimming of slopes, as specified, per 1000 c. ft., | 8 | 4 | 0 |
| Excavation of foundations in soil, clay, gravel or sand, where no pumping or baling is required, including all planks, shores, struts, and refilling, &c., per 1000 c. ft., .. .. .. .. | 10 | 0 | 0 |
| Excavation of foundations in soil, &c., where pumping or bailing is required, per 1000 c. ft., .. .. .. .. .. | 50 | 0 | 0 |
| Excavation of foundations in soil, &c., where a timber coffer-dam or sheet piling is required, including cost of coffer-dam or piling, pumping or baling, per 1000 c. ft., .. .. .. .. | 500 | 0 | 0 |
| Excavation of foundations in rock where no pumping or baling is required, per 1000 c. ft., .. .. .. .. .. | 100 | 0 | 0 |
| Excavation of foundations in rock where pumping or baling is required, per 1000 c. ft., .. .. .. .. .. | 150 | 0 | 0 |
| Rock cuttings on line, per 1000 c. ft., .. .. .. | 50 | 0 | 0 |
| Gravel cuttings on line, per 1000 c. ft., .. .. .. | 12 | 0 | 0 |
| Grassing slopes of all embankments or cuttings, per 1000 s. ft., .. | 1 | 12 | 0 |
| Extra lead in forming line embankments from line cuttings when ordered, for every 300 lineal feet of average lead along the line, per 1000 c. ft., .. .. .. .. .. .. | 4 | 0 | 0 |
| Ballast for main line and sidings, laid and trimmed, per 1000 c. ft., | 45 | 0 | 0 |
| Road metalling, the quantity to be measured after ramming, per 1000 c. ft., .. .. .. .. .. .. | 60 | 0 | 0 |
| Smooth-faced or tooled ashlar masonry not in arches, per c. ft., .. | 1 | 12 | 0 |
| Smooth-faced or tooled ashlar masonry in arching, including centering, per c. ft., .. .. .. .. .. .. | 2 | 12 | 0 |
| Fair-broached and rock-faced ashlar masonry not in arches, per c. ft., .. .. .. .. .. .. .. | 1 | 8 | 0 |

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WORKS.—*(Continued.)*

| | R. | A. | P. |
|---|---|---|---|
| Fair-broached and rock-faced ashlar masonry in arching, including centering, per c. ft., .. .. .. .. .. | 2 | 8 | 0 |
| Coursed rubble masonry in face-work of every description except arching, per 100 c. ft., .. .. .. .. .. | 50 | 0 | 0 |
| Coursed rubble masonry in arching, including centering, per 100 c. ft., .. .. .. .. .. .. .. | 70 | 0 | 0 |
| Rubble masonry in backing of walls and haunches of arching per 100 c. ft., .. .. .. .. .. .. | 26 | 0 | 0 |
| Stone pitching as specified, per 100 c. ft., .. .. .. | 46 | 0 | 0 |
| Brickwork not in arches, per 100 c. ft., .. .. .. | 42 | 0 | 0 |
| Brickwork in arching, including centering, per 100 c. ft., .. | 62 | 0 | 0 |
| Khoa work, per 100 c. ft., .. .. .. .. .. | 50 | 0 | 0 |
| Concrete, per 100 c. ft., .. .. .. .. .. | 26 | 0 | 0 |
| Plastering, ½ inch thick or under, per 100 s. ft., .. .. | 5 | 0 | 0 |
| Plastering over ½ inch to 1 inch thick, per 100 s. ft., .. .. | 8 | 0 | 0 |
| Well-sinking, per centage on actual cost of sinking, as specified, per cent, .. .. .. .. .. .. .. | 25 | 0 | 0 |

PERMANENT WAY.

| | | | |
|---|---|---|---|
| Carriage of sleepers from jungles, and depositing them alongside of line, including loading and unloading, per 100 sleepers per mile, | 5 | 6 | 0 |
| Carriage of permanent way, &c., along the top or side of line, or on unmetalled roads, including loading and unloading, per ton per mile, .. .. .. .. .. .. .. | 0 | 10 | 0 |
| Carriage of permanent way, &c., along the Deccan or other metalled road, including loading and unloading, per ton per mile, .. | 0 | 6 | 0 |
| Maintenance of line for twelve months ofter opening the same, as specified, per mile, .. .. .. .. .. | 1,000 | 0 | 0 |
| Providing, fixing, working, and maintaining the Electric Telegraph, as specified, .. .. .. .. .. .. | 1,45,000 | 0 | 0 |

STATIONS AND STATION BUILDINGS.

| | | | |
|---|---|---|---|
| Lime whiting, in two coats, as specified, per 100 s. ft., .. .. | 1 | 0 | 0 |
| Glass-pannelled doors and windows, inclusive of frames, measured in the clear inside of frames, per s. ft., .. .. .. | 3 | 8 | 0 |
| Timber-pannelled doors, inclusive of frames, measured in the clear inside of frames, per s. ft., .. .. .. .. | 3 | 0 | 0 |
| Jill-mill or venetian doors and windows, inclusive of frames, measured in the clear inside of frames, per s. ft,.. .. .. | 3 | 0 | 0 |
| Timber in roofs and architraves, per c. ft., .. .. .. | 4 | 0 | 0 |
| Wrought-iron in tie-bars, straps, belts and nuts, &c., per lb., .. | 0 | 5 | 0 |
| Cast-iron in water-pipes, sockets for beams, and other miscellaneous castings, per cwt., .. .. .. .. .. | 25 | 0 | 0 |
| Wrought iron in roof or floor girders, skew backs to arched roofing, &c., per cwt., .. .. .. .. .. .. | 25 | 0 | 0 |



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# No. LIII.

## INDUS SILT EXPERIMENTS.

*Description of the mode adopted in taking the Observations recorded below, to determine the Velocity of, and the amount of Solid Matter in, Water at different depths in the Indus, and in some of the Canals in Sind.* By Colonel Tremenheere, R.E., *Chief Engineer in Sind.*

Plate V., Fig. 1, represents the instrument used for taking the velocities, and is a modification of Woltmann's Mill. It was fitted to a round pole, 16 feet long, and guided by a groove. An iron cross-head fixed to the top of the pole shewed the direction of the instrument, which could thus be made to correspond with that of the surface current. The correctness of the instrument had been previously ascertained by trials. The number of revolutions made by the vanes in a measured distance, when dragged through still water, at various velocities, was found in each case to correspond.

The observations on the river were taken from a boat fastened to the bank. The instrument was clamped to the pole at the required depth. As soon as the pole was in an upright position, with the cross-head in the proper direction, the trigger was pulled. The vane was usually allowed to revolve for 30 seconds, when the trigger was dropped, and the result registered by the index recorded. The observations were in every case repeated; no single observation was relied on, and whenever there was any material difference between two experiments, the observations were continued.

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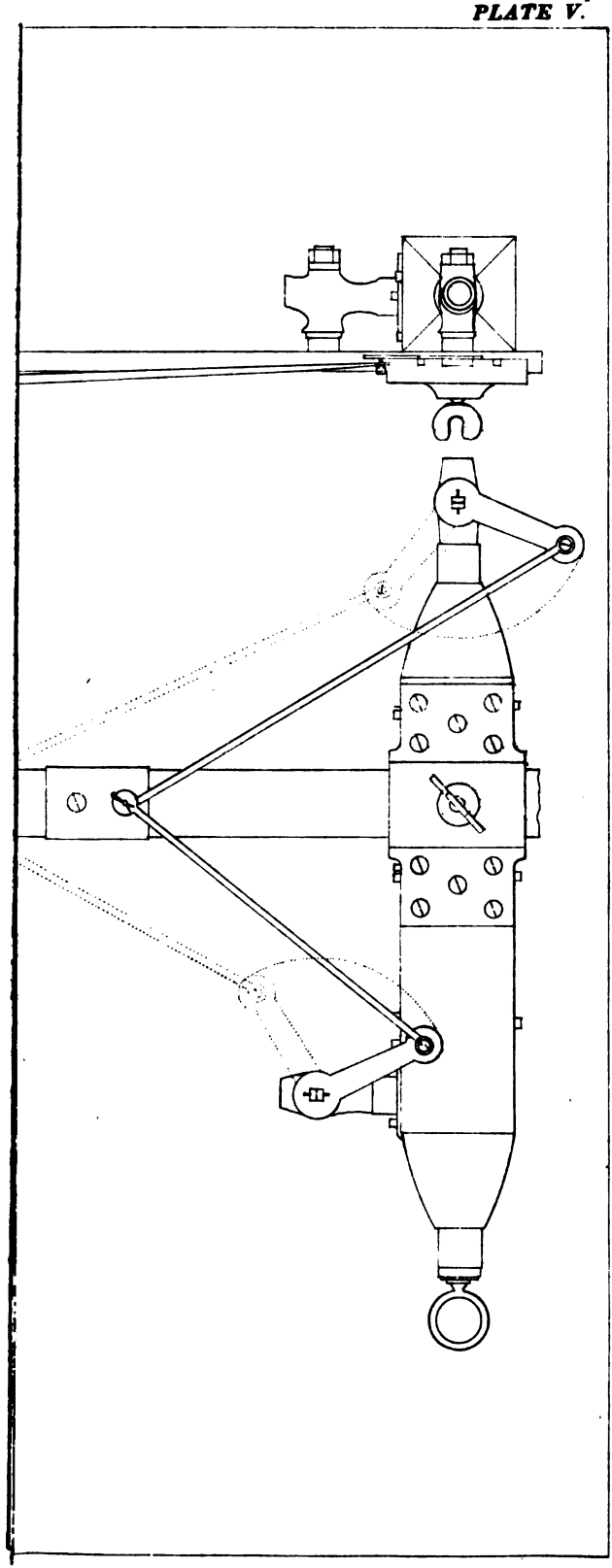

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The observations made in Canals were taken also from a boat, either anchored in the middle, or moored to a rope stretched across between the banks. In one experiment, viz., on the Oomercus, the regulating bridge was made use of, and the observations taken in the waterway of one of the arches.

In very strong currents, such as that at A on the sketch, and at any depth below the surface, the instrument gives readings which vary considerably from one another; but this is owing to the difficulty of holding the rod in the direct line of the current, and to its vibration, but even in such cases it is not difficult to obtain reliable results. The following observations were taken at this spot:—

| No. of Observation. | Revolutions. | No. of Observation. | Revolutions. |
|---|---|---|---|
| 1 | 183½ | 5 | 194 |
| 2 | 226 | 6 | 204 |
| 3 | 233 | 7 | 233 |
| 4 | 225 | | |

It may perhaps be taken for granted that the 2nd, 3rd, 4th, and 7th are nearly correct, and that the instrument was not held quite in the direction of the stream in the other cases. The mean of the above four gives 229 revolutions, equivalent to 9½ feet per second, or very nearly 6½ miles an hour.

In every case the observations for velocity were taken first, and then the samples of water were drawn from corresponding depths. The apparatus employed to effect this is shewn in Plate V., Fig. 2. The iron rod, on which the bottle could be fixed at any required height above the foot, was 14 feet in length. The valves or cocks were worked by strings fastened to the brass slide, and passed over pulleys at both ends of the rod. These valves were smaller than they ought to have been made, and did not allow the air to escape from the bottle so fast as was desirable, but this did not affect the correctness of the observations. The water so drawn was at once put into bottles arranged in order in a box made for the purpose, and the whole then carefully filtered. The filters previous to use were adjusted in the usual manner, and with the deposit were thoroughly dried on a sand bath, and weighed in opposite scales. The quantity of water was accurately measured in the usual graduated glass measures, and the specific gravities were obtained by means of the specific gravity bottle.

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RECORD OF OBSERVATIONS TO ASCERTAIN THE AMOUNT OF SILT CONTAINED IN THE WATER OF THE INDUS, AND IN CANALS OF UPPER SIND, BY COLONEL TREMENHEERE, R.E., IN THE MONTHS OF JULY AND AUGUST 1864.

| Date. | Site. | Gauge. | Depth of Water. | Depth from Surface. | Velocity per Second. | Quantity of Water. | Deposit on Filter. | Proportion of Silt to Water. | Specific Gravity of Silt. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Ft. In. | Ft. In. | Ft. In. | Feet. | lbs. oz. drs. | Grains. | | | |
| July 23, | Sukkur A, | 10 11 | 10 0 | 6 10 | 9·5 | 2 2 5 | 62 | 1-244 | | |
| | | | | | | 1 1 1½ | 36 | 1-208 | | |
| | | | | | | 0 14 0 | 26 | 1-235 | | |
| | | | | | | 4 1 6½ | 124 | 1-282 = ·00431 | | |
| July 25, | „ C, | 11 4 | 8 6 | 6 10 | 3·5 | 2 0 0 | 50 | 1-280 | | |
| | | | | | | 1 13 0 | 51 | 1-248 | | |
| | | | | | | 1 15 0 | 47 | 1-288 | | |
| | | | | | | 5 12 0 | 148 | 1-272 = ·00368 | | |
| July 27, | „ B, | 11 8½ | 8 9 | 8 9 | 4·58 | 2 4 2 | 72 | 1-220 | | |
| | | | | | | 2 2 6 | 75 | 1-202 | | |
| | | | | | | 1 13 4 | 63 | 1-204 | | |
| | | | | | | 6 4 4 | 210 | 1-209 = ·00478 | | |
| July 28, | „ B, | 11 11 | 9 2 | 6 2 | 4·2 | 2 2 3¾ | 64 | 1-235 | | |
| | | | | | | 1 12 1½ | 51 | 1-241 | | |
| | | | | | | 2 3 3 | 85 | 1-182 | | |
| | | | | | | 1 12 2 | 70 | 1-176 | | |
| | | | | | | 7 14 2¼ | 270 | 1-204 = ·00490 | | |
| July 29, | „ D, | 11 11 | 12 0 | 10 0 | 3·1 | 1 14 0 | 57 | 1-230 | | |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1 9 6 | 73 | 1-154 | |
| | | | | | | | 2 4 0 | 70 | 1-225 | |
| | | | | | | | 2 4 4 | 78 | 1-204 | |
| | | | | | | | 8 0 2 | 278 | 1-202 = ·00495 | 2·317 |
| Aug. 1, | Sukkur | D, | 12 2 | 8 6 | 6 6 | 2·6 | 2 3 3 | 62 | 1-249 | |
| | | | | | 4 6 | 3·2 | 2 3 3 | 59 | 1-262 | |
| | | | | | 2 6 | 4·0 | 2 2 6½ | 47 | 1-317 | |
| | | | | | 1 0 | 4·2 | 2 3 3 | 50 | 1-390 | |
| | | | | | | | 8 12 1½ | 218 | 1-281 = ·00356 | |
| Aug. 8, | „ | B, | 12 3½ | 9 6 | 7 6 | 3·8 | 2 3 0 | 62 | 1-247 | |
| | | | | | 5 6 | 4·1 | 2 0 0 | 65 | 1-205 | |
| | | | | | 3 6 | 4·6 | 1 12 3 | 49 | 1-253 | |
| | | | | | 1 6 | 3·5 | 1 8 0 | 39 | 1-269 | |
| | | | | | 0 6 | 3·9 | | | | |
| | | | | | | | 7 7 3 | 215 | 1-242 = ·00413 | |
| Aug. 9, | „ | C, | 13 0 | 8 6 | 6 6 | 3·6 | 1 13 2½ | 47 | 1-272 | |
| | | | | | 4 6 | 4·1 | 2 0 5 | 50 | 1-288 | |
| | | | | | 2 6 | 5·2 | 1 4 4½ | 26 | 1-346 | |
| | | | | | 0 6 | 5·4 | 2 1 0 | 48 | 1-300 | |
| | | | | | | | 7 3 4½ | 171 | 1-295 = ·00339 | 2·464 |
| | | Total, .. | ..... | ..... | ..... | ..... | 55 7 7½ | 1634 | 1-237 = ·00422 | Mean result of all observations at Sukkur. |
| Aug. 3, | „ | B, | 12 3½ | 11 0 | 8 6 | About 4 feet, | 13 3 0 | 449 | 1-205 | Total weight of deposit, 904 grains. |
| | | | | | | | Sand, | 228 | 1-405 | Sand 228 Mud 221. |
| | | | | | | | Clay, | 221 | 1-418 | „ 224 „ 231. |
| | | | | | | | | 452 | | 452, or exactly half. |
| Aug. 9, | „ | B, | 13 0 | 11 0 | 10 0 | | 13 12 4½ | 455 | 1-212 | |
| | | | | | | | Clay, | 221 | 1-417 | |
| | | | | | | | Sand, | 224 | 1-430 | 2·688 Sand only. |

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| Date. | Site. | Gauge. | Depth of Water. | Depth from Surface. | Velocity per Second. | Quantity of Water. | Deposit on Filter. | Proportion of Silt to Water. | Specific Gravity of Silt. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Ft. In. | Ft. In. | Ft. In. | Feet. | lbs. oz. drs. | Grains. | | | |
| July 28, | Floating down Pass between Sukkur and Bukkur, | 11 11 | 80 to 90 feet. | 11 9 | Not observed. | 2 4 0 | 75 | 1-210 | | |
| Aug. 18, | Floating down near Seeta in centre of current, | 13 3 | Unknown. | | Do. | 1 12 0 | 57 | 1-315 | | |
| | | | | | | 4 0 0 | 132 | 1-212 = ·00472 | | |
| July 30, | Mouth of Nara Supply channel below the Arore, | 12 0 | 12 0 | 10 0 | 3·6 | 2 4 5 | 67 | 1·239 | | |
| | | | | | | 2 5 2½ | 97 | 1-166 | | |
| | | | | | | 2 1 3 | 32 | 1-456 | | |
| | | | | | | 2 4 7½ | 60 | 1-269 | | |
| | | | | | | 1 2 3 | 27 | 1-297 | | |
| | | | | | | 10 2 4½ | 283 | 1-251 = ·00398 | | |
| Aug. 2, | Supply channel half way to Regulator in centre of channel, | 12 3 | 8 2* | 6 2 | 2·9 | 1 10 3 | 40 | 1-288 | | * Shews a deposit of at least 6 feet in depth in the bed. |
| | | | | 4 2 | 2·8 | 2 5 0 | 61 | 1-265 | | |
| | | | | 2 2 | 4·2 | 2 5 6 | 46 | 1-359 | | |
| | | | | 0 3 | 4·9 | 2 5 2 | 38 | 1-428 | | |
| | | | | | | 8 10 3 | 185 | 1-327 = ·00306 | | |
| July 26, | Oomercus Canal Bridge, | 11 6½ | 6 10 | 2 10 | 2·08 | 1 14 7½ | 53 | 1-255 | | |
| | | | | | | 1 11 2½ | 42 | 1-284 | | |
| | | | | | | 1 9 6 | 40 | 1-281 | | |
| | | | | | | 5 4 0 | 135 | 1-270 = ·00370 | | |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Aug. 12, | Mouth of Ghar, | 13 1½ | 11 8 | 9 8 | 2·9 | 1 13 2 | 42 | 1-304 |
| | | | | 7 8 | 2·7 | 2 2 6 | 54 | 1-281 |
| | | | | 5 8 | 3·1 | 1 9 2½ | 36 | 1-308 |
| | | | | 3 8 | 3·1 | 2 4 5½ | 51 | 1-315 |
| | | | | 0 8 | 3·2 | | | |
| | | Bukkur Gauge. 12 7 | | | | 7 14 0½ | 183 | 1-301 = ·00332 |
| Aug. 5, | Ghar at Larkhana, | 15 11 on lower side of bridge. | 12 0 | 10 0 | 2·1 | 2 5 5½ | 36 | 1-455 |
| | | | | 8 0 | 2·2 | 2 3 0 | 37 | 1-414 |
| | | | | 6 0 | 2·8 | 2 4 4 | 39 | 1-409 |
| | | | | 4 0 | 3·0 | 2 5 4 | 34 | 1-482 |
| | | | | | | 9 2 3½ | 146 | 1-438 = ·00228 |
| Aug. 6, | Humeer Canal, | Bukkur, 12 8 | 8 0 | 6 0 | 2·0 | 2 5 0 | 44 | 1-368 |
| | | | | 4 0 | 2·4 | 2 5 4½ | 43 | 1-382 |
| | | | | 2 0 | 2·5 | 1 15 0 | 30 | 1-449 |
| | | | | 0 8 | 2·5 | 2 2 6 | 32 | 1-475 |
| | | | | | | 8 12 2½ | 149 | 1-412 = ·00243 |
| Aug. 7, | Gharree Sind Gaheeja, | 12 9 | 11 6 | 9 6 | 3·0 | 2 2 2 | 9 | 1-1665 |
| | | | | 7 6 | 3·5 | 2 3 2 | 8 | 1-1927 |
| | | | | 5 6 | 3·7 | 1 12 1½ | 10 | 1-1238 |
| | | | | 3 6 | 3·5 | 2 4 4½ | 6 | 1-2668 |
| | | | | 0 6 | 3·5 | | | |
| | | | | | | 8 6 2½ | 33 | 1-1780 = ·00056 |
| Aug. 8, | Sind Shikarpore, | 12 9 | 8 0 | 6 0 | 2·3 | 2 5 0 | 37 | 1-437 |
| | | | | 4 0 | 2·6 | Filter broken. | | |
| | | | | 2 0 | 3·0 | 1 15 1½ | 25 | 1-545 |
| | | | | 0 6 | 3·1 | 2 5 2½ | 26 | 1-628 |
| | | | | | | 6 9 3½ | 88 | 1-524 = ·00191 |
| | Kotree [bank, River | | | | 2·4 | 8 10 2 | 192·5 | 1-314 = ·00318 |

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OBSERVATIONS ON THE ABOVE.

The mean result of 29 observations taken at Sukkur is that the silt amounts to the 1-237th (·00422) part of the water by weight; but, adding the two observations taken on August 3rd and 9th, it amounts to the 1-227th (·00441.) The addition of that taken on July 28th leaves the last fraction unaltered. The experiments at B on the 3rd and 9th August are remarkable for agreeing so closely with each other; the proportion of sand and clay in the two combined being exactly one-half of the deposit. In these cases the sand was easily separated from the clay; as the sand settled at the bottom of the vessel the water containing the clay in suspension was thrown on the filters; the residue was then washed with portions of the clear water, which was then again passed through a filter, the same course being repeated until the water after agitation appeared to be quite free from discoloration. The result is, that the River water contains about 1-210th (·00476) part of its weight of matter in suspension. One-half, or 1-420th (·00328) part consists of clay, and the other half of sand of specific gravity varying between 2·430 and 2·688, or from 150 to 168 lbs. per cubic foot. The observations in the Eastern Narra supply Channel give exceptional results. The regulator being to a great extent closed, the top water was comparatively clear, though running at a high velocity.

The observations at the Oomercus and the mouth of the Ghar shew perhaps the ordinary proportion of silt in Canals led direct from the River, at a short distance from their mouths, which may be stated at 1-300th (·00333). The two following observations of the Ghar at Larkhana, and the Hummer, a branch of the Ghar, indicate that about one-third of the heavy material carried into the Canal, or 1-900th of the whole had been deposited before those points had been reached, leaving about 1-450th still in suspension. The Sind at Shikarpoor, a Canal which does not derive its water directly from the River, was found to contain only 1-524th (·00191). The most remarkable case is that of the Gharree Sind, in which an unusually small amount of silt was found. This is a case in which the Canal is supplied during the height of the inundation from water which is naturally filtered by passing across an island covered with low jungle and high grass.

It must be admitted that a more extensive series of observations is

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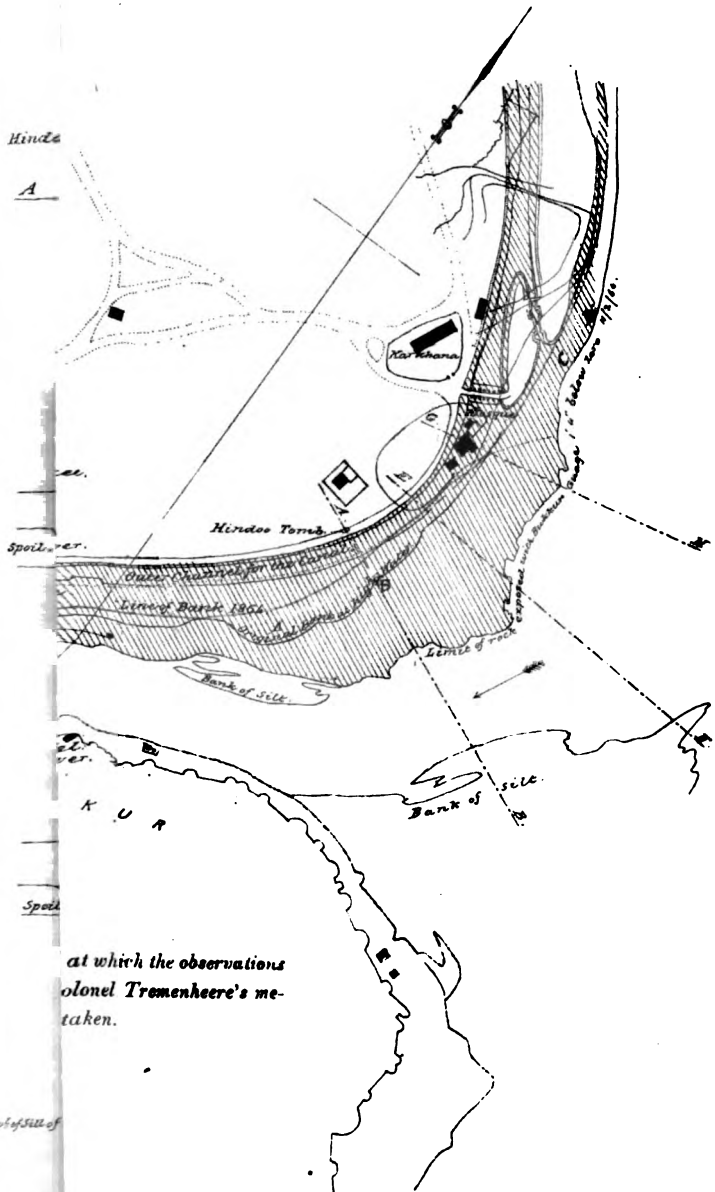


*at which the observations*
*olonel Tremenheere's me-*
*taken.*

Line of Silt of

*shews the probable amount of rock excavation required under the two*
*ojects. The blue water line shews the high water limit of*
*the approaching inundation, 1864.*

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**Scale—600 Feet to an Inch.**

LITHO.

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UNIV. OF MICH.

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desirable, but the table given above appears to point to the following conclusions, which may perhaps for the present be accepted:—

1*st*. That the water in Canals which derive their supply from branches separated from the main River by islands covered with brushwood and long grass, contains a comparatively small amount of material in suspension.

2*nd*. That the water in Canals whose head is on the main stream, where the velocity of the current is not exceptional, may be expected to contain an amount of sand and silt equal in weight to about 1-300th of the weight of the water, and that one-third of this, or 1-900th, will be deposited in the bed of the Canal within a distance of its mouth which will vary with the velocity maintained in the Canal.

3*rd*. That Canals constructed so as to derive their supply from a part of the River where the section is contracted, and the velocity is much augmented and exceptional, will probably contain sand and silt varying from 1-200th to 1-250th, the half of which, or 1-400th to 1-500th, will be heavy sand, which will be deposited in any Canal in which the velocity is so low as $1\frac{1}{2}$ or 2 feet per second.

The former rulers of Sind appear to have well understood the peculiarities of the River, upon which the prosperity of their country so entirely depended, and to have studiously selected spots for the Canal heads which are screened from the full force of the current during the inundation. The point which particularly strikes an Engineer, or even a non-professional man in travelling up the River during the inundation, is the absence of almost all signs of Canal irrigation on the banks. He has been told, or he is aware, that nearly the whole Revenue of the Province is dependent upon Canals which are led off from the River, and whose branches cover the whole country with a perfect network of water channels, but he looks almost in vain for any signs upon the River banks of such a system being in operation. From Kotree the whole way to Sukkur he passes the mouths of only two Canals* of any size on the left bank which are taken directly from the main stream, and both these he finds on enquiry have been dug by the British Government. It is the same on the right bank: omitting the natural channels of the Arul and Narra, the Ghar is the only Canal upon the River bank, and its present mouth is also the work of our own Government.

* The New Foolallee and the Nusseer.



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It may be useful to add a calculation of the amount of sand which would be deposited on the first few miles of a Canal with a bottom width of 30 feet, side slopes of $1\frac{1}{2}$ to 1, bed slope 4 inches per mile, and a depth of 10 feet, giving a discharge of 750 cubic feet per second, the amount of solid matter in the water being 1-250th, the half of which is sand.

$750 \times 60 \times 60 \times 24 =$ cubic feet per diem $= 64{,}800{,}000.$

$\frac{64{,}800{,}000 \times 62\frac{1}{2}}{500} =$ weight of deposit per diem $= 8{,}100{,}000$ lbs.

$\frac{8{,}100{,}000}{168} = 48{,}214$ cubic feet, or 4,821,400 cubic feet in 100 days.

As such a Canal should be kept open for at least 300 days in each year, some allowance should be made for the deposit, which, supposing the mouth not to be closed by the above quantity of sand, would take place in the additional period of 200 days; but as the River would not be in flood for the larger portion of this period, the proportion of silt carried by the water would decrease. The Canal also could not be maintained at so high a level for so long a period.* It is impossible under these fluctuating circumstances to make any calculation of the additional amount of deposit during the above time; it may suffice to make the supposition that the accumulation during these 200 days may be one-half the quantity deduced above for 100 days, which will give a total of 7,232,100 cubic feet. The smaller of the above quantities, viz., 4,821,400 cubic feet, if spread in an even slope over a length of 7 miles of the Canal, would give a depth of 7 feet of deposit at the head. This, as it would leave less than 3 feet as the maximum depth of water available between the 15th of October and the 5th April, would render the Canal useless for the purpose for which it was proposed, viz., to afford a perennial supply, and to irrigate the Rubbee crops.

Another case may be stated,—that of a Canal taken from the same point, with a bottom width of 35 feet, side slopes, of $1\frac{1}{2}$ to 1, bed slope 4 inches per mile, a depth of 6 feet, and discharge 400 feet per second. The proportion of solid matter being the same as in the former case, we have:—

$400 \times 60 \times 60 \times 24 =$ cubic feet per diem $= 34{,}560{,}000.$

$\frac{34{,}560{,}000 \times 62\frac{1}{2}}{500} =$ weight of deposit per diem $= 4{,}320{,}000$ lbs.

* From observations made, extending over 15 years, a Canal with its bed 6·65 feet below zero on the Bukkur Gauge would carry a depth of 10 feet for 230 days.

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$\frac{4,820,000}{168} = 25,714$ cubic feet, or 2,571,400 cubic feet in 100 days.

As the velocity in this case would be only 17 inches per second, as compared with 20 inches in the previous example, the limit which the sand would reach may be stated at 6 instead of 7 miles, and the depth of the deposit at the head of the Canal at $4\frac{1}{8}$ feet. The bed in this case may be taken at 5 feet below zero on the Gauge. With 4 feet deposit, the depth of water in the Canal, as ascertained by the Gauge Returns, between the 15th October and the 15th March, would vary from $4\frac{1}{8}$ feet to 1 foot 7 inches. The discharge at these depths would be quite inadequate to water the extent of country for which the Canal would be required.

The circumstance that the deposit will not assume an even surface extending over a distance of 7 miles has not been overlooked: were it to do so, the bed slope would be increased to 1 foot 4 inches a mile, and the velocity would be greatly augmented, and the sand carried forward. The actual form it will assume cannot be determined, although with a fixed discharge the quantity of sand deposited, as far as these experiments are reliable, may be stated with an approach to accuracy. The sand will probably form ridges, which near the head of the Canal may very possibly exceed the height deduced in the calculations, in which case the effective discharge would be reduced still earlier in the season.*

The results to which the consideration of these experiments appear to point are—

1*st.* That Sukkur is not a suitable spot for the head of a Canal.

2*nd.* That if a Canal be opened at that place, the deposit of sand, near its head will be so great during the inundation that it will not be effective for Rubbee cultivation.

*Postscript.*—It may be interesting to consider the amount of solid matter which must be carried down by the Indus. The discharge of the River at Sukkur during the inundation, with a depth of 13 feet on the Gauge, amounts to 3,80,000 cubic feet per second. On the supposition

* On the supposition that the Gates proposed by Lieut.-Colonel Fife, in No. III., Vol. I., of Professional Papers on Indian Engineering, were applied at the regulator of such a Canal, and the level of the floor 6·65 feet below zero on the Gauge, the depth of water on the outer side in the height of the inundation would be 20 feet. The top of the middle piece being 5 feet 11 inches above the floor of the regulator, the depth over it would be 14 feet 1 inch, and seven openings 10 feet by 6 inches, would maintain a depth of 10 feet in the Canal, the water to supply which would be drawn from a mean depth of 13 feet 10 inches from the surface; the Canal supply would consequently not be obtained from the top water. The above depth considerably exceeds that at which any of the experiments given in the table were made, and it is reasonable to conclude that the proportion of sand would rather exceed than fall short of that made use of in the above calculations.

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that only 2,50,000 cubic feet are discharged into the sea for 100 days, and that the water so discharged contains the same proportion of silt as it has been ascertained to hold at Sukkur, viz., 1-250th part, the total quantity will be found to exceed 119 millions of cubic yards, or sufficient to cover a surface of $38\frac{4}{10}$ths square miles, with a deposit 1 yard in thickness.

It may be observed that the actual quantity of sand and silt moving forward with the current must be the same in each section of the River. The rule which is applicable to the uniform discharge of water in different river sections must apply equally to the solid material held in suspension. Where the velocity is exceptional, as in the narrow pass at Sukkur, the water and sand are more intimately mixed, and the surface water will contain a larger proportion of sedimentary matter than elsewhere, but the total quantity of solid matter is no more affected by the additional velocity than is the volume of water discharged by the River.

C. W. TREMENHEERE, COLONEL, R.E.

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NOTE BY EDITOR.

Exact details of the whole process of filtering above described would be very useful.

It is to be regretted that these very valuable observations were not taken in every month of the year; observations made in July and August alone must give an exaggerated idea of the quantity of silt contained in the river.

In the case of the Indus Innundation Canals of the Lower Derajat, most of them have their mouths on the main stream of the river, though it is quite possible they may have been cut from a branch in the first instance, and the set of the water down the Canals may have had some influence in converting the branch into the main stream. No doubt the beds of such Canals as a rule silt up very much, but the chief cause of that I have always attributed; 1st, To the want of any outlet at the tail, owing to which the silt is carried forward, heaped up, and has no escape; and 2ndly, To the great sinuosity of their channels. Were these channels straightened so as to increase the available slope of their bed and a scour maintained by tailing them (where possible) into a nullah or back into the river, the deposit of silt would be very greatly diminished.

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The following Silt Estimates were made by H. B. Medlicott, Esquire, (of the Geological Survey) on the water of the Ganges River and Canal, and were published in the Asiatic Society's Journal, Vol. XX., Parts 3 and 4.

SILT ESTIMATES, PARTS IN 10,000.

| No. | Date. | Hurdwar. | Asufgurh. | Roorkee. | |
|---|---|---|---|---|---|
| 1 | 4 May, 1856 .. | 2·08 | ·33 | 3·37 | |
| 2 | 1 May, 1857 .. | ·09 | .. | 1·28 | |
| 3 | 1 May, 1858 .. | .. | .. | .. | |
| 4 | 22 May, 1861 .. | .. | .. | 3·82 | |
| 5 | 5 June, 1856 .. | 6·05 | 7·34 | 5·19 | 4 feet of water at Roorkee |
| 6 | 10 June, 1857 .. | 6·88 | .. | 2·75 | 4 feet of water at Roorkee |
| 7 | 1 June, 1858 .. | 3·41 | .. | 3·85 | |
| 8 | 13 June, 1861 .. | 13·65 | .. | .. | |
| 9 | 4 July, 1856 .. | 14·50 | 8·00 | 11·79 | |
| 10 | 4 July, 1857 .. | 10·45 | .. | 5·17 | |
| 11 | 2 August, 1856 | 23·10 | 13·30 | 26·10 | |
| 12 | 2 August, 1857 | 17·98 | .. | 5·83 | |
| 13 | 2 Sept., 1856 .. | 6·89 | 81·00 | 7·66 | |
| 14 | 1 Sept., 1857 .. | 5·39 | .. | .. | |
| 15 | 4 Oct., 1856 .. | clear | .. | ·85 | |
| 16 | 1 Oct., 1857 .. | 1·98 | .. | 1·00 | |
| 17 | 5 Nov., 1857 .. | ·61 | 3·30 | 2·20 | 6·5 feet of water at Roorkee |
| 18 | 1 Nov., 1857 .. | ·44 | .. | .. | |
| 19 | 1 Dec., 1856 .. | ·20 | 1·43 | ·55 | |
| 20 | 1 Dec., 1857 .. | clear | .. | 1·32 | |
| 21 | 1 Jan., 1857 .. | .. | ·45 | 1·67 | |
| 22 | 1 Jan., 1858 .. | clear | .. | 1·32 | |
| 23 | 1 Feb., 1857 .. | 1·02 | ·12 | 1·26 | |
| 24 | 1 Feb., 1858 .. | .. | .. | .. | |
| 25 | 1 March, 1857 | .. | 1·27 | ·99 | |
| 26 | 1 March, 1858 | .. | .. | .. | |
| 27 | 1 April, 1857 .. | ·37 | ·45 | ·82 | |
| 28 | 1 April, 1858 .. | .. | .. | .. | |

Hurdwar is where the Ganges leaves the Siwalik hills to enter upon the plains; the stream is much more rapid there than lower down. Asufgurh is on the Ganges, about eighteen miles below Hurdwar. Roorkee is eighteen miles below Hurdwar, on the Ganges Canal. These estimates are of course exclusive of the soluble ingredients. If the single series of estimates from Asufgurh for 1856-1857 can be trusted, they seem to indicate approximate equality with Hurdwar during the period of low water; a very decided diminution during the period of greatest flood, involving a very considerable deposition along the bed and low branches of the river below Hurdwar, and a marked increase about the rise (from snow-water) and fall, before and after the rains in the mountains have charged the river with sediment, the lower reach of the river thus preying on its muddy banks. No. 13, from Asufgurh, may be questionable; for all the samples from there I had to depend upon a native messenger.

The proportion of silt in the canal water at Roorkee, as compared with the head, seems to depend upon the depth of water, producing either silting-up or erosion.

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Some cases, show how very indefinite such silt estimates must sometimes be; samples collected by myself at the same time, in the same way, and with equal care, showing a difference of a third—See 6 and 7.

OCCASIONAL SILT ESTIMATES, PARTS IN 10,000.

| No. | Date. | | |
|---|---|---|---|
| 1 | 4 July, 1856 .. | Solani at Roorkee, a 3 feet flood .. .. | 47·80 |
| 2 | 16 July, 1856 .. | „ „ 3·5 feet flood .. .. | 93·90 |
| 3 | 19 July, 1856 .. | „ „ 6 feet flood .. .. | 80·00 |
| 4 | 19 July, 1856 .. | „ „ same time as No. 3 .. | 87·10 |
| 5 | 22 Sept., 1856 .. | „ „ 5·5 feet flood .. .. | 68·50 |
| 6 | 31 July, 1857 .. | „ „ 9 feet flood .. .. | 228·60 |
| 7 | 31 July, 1857 .. | „ „ same time as No. 6 .. | 148·50 |
| 8 | 1 June, 1861 .. | Jumna, at Canal head .. .. .. | 1·04 |
| 9 | 10 June, 1861 .. | „ „ .. .. .. | 3·05 |
| 10 | 1 June, 1861 .. | E. Jumna Canal, 96th mile .. .. .. | 10·50 |

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## No. LIV.

## OIL-MILLS FOR THE EAST INDIAN RAILWAY.

*From the Agent East Indian Railway, to the Consulting Engineer to Government of Bengal, Railway Department.*

*Calcutta, April 13th, 1864.*

SIR,—I have the honor to forward an indent with design and estimate for a pucka shed for four Oil-mills, to be erected on the Railway Company's ground at Mokameh. The Chief Engineer states that, the stations of Barh and Mokameh would both be well situated for the erection of Oil-mills, as there is a large quantity of castor oil grown in the neighbourhood; but, of the two, Mokameh would be the best adapted for the purpose.

Mr. Campbell has submitted a tracing of Messrs Shanks and Carrick's Oil Press, which I forward herewith, together with a memo. by Mr. Carrick. Mr. Campbell states that, from his own knowledge of this press, he can recommend it as being the best and most economical of any in use in this country.

The cost of each Oil Press complete and ready for fixing is Rs. 650 each; five of them will produce 9,000 gallons of oil per month. The amount of the indent is Rs. 8,176, which includes cost of shed, construction of oil presses and fixing of the same.

The Company is the largest consumer of oil in India, and oil it must have at any price and whatever the quality, unless it can be placed beyond the power of the manufacturers.

This was so fully exemplified in the N. W. Provinces, that I obtained

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in 1862, the sanction of that Government to manufacture oil, the cost of which had run up solely owing to the requirements of the Company, to 12 rupees per maund. The average cost at which it was produced from the commencement up to April last, was about Rs. 7-5-2 per maund, and the saving effected upwards of Rs. 12,000. This, however, by no means represents what the saving would have been if the single oil-mill erected at first could have turned out the whole quantity required by the Company, although it had the effect of bringing the bazar price down 25 per cent. for the balance.

The out-turn has been fairly debited with its legitimate charges, and as soon as the concern was in proper working order, with an additional charge of 12 per cent. per annum on the value of the block. Rent was not charged, only because the manufacture had been carried on in an abandoned temporary workshop at Allahabad, pending construction of a building at Etawah in the centre of the seed districts, the rent for which would be met by a reduction in the freight of seed.

The price in Calcutta, and up the line in the Bengal Division, is from Rs. 12-4-0 to 13 per maund of oil; and I have been forced on more than one occasion to accept inferior oil, at the last moment or go without, either of which contingencies is a serious matter on a Railway, where safety depends upon clearly burning lights.

The consumption for this purpose on the Bengal Division amounts to about 1,000 maunds per month, and according to the supplies the ordinary trade profit of 30 per cent., the saving to be effected will scarcely be less than Rs. 4,000 a month, and while manufacture itself is so simple that it does not require any unusual qualifications to carry it on.

I have, &c.,

CECIL STEPHENSON.

Estimated cost of erecting shed at Mokameh Station, to contain four Oil Screws with Boilers and Crushing Rollers, with godown attached: length of building 100 × 30 feet.

| c. ft. | | Rs. |
|---|---|---|
| 13,000 | Brick-work, at Rs. 15 per 100, - - - - - | 1,950 |
| s. ft. | | |
| 3,000 | Floor paving, at Rs. 12 per 100, - - - - - | 360 |
| 4,000 | Roofing, at Rs. 22 per 100, - - - - - - | 880 |

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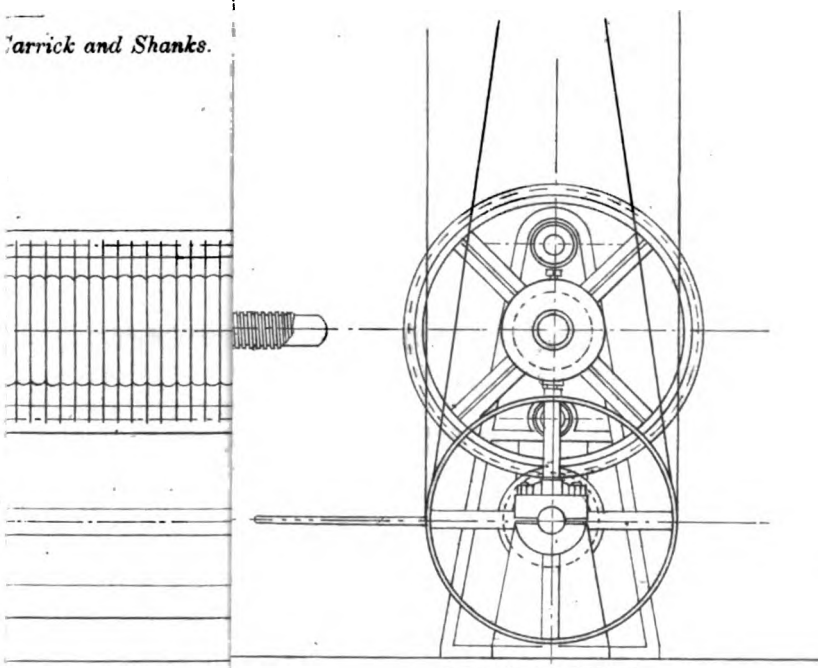
INDIAN RAILW

*Parrick and Shanks.*



END ELEVATION.

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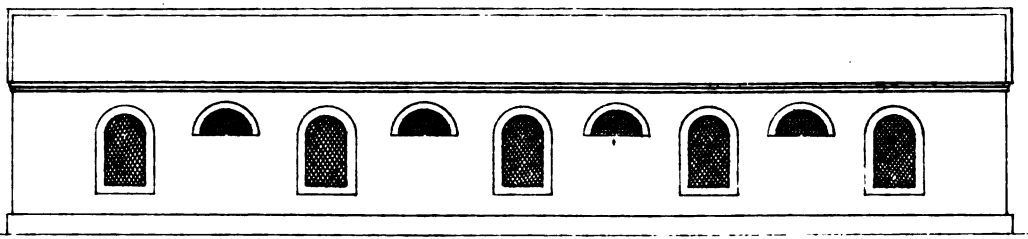
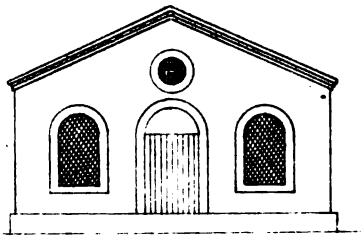
# OIL-MILLS ON EAST INDIAN RAILWAY

*Proposed Shed at Mokameh Station, to contain Four Oil Presses and Godown.*

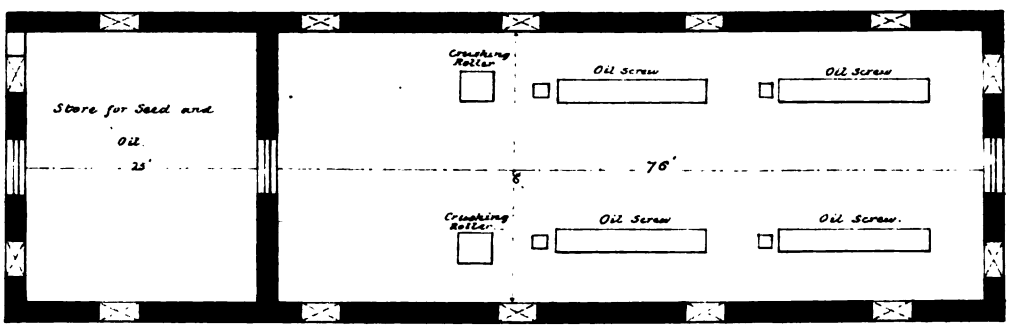
ELEVATION.



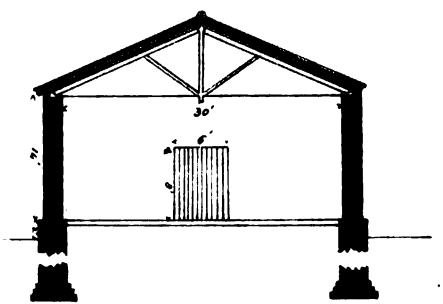
END ELEVATION.



PLAN.




SECTION.




Feet. 10 5 0 10 20 30 40 50 feet.

PLATE VIII

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| c. ft. | | Rs. |
|---|---|---|
| 14,000 | Excavating and filling, at Rs. 5 per 1,000, - - - | 70 |
| 500 | Timber in roof, at 3 Rs. per foot, - - - - - | 1,500 |
| s. ft. | | |
| 144 | Doors, at Rs. 1-8, per foot, - - - - - - | 216 |
| | | 4,976 |
| | Cost of 4 Oil Presses, at Rs. 650 each, - - - - | 2,600 |
| | Carriage and fixing of the same, - - - - - | 600 |
| | Total Rupees, - - | 8,176 |

Saul trusses available at Mokameh, to be used 30 feet span. Roof to be pipes in mortar, with common tiles over.

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MEMO. BY MR. CARRICK.

You will at once see from the tracing the many advantages this has over the ordinary presses. One of the principal ones is the use of a clip block for keeping up the pressure on the bags when the screw is run back for more seed to be put in. In the old presses the bags spring back as much as 2 feet when the screw is run back, because there is no means of keeping up the pressure.

Five of them will produce 9,000 gallons of oil per month; but I should recommend not less than six or eight. The cost of each machine complete and ready for fixing will be Rs. 650, and they can be made in six weeks or two months from date of receiving order. I have arranged with Messrs Lackersteen and Co., of the "Hope Foundry," to make them if you decide upon having them, and I am certain that they will not only prove much superior to the ordinary presses now used, but their first cost will be less than that of the number of common presses which would be required to produce the same quantity of oil.

HENRY CARRICK.



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## No. LV.

# THE INDUS TUNNEL.

*Abridged from a Report upon the Indus Passage at Attock, on the line of the Trunk Road, and on the means of providing for it in the best and most economical manner, prepared agreeably to the Orders of the Government of India.* By Lieut.-Col. Alaric Robertson, *Superintending Engineer.*

The Fort of Attock is situated just below the junction of the Cabul river with the Indus, and at the gorge where the united rivers enter the hills, which extend from Attock to Kalabagh. The river gradually contracts in breadth as it approaches the fort, forming a sort of funnel mouth, the fort being situated at the neck; and at this point, the ferry, on the Trunk Road from Lahore to Peshawur, is worked. The bridge-of-boats is generally established just above the fort, and sometimes at the end of the season removed to a site some short distance below it; Attock is situated on the east or left bank, and on a spur of the hills which here run down to the river.

On the right bank opposite the fort, and extending up to the Cabul river and its junction with the Indus, the ground is comparatively flat, but the hills bound this small plain on the west and south, and run down to the river only a very short distance below the fort, and within rifle range of it. The old fort of Khariabad is on the south-east corner of this plain and nearly opposite that of Attock. These hills, of slate and limestone, are wild, broken, and rugged.

For many miles above Attock, the Indus flows in a wide divided stream (at no very high velocity,) through the plains of Chuch, but as

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it approaches Attock, the stream becomes contracted and united; the velocity increases, and it flows past the fort, in the hot season, with a velocity of about 13 miles an hour. Colonel Crommelin,* gives the velocity above the fort, at the site of the tunnel (his Bridge, No. 1) at 5 to 7 miles an hour in the cold, and 13 to 14 in the hot season, and surmises that it is higher at the fort, but was unable to measure it in the floods. I measured the velocity of the river and calculated the discharge in December 1860. The surface velocity of the river, given as 9 miles an hour at the centre, was the mean of several observations.

The contraction of the bed causes the river to rise to a great height, amounting to about 50 feet above the cold weather level of the stream in high floods of ordinary season; and a variation of level in the river, of from 5 to 7 feet in the course of the 24 hours, is not unusual.

In addition to the great height of the ordinary rise of the Indus, this river is subject to extraordinary floods, occurring at uncertain intervals, and caused by the damming up of branches of the river in the mountain valleys,† and the sudden yielding of the dam by topping or bursting. The only record we possess of these floods extends back but to 1841; from the most careful enquiries, the flood of that year appears to have risen 92 feet above the usual cold weather level of the river. The next flood occurred in 1858, and this from careful levels I found to be 80 feet above the cold weather level. There is nothing in the formation of the country, (*i. e.*, no other line of escape for the water,) to prevent a much more serious rise than either of these floods; and from the nature of their origin, there seems no reason why a much higher one should not occur at any time.

From the various causes above stated, the Indus passage at Attock is one of much difficulty and danger, and its improvement has occupied the attention of Government from the time of annexation, but up to the present, nothing has been effected beyond an improved boat-bridge in the cold weather, more efficient ferry boats for the hot season, and the addition of light row boats for the dâks, travellers, &c. I may here note, that the present ferry boats cross the stream by the aid of oars or sweeps, and are carried down a considerable distance by the strength of the current. The object aimed at, is to enter a back water which flows up river in certain

* In his Report of 1853, forwarding a design for a Suspension Bridge for two alternative sites.—[Ed.]

† By Land or Ice slips.—[Ed.]

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places on each side. If this is attained, the boat is carried up by the stream, or towed in slack water, to nearly opposite the starting point and with no great delay; but if the point is missed, the boat is either dashed against the rocks and sunk, or carried down river. The ferry boats are necessarily of moderate size, and in addition to the difficulties of access to the ferry (which might be improved), there is great delay in unloading and putting carts, cattle, &c., into the boats, and in again landing them. From the difficulties of the river, more commodious platform boats on which carts, &c., could be run, cannot be introduced.

The schemes submitted for the passage of this river have been numerous, but the only one really tried, was that by Colonel Taylor, of maintaining a bridge-of-boats during the hot weather. The experiment failed, and though no doubt the difficulties might have been overcome, had Colonel Taylor been permitted to persevere, yet success could only have been looked upon as a temporary expedient, liable to too many casualties to admit of its being depended on for so important a passage as the Indus at Attock.

At the present point, it may be advisable to enter somewhat into the detail of the importance of the passage, in a military and commercial point of view.

The force in the Peshawur valley, consists of from 7,000 to 8,000 men; all the reliefs, stores and supplies have to cross the Indus at Attock; Kohat and Bunnoo are also on ordinary occasions supplied by this route, but another route by Kooshealghur is open to them.

In ordinary circumstances, all reliefs are effected, and stores sent up during the cold season when the boat-bridge is up; and it is only invalids for Murree, &c., that suffer the inconveniences of the ferry; but in times of difficulty and danger the case is altered. During 1857, batteries of Artillery, troops of all descriptions, stores, &c., had to be passed, and the delay and exposure of the men in the height of the hot season was most serious; and though we may hope to be spared another mutiny, we must always look for emergencies on the frontier, to necessitate the movement of troops at all seasons. Any disturbance with the Kuttuck tribe, who claim the hills on the west bank of the river, might close the passage unless the occupation of these hills by our troops secured it for us.

The possibility of our position at Attock being turned by any of the lower passes, and our having to fall back for a time, will be referred to when considering the different means of crossing the river.

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In a commercial point of view, the trade is not very large, but still of such considerable amount as to call for some facilities being given, and to justify a moderate expenditure for that object alone. From the best information I have been able to obtain, the value of the trade crossing the Indus at Attock, amounted in 1855 to Rs. 14,87,786, and without doubt the trade has very much increased since then; the rent of the ferry at Attock in 1855 was Rs. 15,000; it is now Rs. 17,000. That the trade by this route can be much increased, I do not think probable, though every facility added to the route must have some effect, but the Afghan valleys are, I believe, cultivated almost to their utmost extent, and for the country beyond, the water carriage and shorter land route through the Persian Gulf for our own trade, and the Russian line by the Caspian sea, must limit our extension of trade through the Khybur.

I will now refer to the various projects brought forward with regard to this passage. We may divide them into—I. Those for passing the river itself. II. Those for passing *over* it. III. Those for passing *under* it. Under the first head we may class—1st, a Permanent Boat-bridge; 2nd, Flying bridges of various denominations; 3rd, a Steam Ferry.

I. Of the 1st, viz., a Permanent boat bridge—I have already I think said all that need be said on the subject; it is a temporary expedient, of too uncertain a nature, and too liable to accidents or wilful injury, to allow of its being considered as a permanent provision for the passage; though by the use of closed iron pontoons, and other precautionary expedients it might be maintained in ordinary circumstances.

Of the 2nd means, by Flying bridges—1st, by a barge anchored to a mooring in the centre of the stream, the cable supported on pontoons, and the barge crossing by the action of the current. The great variations in the level of the river would be troublesome, but the serious objection is the moving of masses of sand and shingle by the current, which would bury and run up the cable, and render it inefficient, while even if these difficulties were overcome, it would be but a temporary expedient liable to all the objections of a permanent boat bridge.

A flying bridge by a barge working on a cable stretched across the river, would also come under the head of a temporary expedient.* The varying level of the river would necessitate the lengthening and short-

* This I believe is about to be tried this season by Colonel Taylor.

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ening of the attaching cable, and consequent alteration of landing places; floating landing stages would be required on the edge of the back water, or up current, which exists at the sides, and into which of course the flying bridge could not be brought, and the landing stages must be connected with the shore (these objections also apply to the other description of flying bridge.) The dangers and difficulties of working such a bridge in a current of 13 miles an hour, especially when the river is falling and runs in high waves, would be great; and it is doubtful even if the barge was not swamped in such circumstances, whether with such pressure as there would be on the block, it would travel up the curve of the cable, after it has passed the centre of the stream. Lastly, what would be the fate of the barge in case of the breaking either of the carrying or attaching cable? If the former gave way the bridge would be stopped for the season, as the cable could not be replaced until the cold weather, as boats could not be anchored out for this purpose in the floods.

All the above expedients I think may be classed as of too temporary and uncertain a nature, and too liable to accidents, to meet the requirements of the Indus passage, though I enumerate them, as I wish to make the subject as full as possible.

The last of the schemes for passing *on* the river itself is by a Steam Ferry; this was fully discussed in 1858, and all the papers on the subject published in Vol. IV., No. 3, of the Punjab Selections, so I will only say that I can add nothing to what I then stated, but that late experience at home confirms my views that boats of sufficient speed could be easily obtained. The cost of such an arrangement is however I think a sufficient bar to its adoption. The tear and wear of boats of such high speed is enormous. It has been objected to a steam ferry, that no boat, however great the power, would be manageable in such broken water, at such a high velocity; I do not think that any difficulty would be found with a short handy boat, with plenty of power; though of course a very long boat would be open to these objections.

II. The next point I purpose to consider is the means of passing *over* the river. The first difficulty that presents itself is, with our records only extending back 20 years, and with a flood within that period which rose 92 feet, and a formation of country admitting of a rise very greatly in excess of this, even 150 feet, and the course such as would appear to have no fixed limit, where are we to place a bridge?

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Colonel Crommelin* in preparing his designs placed his bridge 96 feet over the low water level; this only gives 4 feet clear of a known flood, only 20 years back, while the land arches in his approaches would all be closed, even with a flood such as that of 1841; the next flood may be 120 feet, and what becomes of the bridge? These floods bring down trees, stacks of corn and fodder, huts, cattle, &c., so that even a clear space of 10 feet between the river level and the lowest point of the trussed railing or crown of arches, would not save the bridge from being carried away. But let us assume that some fixed height, 110 or 120 feet, is to be risked, what is to be the nature of the bridge? The spans should be large, for not only will the foundations be expensive, but every pier put into the river contracts the waterway, and will increase the height of the next flood, if the bridge is at the narrowest point; or contracts the water vent beyond that of the narrowest point in the immediate neighbourhood.

Colonel Crommelin gives the span of the flood of 1841 at the lower site as 1,400, and at the upper as 2,280; at the lower site, the flood extended much beyond this, but the water was shallow and probably of no high velocity; this may be said also of the upper site.

These spans are the least, I think, which would suffice for the length of the bridge. Colonel Crommelin fixes 1,125 and 1,890 feet, and proposes to provide for the great floods by the land arches in the approaches; the ordinary flood spans are given as 1,280 feet, and 1,880 feet; the width of roadway proposed, is 24 feet.

Colonel Crommelin admitting the necessity of large spans, selected the suspension principle as the cheapest means for this purpose, his estimate for the lower bridge was Rs. 9,68,635.

| | | | | |
|---|---|---|---|---|
| Suspension bridge,.. | .. | .. | .. | 8,42,651 |
| Approaches, .. | .. | .. | .. | 1,25,984 |

or about £3-12 per square foot of roadway for suspension bridge, not including the approaches.

The upper bridge he did not estimate. In this estimate the iron work is put down at £10 a ton, and the carriage from Kurrachee at Rs. 25. First quality bar-iron in England would cost from £16 to £18 a ton, and the chains for a suspension bridge with bolts, &c., would not I think be under £25 to £30 a ton; the Tehseeldar, at Attock, gave me the cost of freight from Kurrachee to Attock at Rs. 58 a ton.

* In his Report of 1853.

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Now let us compare this estimate with the cost of suspension bridges in Europe, and let us remember that the bridge for the Indus must be made at home; and to the cost of a home-made bridge, must be added the cost of bringing it out to Kurrachee, and up the Indus to Attock; and also the difference of cost between masonry in the Indus, 110 or 120 feet high, and that of bridges at home.

The difficulties of foundations in the Indus have yet to be tried, but without doubt they will be very great; steam power alone, and that of great extent, will keep down the water, and the quality of masonry must be very fine, and the mass great, to stand against a flood of 92 feet depth running against the piers with a velocity of probably 20 miles an hour, and carrying with it timber, stacks of corn, &c., &c.

I obtain the following from the "Engineer and Contractor's Pocket Book" for 1855. Hungerford bridge, consisting of one main and two half spans; between abutments, 1,352 feet; width of roadway, 14 feet; cost, £80,000, or £4·226 per square foot of roadway. Fribourg Suspension Bridge, (lower,) span, 870; width, 28 feet; cost, £107,000, or £4·4 per square foot. Menai Suspension Bridge, span, 580; width, 28 feet; cost, £120,000, or £7·388 per square foot; but this includes the cost of seven land arches of 52·6 span. If we deduct for this, however, £10,000, which is a full rate, it still leaves per foot, £6·77. This bridge is the only one to compare with the Indus in height, &c. The Hungerford Bridge is only 31 feet above high water; the Fribourg, though high over the valley, has its piers on the bank, little below the level of the roadway.

I regret I can find no more examples, but to apply those above given, and taking a low rate, say £5 per square foot, as the cost of a bridge in England, such as is required for the Indus; to this has to be added the cost of transport of the iron-work to Attock, with the machinery to put it up; but I will not attempt to estimate this, but take simply the English cost. We have Colonel Crommelin's lower site, 1,400 feet, and upper as 2,280, these are the spans of the flood of 1841, as far as the main stream is concerned, and take Colonel Crommelin's width of road, 24 feet.

$$1{,}400 \times 24 = 33{,}600$$
$$2{,}280 \times 24 = 54{,}720$$

which at £5 per square foot, gives Rs. 16,80,000 and Rs. 27,36,000, respectively, and taking Colonel Crommelin's spans,

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$$1{,}125 \times 24 = 27{,}000$$
$$1{,}890 \times 24 = 45{,}360$$

we get Rs. 13,50,000 and Rs. 22,68,000.

It is true that the span of the suspension bridge at the upper site might be reduced, and the floods attempted to be provided for by land arches in the approaches, but this would of course much contract the waterway, and I think, endanger the whole structure. This is as far as first expenditure, the cheapest bridge that could be made.

Now let us see the cost of a more permanent bridge, such as the Britannia Tube. This cost £14·22 per square foot; and as the difficulties of foundations and height may be considered similar, for the lower site, the cost without approaches, would be Rs. 47,77,920, and for the upper, Rs. 77,81,184, and what is to be added for bringing the material, machinery, &c., from Europe, and for approaches?

I do not enter upon the subject of Wooden Bridges, for I do not think in the situation, any one would advocate the use of such a material.

It now becomes necessary to consider the value of a bridge in all its bearings—1st, Military; 2nd, Permanence and current cost. It may be sufficient to look at the suspension bridge.

1st. A Bridge at the lower site is completely under rifle range from the hills, and the upper is still within long range. This of course could be guarded against by a sand bag parapet, or other precaution, but every movement could be watched; and a single gun in a short time would entirely destroy the bridge, by battering down one of the supporting towers. 2nd, in case of our having to fall back from Attock, we must either destroy the bridge ourselves, or leave it to the enemy to do so. The bridge on the Khairabad side would require to be covered by an outwork, which should probably be considered in dealing with the cost of a bridge.

As to Permanence, with a known flood of 92 feet, there is no room for ties to limit vibration vertically; we can only obtain this to a small extent by deep trussed railings; and for lateral vibration, the effect of storms, if ties are to be applied, it must be by lengthening the piers, and increasing greatly the cost. The risk of accidents from the march of troops, &c., is also always considerable, and from high winds at Attock, it would be serious even with lengthened piers and ties. Last season the bridge of boats was carried away by being forced up the stream against the strong current, by the violence of a storm; of course the narrower the



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bridge and the larger the spans, the weaker it is to resist this. The maintenance of a roadway, and an iron structure to be protected from the weather, would be heavy items, though the actual amount can only be calculated when a bridge is designed, but without doubt, it will not be less than equivalent to the renewal of the whole superstructure, *i. e.*, chains, roadway, &c., once in 30 years. For the cheapest bridge at the lower site, the estimate is Rs. 13,50,000, of this the iron-work and roadway would be about 12 lacs, or Rs. 40,000 annually for cost of maintenance; and this I consider low.

Of the uncertain existence of Suspension bridges, it is only necessary to refer to the constant accidents occurring. Scarcely a year passes that we do not hear of the fall of one, in spite of all the modern precautions and improvements.

A Tubular bridge at the upper site, would not be open to so many objections as a Suspension, either as to its military bearing or permanence, but it still would be open like the other to destruction by floods, and in case of our having to fall back.

With such a torrent as the Indus, there must be great difficulties to contend with in all schemes for passing on, or over it, and I have endeavoured to the best of my ability to state them in detail; but in the end, the real crowning objection to all schemes of the kind, is the extraordinary floods and the uncertainty as to their limits; we may theorize and argue, and fix for ourselves imaginary limits, but while the cause is such as is known in this case, and there is no other outlet within reasonable limit for the water, such an amount of real danger exists, as I think no Government would like to risk, if any other means was available of accomplishing the same object, avoiding that risk.

III. The last means of improving the passage is by passing under the bed by a Tunnel.

This scheme was first submitted by me in 1859, and the following is an extract from my Report of that year:—

"The banks of the Indus at Attock are of a compact slate rock, and this also extends across the bed; the rock is easily worked, and apparently not broken up by any great fissures which might endanger the work. In fact the situation is most favorable for a tunnel, and such a work meets all our difficulties. The floods and velocity of the river cease to be matters to be taken into account further than placing the entrances well beyond

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all risk. The military objections to an exposed bridge within reach of the cover of the hills disappear, and we secure a safe concealed means of crossing with every facility of closing it against an enemy without being forced to destroy or injure an important and expensive work. Once completed we have a permanent work available for the passage of railway or any other traffic, and free from the expense and wear and tear of any bridge or similar structure. The expense and difficulty attending the obtaining from Europe of the materials for a bridge, and the machinery for erection, which after use for the one purpose become almost valueless, are all avoided; and we only require the ordinary labor of the country, or our own Sappers and Miners.

The dangers and difficulties and expense of the Thames Tunnel are likely to occur to all, but we must remember that this work was carried through the loam and silt of the bed of the river, or the upper part of the London clay; while here we have a solid compact rock to deal with, and run no risk from the principal difficulties that beset the Engineer of the Thames Tunnel.

I will now proceed to consider the details of the scheme. The bed of the river has been carefully sounded and examined, and the detail is shown in the accompanying sections; the deepest part of the river is under the right bank, here I have reached the rock at two points at depths of 28 feet and 31 feet 4 inches; but at an intermediate point between them, I could not make sure of being on rock at 34 feet 8 inches. In the stream under the left bank I could not get a rod down, as the bed is of large shingle; but I think we have sufficient data to show that the rock is at no point 40 feet under the low cold weather surface of the river; and allowing a safe thickness of rock between the roof of the tunnel and bed of the river, I fix the upper level of the excavation at 60 feet under low water mark. The dimensions I purpose for the tunnel inside are 24 feet wide by 20 feet in height, and a lining under the river of brick masonry 2 feet thick. This places the foundation level of the roadway 82 feet under the low water level, and placing the entrances 100 feet above this level for safety, we have 182 feet to descend and ascend.

The grade I purpose is 1 in 20; this is rather steep for railway traffic, but offers no difficulties to ordinary traffic, and I think we ought not to sacrifice largely in present expense, to provide for a probability only, which I consider a Railway to Peshawur to be.

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The width of the river bed at the point I have selected for the tunnel is 1,215 feet, and this portion I propose should be nearly horizontal, having only an inclination sufficient for drainage towards the Attock bank. It would be more convenient, as the deepest channel is on the right bank, to have the inclination to this side, but I think it important that all the works connected with the tunnel should be on the Attock side under the protection of the fort.

The ascending grades commence from each bank of the river, and the height, 182 feet on the right bank, gives a distance of 3,640; and for 186 on the left bank (allowing a fall of 4 feet for the drainage) we have a distance of 3,720 feet; but deducting from these distances 660 and 700 feet, respectively, for open cutting, we get for the tunnel, 2,980 and 3,020 feet, or a total length of tunnel of 7,215 feet.

I propose to line the tunnel with brick masonry 2 feet thick under the river, and with masonry 1½ feet thick from the bottom of the ascent up to the low water level, or for 1,640 feet on the right bank and 1,720 feet on the left; beyond this I think the lining may be dispensed with on the left bank or Attock side, and on the Khariabad side as far as the rock extends, and for this I have estimated; in the clay on the Khariabad side of course the lining must be continued.

The Drainage I have provided for by a culvert 3 feet span under the centre of the road, with suitable openings for the admission of the surface drainage of the open cutting, and for any percolation in the body of the tunnel. This culvert terminates in a well at the bottom of a shaft on the Attock side, and I propose to provide a ten-horse power pumping engine for the purpose of raising the water.

The Ventilation I propose to effect by means of ten shafts, 9 feet diameter, which will also be used as working shafts during construction. These shafts are 600 feet apart, except under the river, where the distance between the shafts on each bank is 1,580 feet. I have given the diameter of the shafts as 9 feet; this is the case with all the shafts but the one to be used for the pumps, &c., which is increased to 10 feet. These shafts are lined throughout with 1 foot thick of brick masonry, and where situated within the influence of the river flood, are carried up in massy columns formed as cut-waters on the up river side; the tops of the shafts are covered with iron gratings to prevent accidents from stones or other substances falling down them.

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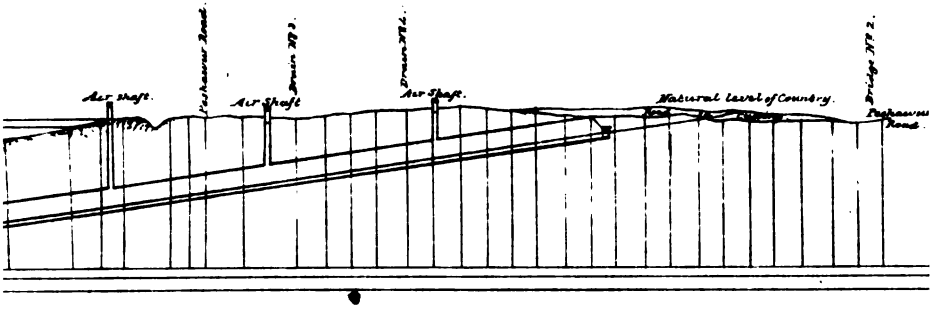
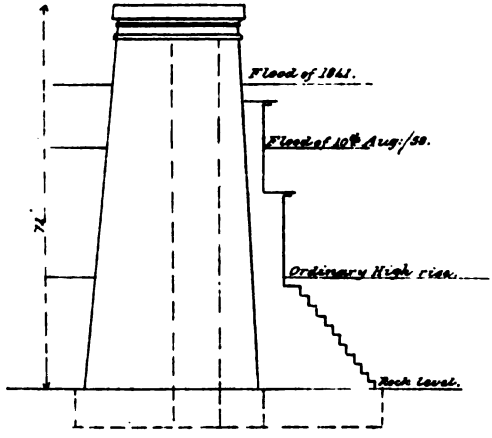
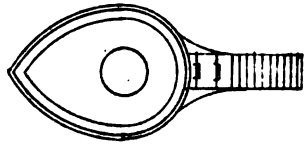



Air Shaft N° 1 West Side.

Elevation




Plan.



Scale 36 feet = 1 inch.

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In the cold weather the ventilation will be very active, but in the hot season when the temperature in the tunnel will be generally lower than the external air, it may be necessary to apply artificial means; and this is provided for by a Steam Jet in the Pumping Shaft, and by gas burners in the others.

The Lighting I propose to effect by means of Oil Gas, manufactured on the spot and distributed to lamps placed at intervals of 25 feet. In general the lighting of every alternate lamp will be found sufficient."

In consequence of that report the sum of Rs. 10,000 was sanctioned to enable a trial drift to be commenced, and on the 12th March 1860, the sinking of shafts was begun by the Pioneer Regiment, which was placed at my disposal for the purpose.

When the shafts were sunk, it was found that pieces of rock were constantly becoming detached and falling down, endangering the workmen; this necessitated the lining the shafts at once; which though part of the estimate of the completed tunnel, was not contemplated in the first experiment. When the river rose in June, the leakage through the upper rock, at the west shaft, became more than means could meet, and necessitated a suspension of work for some months on that shaft, though endeavours were still continued to keep down the water.

In January 1861, finding that the original grant was likely to be exceeded, I reported at once, and a second amount, Rs. 10,770 was sanctioned. It included a horse-jin for raising water from the west shaft, (which was our great difficulty). Delay arose in the supply of the necessary machinery from Roorkee, and again work was stopped from May to November 1861, while great expense was incurred on temporary expedients to supply the place of the horse-jin; a heavy slip in the east gallery also occurred, and that, with the increase of water, caused a suspension of work on this side also for nearly three months. Again, in the hot weather of 1862, the main shaft of the horse-jin, (which had been made of cast, instead of wrought-iron, as I intended,) gave way and stopped work, the machine being fully up to the duty when in order.

The cost of the drift, Rs. 59,300, inclusive of working pay to the Sappers and Pioneers, having much exceeded the first rough estimate, led to the inference that the estimate for the tunnel would be found equally insufficient, and Government decided upon a suspension of the work until the matter could be thoroughly investigated.

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My original estimate, made before ground was broken, was necessarily very rough; and as stated in my report, the actual probable cost could not be definitely fixed until the gallery was carried under the deep water channel of the river, and until the true cost of the machinery to be obtained from Europe was ascertained.

Work on the galleries was stopped in November last, when only 258 feet remained to complete the junction across the river.

The work done is as follows:

| | cubic feet. |
|---|---|
| Excavation in rock under ground, .. .. | 100,684 |
| Excavation of rock above ground, .. .. | 6,090 |
| MASONRY. | |
| Rubble under ground, .. .. .. | 13,200 |
| „ above „ .. .. .. | 18,262 |
| Brick under „ .. .. .. | 9,876 |

Rating off the masonry and work above ground at the estimated rates, we get the real cost of the under ground excavation at Rs. 50·68 per 100 cubic feet, which, deducting the value of the plant on the ground, is reduced 41·08 Rs.; or if executed by coolies in the ordinary way, instead of by Sappers, to Rs. 38·56.

The galleries from first to last have cost from 30 to 40 Rs. per foot run, or about from 120 to 160 Rs. per 100 cubic feet, and the shafts Rs. 18 per 100.

| | Square feet. |
|---|---|
| Now the area of the gallery was, .. .. .. .. | 25 |
| The mean of the shafts, .. .. .. .. | 104 |
| And the tunnel will be, .. .. .. .. | 560 |

The cost of galleries was therefore about eight times the cost of shafts, and the areas as 1 to 4. The tunnel is more than four times the area of the shaft; in the same proportion, it ought to cost about 2-8 per 100, or Rs. 25 per 1,000. But of course this is too low, as material has to be raised, and there is more expense of stores, &c., &c. It is the cost of mining which is so much reduced. But we, I think, are perfectly safe in saying that as the

| | |
|---|---|
| Galleries cost, ... ... ... ... | 150 per 100 |
| The shafts, ... ... ... ... ... | 18 „ |
| The tunnel will not exceed half that, or, ... ... | 9 „ |

and this includes every charge. With the steam engine for pumping,

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and even with horse-jins until it arrives, and with well organized establishments of all kinds, exactly suited to our requirements, (now well known,) I do not believe the work will cost half these rates.

To conclude this part of the subject, I will compare these rates with the cost of work in England.

The only work of the kind of which I have full details is Blechingly tunnel, on the South Coast Railway, 24 feet wide, and 21 feet high, through sandstone rock, shale, and weld clay, with considerable quantity of water. Total cost per yard run £71-18-7, say Rs. 719.

The cost of the drift and shafts together, was at the rate of Rs. 19·5 per 100 cubic feet, against our rate of Rs. 38·56.

The main excavation of Blechingly tunnel cost 6·1 per 100. Drift and shafts, 19·5. Apply to our rate, 38·56, the same rule, as 6·1 is to 19·5, we get 12·00 per 100. This should, I think, give confidence in the above calculations of rates.

The original estimate for the tunnel submitted by me, was Rs. 5,18,952, but after the galleries had been commenced, I made use of the data then obtained, and raised the amount to 6 lacs; the machinery still remaining an uncertain item.

Colonel Taylor submitted an estimate for an enlarged tunnel with reduced gradients or benches in approaches, but this when reduced to the original project, amounted to about 10 lacs.

In the estimate I now submit, I have adopted Colonel Taylor's rates in every case, except where my own deductions from the experience of the drift, led me to think he had estimated too low, or where other known rates exist. The machinery in his estimate, is of course equally imperfect with that of my first estimate, and in this case, I have substituted the tenders of firms at home.

I adopt Colonel Taylor's rates in preference to exercising my own judgment, as I know, however much we may endeavour to guard against it, yet when the value of a scheme is to be judged entirely by cost, there is a tendency in the projector to pinch and cut down, and at least to run an estimate very close. Even the estimate of one favorable to the scheme would be liable to the same fault, but in Colonel Taylor's I have that of an officer who has always opposed the scheme, and entertains ideas of its great costliness, as compared with a bridge.

The estimate I now submit amounts to Rs. 10,44,076·379, and to shew

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how this tallies with the cost of tunneling at home, I annex the cost of some of the principal tunnels in England.

| | | £ | s. | d. |
|---|---|---|---|---|
| Blechingly tunnel, blue clay, shale, and sandstone rock, | per yard. | 71 | 18 | 7 |
| Saltwood, middle beds of lower green sand (water,) | „ | 118 | 0 | 0 |
| Merstham, chalk, ... ... ... ... | „ | 63 | 0 | 0 |
| Clayton, chalk and sandstone, ... ... | „ | 57 | 0 | 0 |
| Edinburgh and Dalkeith, clay, ... ... | „ | 20 | 0 | 0 |
| Leeds, shale, coal measures and rock, ... ... | „ | 25 | 0 | 0 |
| Kilsby, ... ... ... ... | „ | 125 | 0 | 0 |
| North Shields, ... ... ... ... | „ | 16 | 10 | 0 |
| Royston, red sandstone and bind, ... ... | „ | 50 | 0 | 0 |
| Claycross, ... ... ... ... | „ | 100 | 0 | 0 |
| Mean of 10, ... ... | | 640 | 0 | 0 |
| Indus tunnel, estimate now submitted, Rupees, ... | | 10,44,076·379 | | |
| Rate, per yard run, ... ... ... | | | | 435 |

The width of the above tunnels is stated to be from 24 to 30 feet, and the height the same, while the Indus is 24 × 20. Our saving is in masonry.

The rates I have adopted are as follows:—

| | | |
|---|---|---|
| In excavation under river, Colonel Taylor's rate of, .. | 100 | per 1,000 |
| In approaches, rock „ „ „ .. .. | 80 | „ |
| In approaches, clay „ „ „ .. .. | 30 | „ |
| Footway and in shafts, I have taken a higher rate than Col. Taylor, as the data of the drift done shews this should be so, Colonel Taylor takes 80, I take, .. .. .. | 150 | „ |
| Open cutting, .. .. .. | 16 | „ |
| Clearing ground, „ .. .. | 10 | „ |
| Masonry under ground rubble, } Colonel Taylor's rates, .. { | 16 | „ |
| „ „ „ brick, } | 35 | „ |

Shoreing, I have made Rs. 5 per foot, instead of 3, by Colonel Taylor. Drift gallery under river, Rs. 40 per foot run; on descent, Rs. 20; in excess of Colonel Taylor's rates, though a part of this is in clay, and the distances between shafts short.

Pumping, as per separate estimate.

The Lighting is fully provided for in the rates and not taken separately.

I will now endeavour to reply to the objections made to the details of the scheme, and add any further explanation that may seem necessary beyond that given in my original report.

The site selected is not the narrowest part of the river, but it is that where the appearance of the rock promises best for continuity and soundness; where the bed is shallowest, and least disturbed (being above the

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neck of the funnel) and is favorably situated as regards access from the Trunk Road. I believe rock would be found all across the river at the fort, the only accessible point where saving in width could be effected, but here the depth of the river is much greater, so that the length of approaches would be considerably increased, and the depth of the shafts, and consequently cost of all the work be much greater. Mr. Medlicott, in his report, expresses his opinion that the site in all respects is the best, and an inspection of the accompanying plan will enable a judgment to be formed on this point.

The width and gradient of the approaches have been objected to.

As to width, 18 feet roadway and 6 feet footpath, or a total of 24 feet is the size proposed; 18 feet is quite sufficient for the easy passing of two conveyances, and with a limited traffic such as that at Attock, what more can be required? but as this matter has been disposed of by the Supreme Government, I will not enter further on the subject.

With regard to the gradient, or slope of the approaches, as I have already shown, the amount of traffic is not heavy, the length of the ascent or descent is under three-quarters of a mile, and therefore no great pull upon the cattle. The grade of 1 in 20, is in modern days considered a little too steep for very fast traffic, but not so much so, for slow. The usual standard for roads in England, except in exceptional cases, is 1 in 30; but these exceptions, even on the first class mail roads, are common. On the London and Cambridge road, at Stamford hill, the inclinations on both sides is at 1 in 20. On the Chingford road, there are still slopes of 1 in 8 and 1 in 9. On the London and Chipping-ongar road at Wilcox Green, the inclination for a considerable distance is 1 in 20, and again at Chigwell Vicarage it is the same. On the London and Dover road, one of the most important roads in the kingdom; from Deptford to Blackheath, the slope is 1 in 17, at another place 1 in 14, at another 1 in 11, and again 1 in 14; at Shooter's Hill, 1 in 18; further on, 1 in 11, 1 in 16, and 1 in 18. In the greatest thoroughfare in the city of London, we have Holborn Hill, with slopes in some parts of 1 in 16½; the same on Snow Hill. Surely this is enough to shew that there can be no serious objections to a gradient of 1 in 20 at Attock, with our very moderate traffic.

The following is the rate of inclination of a road, at which a carriage of any kind would descend of itself, for the different descriptions of



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road covering. The calculations are from Sir John McNeil's experiments.

| | |
|---|---|
| Broken stone surface laid on old flint road, .. .. | 1 in 34 |
| Gravel road, .. .. .. .. .. | 1 in 15 |

and as the roadway of the tunnel is to be of gravel, the road is long within the limit when there would be even a pressure on the bullocks in descending.

There is no disputing that an easier gradient would be an improvement, but it is a simple matter of money; every reduction in the gradient increases the length of the tunnel, and not only adds most materially to the original cost, but to the permanent expenses, in lighting, &c., and I can only say, in my opinion the gradient is fully sufficient for the situation, and the demands of the traffic; and I support my opinion by shewing that steeper slopes were tolerated on the most important roads in England, when roads were all in all, and are now tolerated for what traffic remains.

There are a few points in my original report in which I have made modifications and these I will now note.

I originally proposed to line the tunnel throughout with brick masonry, but the fine quality of the stone in the gallery, has induced me to make the side walls of rubble masonry, using brick only in the arch overhead.

The Steam Engine was erroneously put down as one of 10-horse power, I wrote shortly after submitting my report to correct it to one of 25, and further consideration and consultation with Mr. R. Napier, of Glasgow, has induced me to adopt two small engines of about 15-horse power each, with pumps, &c., complete. The advantages are economy, in only working a small engine instead of a large one, when one is sufficient; and second, always having one available, in case of one being out of order and under repair; while the cost of two small engines is little in excess of one. The specification and tenders for the machinery are all attached to the estimate.

For the Ventilation in each shaft I have provided a sunburner of 16 lights.

Regarding the details of the Gas Machinery, &c., the specification was prepared by me after visiting Frankfort-on-the-Maine, the last city in Europe in which oil gas was used, and getting every information from the engineer of the gas-work, who had been in charge when oil, resin, &c., were used. I had also communication with the principal gas engineers in

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London, and consulted with the engineer who makes the tender, and adopted some improvements suggested by him; and I believe I have gone into the subject in full detail.

Regarding the Lighting I have only to add that one lamp at every 50 feet, as stated in the report, will fully light the tunnel (in broad streets at home the lamps are generally at 100 feet intervals) and that at night, the consumption of gas will be reduced to a minimum, by turning it down at the governor, so as simply to leave a glimmer.

As it is quite within the limits of possibility that we might have to fall back from Attock for a time, I have provided a 12-inch siphon, to be built into the masonry of the west shaft at the level of the top of the rock, or about 25 feet above the cold weather level of the river; the pipe to be carried down the shaft to the level of the floor, and end in a short turn up the shaft; the pipe is provided with a valve, to prevent water entering during the ordinary rise, and there is also an air pump to exhaust the air, and put the siphon in action. This may appear an unnecessary precaution, and it is a point for Government to decide, but its cost is not great and I think it is worth adopting.

I may here state that the Tunnel entrances and the air shafts as estimated, are 100 feet above the cold weather level of the river; and though precautions might be taken to keep out even a higher flood than this, if due warning were given, still we must be prepared for the filling of the tunnel, by an extraordinary flood.

In the Tunnel there is nothing to injure, and the only thing would be the removal of the water, through the siphon provided for filling the tunnel, or by the footways; the water would flow off as the river fell, to a level a little higher than that of the river, and in eighteen or twenty days the steam engines would remove the remainder.

In the present estimate I have provided a small footway on each side of the river, at a grade of 1 in 2, for the use of workpeople, instead of lowering and hoisting them up and down the shafts, which now is a serious item of cost. The path will also be available when the work is finished, for foot passengers to the Fort of Attock, and town of Khariabad; this footway I propose to make 8 feet × 10 feet.

To conclude the subject of the complete Tunnel, it only seems necessary to enter on the current expenses of the work. I annex a separate estimate of this in full detail, including all establishments, &c. It amounts to Rs.

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15,966·45, and as the revenue of the ferry is at present Rs. 17,000, all Government stores, troops, &c., passing free; even allowing for no increase in traffic, the sum of Rs. 1,033·55, becomes a saving; and even if petroleum should fail, and oil be used, the cost would only be Rs. 23,529.

This estimate of current cost is a liberal one, and I think it is more than likely than on it considerable saving may be effected, principally in gas and fuel.

Agreeable to my instructions, I have endeavoured to go into the whole subject of the Indus passage and of the means of effecting it, as fully as possible; I have no doubt there is in this report a strong leaning in favor of my own project, but I trust I have still stated the whole case sufficiently, fully and fairly, to enable Government to decide in the matter.

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ESTIMATE framed by Major A. Robertson, Superintending Engineer, of the probable cost of constructing a Tunnel under the river Indus, with approaches at a gradient of 1 in 20.

SPECIFICATION.

The Tunnel to be 24 feet wide and 20 feet high; to have a cart roadway 18 feet wide, covered with shingle metal 1 foot thick, and a footpath raised 1 foot above the cartway, and with a cut-stone curb on the outside; the footway to be covered with 6 inches of fine sifted shingle, rammed.

The Tunnel throughout to be lined with masonry, the side walls of selected stone from the excavation, and the arch overhead of brick, all laid in hydraulic mortar; the thickness of the lining to be 2 feet under the river bed, and 1½ for the remainder of the tunnel.

A Culvert 8 feet wide and 1½ deep, to run under the centre of the roadway throughout the tunnel, and to terminate in a well under the pumping shaft, to be excavated in the rock and arched over with masonry 1½ foot thick, and through the clay to have an invert and side walls.

When the rock is sound there will be no invert to the tunnel, but through clay or unsound rock there will be an invert of stone from the excavation, laid in hydraulic mortar, 1½ foot thick, except under the river where it will be 2 feet thick.

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The Drainage from the open cutting at each end not to be carried down into the tunnel well, but discharged by a small tunnel 4 × 3 feet, leading out to the low ground from the mouth of the tunnel, where a suitable well and cross drain will be formed for the collection of the water; this outlet or discharge tunnel will be closed by a trap of cast-iron with planed gun-metal faces, built into the masonry, and which while allowing the discharge of the surface drainage will prevent the entrance of water in case of a flood.

Air Shafts 9 feet internal diameter, lined with 1 foot thick of brick masonry, to be formed at intervals of 600 feet, except at the river section, where the interval is 1,515 feet; the shaft on the left bank, which is the pumping shaft, is 10 feet diameter instead of 9 feet.

Cast-iron curbs in 4 pieces, bolted together, and cast with recesses for the bonding in of the brick-work, to be provided for the junction of the brick lining of the air shaft with the arching of the tunnel.

The air shafts where situated within the influence of floods to be carried up in massive rubble masonry columns, formed as cut-waters on the upper side, as shewn in the detailed drawings accompanying, and to a height of 100 feet above the cold weather level of the river.

The air shafts to be covered with wrought-iron gratings and wire nettings to prevent accidents in the tunnel by substances dropping down; iron cramps and masonry blocks, as shewn in the drawings, to be provided for placing ladders to ascend the shafts for repairs or other purposes.

The shafts carried to any height to be provided with lighting conductors, iron rod $1\frac{1}{2}''$ thick, and carried 8 feet above the top of the shaft, and, at least 10 feet down into the soil, and away from the masonry of the shafts.

The Tunnel under the river to have an inclination of 1 in 300 to the Attock side, for drainage, the ascents to commence from the banks on each side and to be at the rate of 1 in 20.

Two Pumping Engines with pit gear complete, as per separate specification, to be provided for keeping the tunnel clear of water, and a steam jet to be provided in the pumping shaft supplied from the engine boilers to promote ventilation.

A small donkey engine to supply the gas work with water, and also to drive the tools in the workshop, with pipes and shafting to be provided; also a turning lathe of 6 inches, and another of 12 inches with drilling, planing, and slotting machines, for repair of steam and gas machinery.

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The Tunnel throughout to be lighted with Oil Gas manufactured on the spot. The gas machinery, as per separate specification and drawings, &c.

The Gas lamps to be fixed on iron brackets projecting from the side of the tunnel over the footway, the lamps to be provided at 25 feet intervals, but only each alternate lamp lighted, except on extraordinary occasions; this will be found amply sufficient for the clear lighting of the tunnel, gas to be laid on in the engine house, gas sheds, and quarters for the establishment.

In the 9 feet ventilating shafts, sunburners of 16 lights each, to be provided for ventilation.

The necessary governors, cocks, metres, &c., to be provided as per separate specification.

Engine house, gas sheds, and boiler sheds with iron roofs, and suitable quarters for the establishments to be provided; also a workshop, stores, and work godowns.

The culvert under the roadway to be provided with cast-iron man-holes built into the masonry with suitable frames, placed at 300 feet intervals, to admit of men going in to clean the culvert.

A Siphon 12 inches internal diameter to be provided for the purpose of filling the tunnel with water, in case of having to abandon it, or fall back from Attock.

The siphon to be carried down into the river 3 feet below the low water level on the right bank close to the masonry shaft, to be carried through the masonry at the level of the ground and down the shaft to the floor of the tunnel, where it is to terminate in an upper turn so as to point direct up the shaft, a valve of the ordinary conical seat construction, to be placed on the pipe 6 feet under the low water level of the river, and with a rod suitably supported carried up to a stage fixed in the shaft above the ordinary high flood level of the river. On the stage a suitable air pump to be placed with a pipe connecting it to the siphon, to exhaust the air when necessary and put the siphon in motion.

A small gas apparatus, as per separate specification, to be provided for the purpose of testing the various substances procurable and suitable for the manufacture of gas.

Jins to be provided for raising the material, water, &c., while work is in progress.

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A small footway 8 feet wide and 10 feet high, at a grade of 2 to 1 to be formed on each side for the use of the workpeople, &c.

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ABSTRACT FOR COMPLETE TUNNEL.

| | | |
|---|---|---|
| r. ft. | | |
| 285· | Drift gallery under river, at Rs. 40, - - - - | 11,400· |
| 4,700· | Rock in approaches, at Rs. 20, - - - - | 1,14,400· |
| 1,020· | Clay „ „ - - - - | |
| c. ft. | | |
| 6,97,341·35 | Rock excavation under river, at Rs. 100 per 1,000, - | 69,734·135 |
| 28,14,351·54 | „ in approaches, at Rs. 80 per 1,000, - | 2,25,148·123 |
| 1,07,325·048 | „ in footway and shafts, at Rs. 150 per 1,000, - - - - | 16,098·757 |
| 4,450· | „ in drainage tunnel, at Rs. 150 per 100, | 6,675· |
| 3,000· | Rock excavation, in discharge from open cutting, at Rs. 60 per 100, - - - | 1,800· |
| 3,23,071·25 | „ in open cutting, at Rs. 16 per 1,000, - | 5,169·140 |
| 50,263·800 | Foundation in hard rock, at Rs. 16 per 1,000, - - | 804·220 |
| 25,002· | „ in clearing ground, at Rs. 10 per 1,000, - | 250·020 |
| 56,032· | „ in gas tanks, &c., at Rs. 20 per 1,000; - | 1,120·640 |
| 6,97,098·048 | Excavation in clay under ground, at Rs. 30 per 1,000,- | 20,912·941 |
| 21,45,611·924 | „ in open cutting and embankment, at Rs. 3·8 per 1,000, - - - - | 7,509·641 |
| 5,16,865·23 | Rubble masonry under ground, at Rs. 16 per 100, - | 82,698·436 |
| 1,97,020·797 | „ in retaining walls, &c., at Rs. 16 per 100, - - - - | 28,643·327 |
| 3,064· | „ in traps and doors, at 16 Rs. per 100, | 490·240 |
| 11,566·66 | Brick and rubble masonry in entrances, at Rs. 20 per 100, - - - - - - - | 2,313·332 |
| 25,726· | Rubble masonry in houses, &c., at 16 Rs. per 100, - | 4,116·160 |
| 8,95,152·05 | Brick „ under ground, at Rs. 35 per 100, - | 1,38,303·217 |
| 1,497·41 | Timber in shafting, at Rs. 1·8 per cubic foot, - - | 2,246·115 |
| s. ft. | | |
| 1,922· | Roofing in main building, at Rs. 30 per 100, - - | 576·600 |
| 880· | „ in verandahs, at Rs. 22 per 100, - - - | 193·600 |
| 1,520· | „ rough, at Rs. 15 per 100, - - - - | 228· |
| 320· | Flooring slate slab, at Rs. 24 per 100, - - - | 76·800 |
| 764· | 350 doors and windows, glass and pannelled, at Rs. 1 per foot, - - - - - - - | 350· |
| | 414 battens, at Rs. 0-12-0, - - - - - - | 310·500 |
| c. ft. | | |
| 1,49,711·25 | Shingle metal, at Rs. 15 per 1,000, - - - - | 2,895·018 |
| 14,490. | Cut stone curb, at Rs. 12 per 100, - - - - | 1,731·600 |
| lbs. | | |
| 2,000. | Cast-iron, - - - - - - - - - - | 250· |

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ABSTRACT FOR COMPLETE TUNNEL (*Continued*).

| | | |
|---|---|---|
| lbs. | | |
| 3,535·379 | Wrought iron, at Rs. 22 per 100, - - - - - | 777·783 |
| | Godown and workshops, temporary, - - - - - | 3,000· |
| | Overseers' quarters, „ - - - - - | 1,500· |
| | Engineers' quarters, permanent,- - - - - - | 4,000· |
| | Machinery, as per separate estimate, - - - - | 1,29,895· |
| ft. | | |
| 7,200 | Shoreing, at Rs. 5, - - - - - - - - | 36,000· |
| | Pumping for 5 years, at Rs. 4,470, - - - - | 22,350· |
| c. ft. | | |
| 4,160· | Flooring footway, at Rs. 20 per 100, - - - - | 832·000 |
| r. ft. | | |
| 180· | Ladders, at Rs. 2, - - - - - - - - | 360· |
| | Clearing out water, re-laying rails, putting machinery in order, &c., - - - - - - - | 4,000· |
| | Total Rupees, - - - | 9,49,160·345 |
| | Contingencies 10 per cent, - - | 94,916·034 |
| | Grand Total Rupees, - | 10,44,076·379 |

A. ROBERTSON, MAJOR,
*Superintending Engineer.*

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# No. LVI.

## MILITARY BRIDGES.

*Some Remarks on Military Bridges.* By Lieut.-Col. A. Cowper, R.E.

In this paper it is proposed to discuss in as succinct and practical a manner as possible the principles and practice of Military Bridge making, and thence deduce the constructive details which will subserve most completely all these conditions.

An instructive experiment in connection with this subject was made in the latter part of 1859 at Poona, under the orders of Sir Hugh Rose, with the Blanshard Pontoons, and the result is shown in the 6th paragraph of the report, which was submitted in consequence by the writer, who then Commanded the Bombay Sappers and Miners by whom the bridge was laid, and which report is below set down at length.

*To the Quarter-Master General of the Army.*

Sir,—In compliance with the wish of His Excellency Sir William Mansfield, that I would state the comparative merits of the Austrian and English systems of Pontooning, as represented by Byrago and Blanshard, I shall have the honor of describing each system and its capabilities in as few words as I am able, and then of estimating each by the standard of practical adaptability to the requirements of actual service generally.

English or Blanshard's System.—The English system at present in use is one instituted by Colonel Blanshard of the Royal Engineers, as an improvement upon Pasley's. It consists, like every other Military Bridge, of supports and superstructure. The former are water-tight tin or copper cylinders with curved ends, and are called Pontoons. The latter consists



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of beams, which extend from one pontoon to the other, and planking, which is placed across the beams; these, in professional phraseology, being termed Balks and Chesses. It is not necessary in this brief sketch that I should proceed to give details that refer to points of internal economy, regarding the suitability of which to their own system there is no question, but that I should rather draw attention to those points of general efficiency and usefulness on which the merits of the two systems must stand or fall. I will, therefore, omit the minutiæ that are laid down in the Drill Book used at Chatham, and proceed first with a brief outline of Blanshard's system, and afterwards of Byrago's.

Easy adaptation to the beds and banks of every variety of stream; stability and firmness as a bridge during the passage of heavy Artillery and Cavalry, strength and durability as an article of Army equipment, and, lastly, portability in transit, seem to constitute the main, and indeed the essential, elements of a good Pontoon system. I have already (in a previous letter) drawn attention to the floating supports of the Blanshard Bridge, which, as I shall hereafter show, affect its adaptability to beds and banks of a certain character, no less than its firmness as a bridge under the passage of Artillery, and its durability as an article of Army equipment. It now only remains for me to describe its portability; any advantage that it may gain in this particular is met by sacrifices of far greater importance than are consistent with efficiency.

A tin Cylindrical Pontoon weighs 565 lbs., and its buoyancy is 7,369lbs. The bridge may be made capable of bearing a greater or less amount of weight by adjusting the Pontoons close together, or wider apart, as follows:—

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| For Siege Artillery, .. | .. | 8 | feet | 2 | inches | apart | from | centre to centre. |
| For Light Artillery, .. | .. | 10 | „ | 4 | „ | „ | „ | „ |
| For Cavalry and Infantry, | .. | 12 | „ | 6 | „ | „ | „ | „ |

The Balks are about 14 feet long by 4½ inches deep by 8 inches broad.
The Chesses are of deal planking about 1½ inches thick.

Such a bridge ought to be lighter than any other, owing to the slight dimensions of the scantling; but, as I have just observed, the advantage that is gained in that respect is more than counterbalanced by the sacrifice of firmness in the roadway, and want of durability in the materials. The system, too, of obtaining buoyancy by bringing the Pontoons close together is open to the objection that it obstructs the current of the river, and ren-

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ders the anchors liable to drag, or the cables to snap, and thus endangers the whole bridge.

A bridge, too, which depends entirely upon floating supports is, of course, useless in all cases (and they are of frequent occurrence in India) when these supports cannot be applied throughout from bank to bank. Where, moreover, the banks of a river are high and precipitous, the water shallow, the bed of the river unfavorable to anchor in, or where the stream partakes of the nature of a torrent, Blanshard's Bridge could not be used; neither could it be constructed where the obstacle is of a dry nature, such as restoring the broken arch of a bridge, passage of a dry, muddy nullah, marshy ground, &c., &c. We are, therefore, limited in its application to those places where the section admits of the use of floating supports throughout, and where the banks permit of the approaches being sloped with but little trouble at an easy gradient to the level of the roadway; consequently, the situations where it can be used are so restricted as to be very seldom available in the presence of an enemy, and even when such favorable spots are met with, it can only be considered an Infantry Bridge, for we have proof that the passage of Artillery and Cavalry, but more especially of the following of an Indian Army, would, even under the greatest care and best arrangements, disable it; so slight is the construction and liable to injury of both the scantling and the pontoons themselves. I am not aware of any instance where this bridge has been used on actual service for the passage of Artillery and Cavalry, but in the experiment made towards the end of 1859 at Poona, under His Excellency Sir Hugh Rose's orders, we had ample proof in corroboration of similar examples at home and elsewhere, how, even under the most favorable circumstances, the oscillation of the whole bridge and the deflection of the roadway frightened the horses and led to a serious accident, in which gun and limber, with team and drivers, were plunged into the river; fortunately, the water was not more than 4 or 5 feet deep in the part where the accident occurred, otherwise several lives might have been lost. The general impression of every experienced observer present was, I believe, that such a bridge was, as I have before observed, only fit for Infantry, and as such quite inapplicable to the purposes of general service in the field. To depend upon it for effecting a retirement across the most insignificant stream in the face of an enemy, on a far smaller scale than that effected the other day by the Austrians in presence of the French forces at Solfe-

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rino, would be utter folly, as the least crowding or confusion could not fail to be attended by, at least, the interruption of the communication across the river, and, probably, heavy disaster in consequence.

The violent oscillation of the whole bridge I attribute entirely to the character of the light floating supports, and the great deflection of the roadway under a team of horses and a 6-pounder gun to that cause, as well as the flimsy planking and superstructure generally. I am convinced that the first evil will always result more or less from the exclusive employment of floating supports, even were those supports firmer than the copper pontoons are; and I can see no remedy for this evil to be compared with the superior principle of combined fixed and floating supports embraced by the Byrago system, to which I shall now have the honor of adverting.

Austrian or Byrago's System.—In considering this system it is difficult to say which is the most to be admired,—the principles on which it is devised, or the constructive ability shown in the details. The supports are of two kinds, fixed and floating; the first called trestles, and the latter pontoons, so that, according to the nature of the obstacle, a bridge can be made, capable of bearing Siege Artillery, either of fixed or floating supports, or of a mixture of the two. It follows from this that double supports are carried with each equipage, and that about half are used and half in reserve in every formation of bridge.

*Austrian Pontoons.*—The Austrian Pontoons are of wood, undecked, and are of two shapes, shown in the plan, called a Bow and Middle-piece. The weight of each is about 6 cwts. and buoyancy 9,800 lbs. These can be used as row or sailing boats, and on any river, however strong the current. They are provided with canvas bulwarks to be used in rough water, so that the waves cannot beat in.

Any number of these Pontoons can be coupled or linked together by means of iron fastenings, so as to give great buoyancy for flying bridges, and ferry or sailing boats. A boat of 5 Pontoons linked together, 2 bow-pieces at the ends, and 3 middle-pieces in the centre, would form a well proportioned double-ended boat of about 60 feet long, and 20 tons burden; and if two of these were lashed side by side, a vessel of 40 tons extreme burden would be formed. As supports to an ordinary bridge, two pieces, a bow, and middle-piece linked together, would be sufficient for the passage of Siege Artillery, and would form no greater obstacle to the stream than

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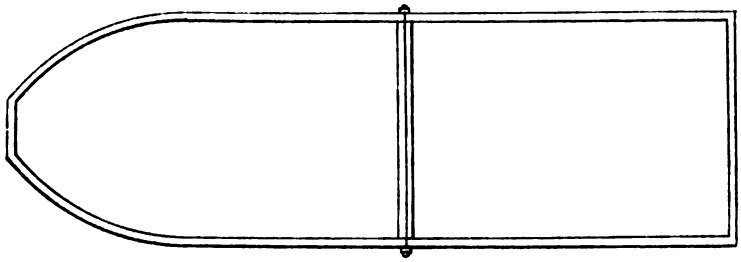
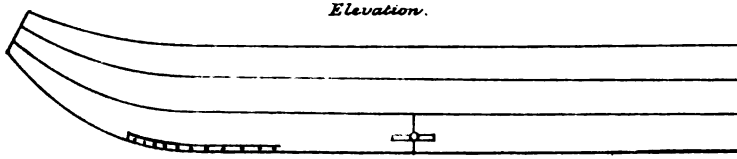
# MILITARY BRIDGES.

## Austrian Pontoons.

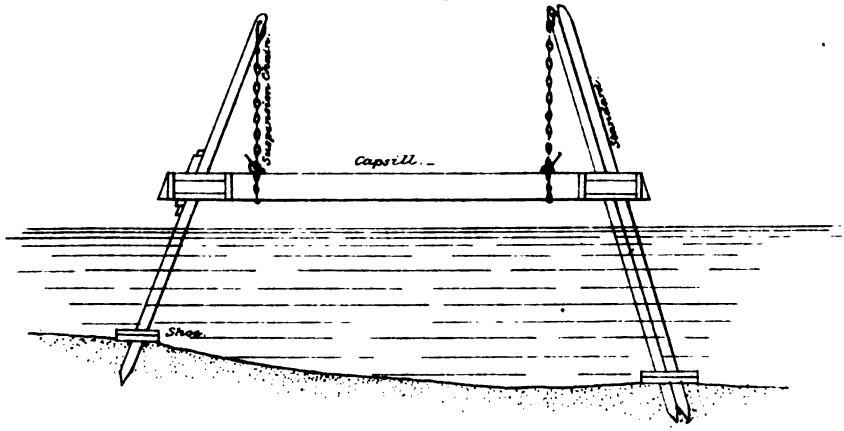
Plan.



Elevation.



## Trestle.




LITHO. T.C. PAGE.

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one pontoon piece. By having the floating supports in pieces a great many most important advantages have been gained. They are very portable, easily loaded and unloaded on and off the waggons, and can be fastened together one behind the other, so as to give the required buoyancy in the water without obstructing the current of the river.

*Byrago's fixed Supports* (*Trestles*).—The trestles are a peculiarly valuable feature in this system, and more especially with reference to India. A tracing of one is given in the plan, with the names of its component parts written opposite each.

A complete trestle consists of a capsill, on which the ends of balks for the roadway rest, and this capsill is supported at the requisite level by means of two standards, which pass through mortices, at the ends of the capsill. Two suspension chains connect the standard and capsill, and keep them in their relative places. These trestles are employed wherever they are preferable to the pontoons, such as, where the roadway of the bridge is required to be at some considerable height above the water level, in shallow or rocky streams, dry nullahs at broken arches of bridges, in torrents, &c. Wherever practicable, they should be used, instead of floating supports, as their capacity for carrying weights is nearly unlimited; they present very little obstruction to the current,—allow of no vibration, whether vertical or lateral, during the passage of material and troops,—are but little liable to get out of order, and easily repaired if they do,—do not require any anchors, and are not liable to shift their place and injure the stability of the bridge by altering its adjustment,—and are much lighter and more handy than pontoons of the requisite buoyancy. The standards are 8, 12, 16, and 20 feet long, so as to be adjusted to any depth of water and to any obstacle. They are provided with shoes, as shown in the plan, to be used in soft ground. Their points are shod with iron as a protection.

*Balks.*—The balks of the system are of large size, being 23 feet long 5 inches broad and 6 inches deep. The breaking weight of each is about 3 tons, and effective strength 1½ tons. Their great strength and size add much to the practical value of the bridge for the transport of heavy and Siege Artillery and Cavalry, which latter could cross the bridge in sections of three's. Every bridge should be capable of transporting Siege Artillery, as it is the most difficult of all arms to transit. Infantry can almost always effect their own passage over obstacles in some manner or other, and Cavalry can surmount many obstacles unaided. The ends

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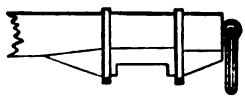
of these balks are half mortised, as shown in the margin, by means of which they can be built up together, so as to form bridges of 40 feet span, or upwards, without intermediate supports, capable of carrying heavy Artillery. They are provided with rings at the ends for handling them, and by means of ropes passed through these they can be dragged on board of pontoons from the shore, &c. The weight of one balk is 150 lbs.



*Chesses.*—The Chesses or planking of the superstructure are 10 feet 7 inches long by 11 inches broad by 1½ inches thick. They can be used indifferently either end or either side up, so that no mistake can possibly occur either by unskilfulness in the men, or from their being laid in the dark.

*Forming the Bridge*—Prior to forming the bridge, a section of the obstacle to be passed is first made, and the nature of the supports to be employed is determined. The trestles enable us to employ fixed supports, until the roadway is 17 feet above the river's bed, pontoons being employed in deeper water than that. In shallow water and on dry ground the trestles can be put together at their proper places, and raised by turning them over on the points of the standards by hand. In deep water they can be put together on pontoons, and slid over the side into their proper places. Those portions of the bridge which have floating supports are boomed or thrust out from the shore, or from the last trestle, as the case may be, in succession, in very much the same manner as the English pontoons are boomed out. The bridge can be broken up and reformed at any other place by packing the superstructure on the pontoons, either singly or in rafts, according to the proposed locality either up stream or down stream.

*Application of both systems to India*—In India rivers are the chief obstacle which would arrest the march of an Army. They may be considered as torrents at certain seasons of the year, and, as a necessary consequence, their section at other times generally presents a considerable breadth of water, banks precipitous,* and a stony or rocky bed, the slope from the water's edge to the centre being very gradual. The seasons of flood differ throughout India; the floods take place in the hot weather in those rivers which rise in snowy mountains, in the rains in those rivers which are under the influence of the South-West monsoon, which never

* This is not the case with the rivers of Bengal, Hindoostan, or the Punjab, except in the upper portions of their course. Below, the banks are low, being often inundated in the rainy season, and the beds sandy.—[Ed].

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fails, and in the cold weather in those under the North-East monsoon, which sometimes fails. A system therefore, to be properly adapted to India must suit these three different kinds of rivers, both when in flood and when the water in them is low.

The character of all these rivers at low-water demands that the supports should be chiefly, if not entirely, trestles, and when in flood, in the great majority of cases, trestles would also have to be used. The only case where floating supports would be required throughout would be, as far as I am able to judge, chiefly during the flood of the first class of rivers, or, in other words, these kinds of supports would only be required in one case out of six. The rivers in India and the Punjaub belonging to the first class might be crossed by floating supports only, but the second and third class of rivers would almost always demand fixed supports. The Southern Mahratta Country and the Madras Presidency afford good specimens of the second and third class of Indian rivers respectively. To recapitulate therefore, and to show the relative merits of the two systems in a tabular form, the following statement is drawn up. The guiding points for determination have been selected from the English "Aide Memoire," page 173, both as setting forth the properties of a bridge very clearly, and being drawn up by the Royal Engineers must be considered as perfectly just to the English system. The numerical value opposite each item has been arbitrarily fixed by me. A consideration of these values will, I think, show that they have been carefully estimated.:—

| Qualities of Bridges. | Value. | Blanshard's. | Byrne's. | Remarks. |
|---|---|---|---|---|
| 1 General applicability, ... | 20 | 8 | 20 | If available as rafts, boats, &c., besides serving as a bridge. |
| 2 Simplicity of character, | 9 | 9 | 7 | So that its management may be easily learnt by all Troops. |
| 3 Capability of rapid construction, | 8 | 8 | 6 | |
| 4 Security from destruction by an enemy, | 6 | 4 | 6 | From peculiarity of construction in detail, or from its general arrangement. |
| 5 Ultimate buoyancy, ... | 9 | 5 | 9 | |
| 6 Stability,... ... ... ... | 8 | 4 | 8 | |
| 7 Height of superstructure above water, | 6 | 3 | 6 | With reference to the section of the floating supports. |

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| Qualities of Bridges. | Value. | Blanchard's. | Byrago's. | Remarks. |
|---|---|---|---|---|
| 8 Ease of management and motion in water, | 8 | 7 | 8 | Implying also lightness and suitability for speed in rowing as a raft boat, &c.; capability of movement as a quadrant of conversion. |
| 9 Facility of detail, construction, and repair, | 12 | 10 | 12 | As requiring only such material and workmanship as are likely to be at hand. |
| 10 Security from destruction by natural causes, | 5 | 2 | 5 | Strength to oppose the violent action of the wind or water, &c. |
| 11 Cost and expenses, ... | 9 | 9 | 9 | Including transport, &c. |
| Total, ... | 100 | 69 | 96 | |

That is, the Austrian system fulfils 96 per cent. of all the qualities necessary to a Bridge system, and the English only fulfils 69. I would beg particularly to request attention to this point, and that the arbitrary values fixed by me may be more particularly scrutinized. I feel, however, certain that if the values I have given be over-ruled, and others fixed by the authorities, the result will still be very much the same as I have given it.

The above, however, by no means gives the full superiority of the Austrian system. The details of the construction, as well as the principles of the bridge, must be taken into consideration. In the English system these details are more particularly faulty, as will be seen from the following statement of some few of the items:—

| Items. | English. | Austrian. |
|---|---|---|
| 1. *Method of securing the shore ends of the Bridge.* (The stability of the whole construction depends upon the ends being perfectly firm and fixed on the rivers' banks.) | No established method. They must be got up from materials on the spot. A very unsatisfactory arrangement. | Is provided with very strong and complete shore fastenings, called Landsills, which are picketed and wedged down, and on which the balks rest. |
| | *Balks.* | |
| 2. *Fastening of the superstructure.* | Are fastened by means of pins between cleats. Owing to warping and shrinking of wood, these fastenings are very difficult and tedious to adjust. | Are fixed into their rests by being half mortised at the ends. No difficulty can, consequently, ever arise in adjusting them. |

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| Items. | English. | Austrian. |
|---|---|---|
| | *Chesses.* | |
| | Are racked down to the saddles at 12′ apart. Require great care in the laying, owing to the somewhat intricate arrangement of the cleats, and would be difficult to lay at night, and liable to mistakes at all times when expedition was required, and skilled pontooners not procurable. | Are racked down throughout to the balks, whereby the whole superstructure affords mutual support, and cannot be easily displaced by an accident, by rough water or heavy traffic. |
| 3. *Transport of the Train.* | Balks are put on the waggons, and then Chesses. The centre of gravity of the load is very high, and the waggons unstable. They are also very cumbrous, and unwieldy in turning, &c. | Chesses first packed, then Balks, by which means they are unloaded in their proper order for forming the bridge; centre of gravity low, and waggons very stable; can turn on their own grounds, and are very handy. Gross weight less than Blanshard. |
| 4. *Pontoons.* ..... | Of tin or copper, very liable to leak and get out of order, and are very fragile. Their form being circular, is extremely unstable. Weight 570 lbs.; buoyancy 7,369. | Are of wood, strongly made, and only liable to leak from the land carriage in the sun. Section extremely stable. Weight 650lbs.; buoyancy 9,800. |

The weight per foot run of the English Bridge is 209, and the Austrian 179 lbs., for the passage of siege Artillery in both cases. For light Artillery 164 and 146, respectively, and for Infantry 4 deep, 136 and 115, showing a large saving of portability in each case in favor of the Austrian system. I am, therefore, of opinion that the Austrian system is in every respect more adapted to the present state of the art of war and operations in presence of an enemy, and more especially to our Indian empire.

I have, &c.,

A. Cowper, Captain.

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The writer having visited England since the date of the above report, has been led to consider the various details connected with the main objects



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of a good Pontoon system, and in the course of his enquiries, the improvements detailed below upon the systems referred to have suggested themselves, and they are now brought forward for the purpose of eliciting discussion.

The subject will be divided under the following heads:—

Necessity of a Bridge Train to accompany an Army.

Requisites of an efficient Bridge Train.

Composition.

Selection of Bridge Sites.

Preparations and details of the Passage.

Carriage of the Train and distribution of materials.

Construction and details of a perfect Bridge System which fulfils all the necessary conditions.

*Necessity of a Bridge Train to accompany an Army.*—In Military opertions, the chief and most serious obstacles to the march of an Army are the rivers and water-courses of all kinds which are met with. The positions of the permanent bridges over these obstacles are perfectly well known to the enemy, and being generally situated on the large lines of made road, are consequently not available for our use when within the circle of the enemy's activity. Neither can we place any reliance on 'bridges of circumstance' to cross these obstacles, owing to the fact that their construction can seldom be effected except under very favorable circumstances as regards materials and at a considerable expenditure of time.

It is rendered necessary therefore by strategetical reasons that every large body of troops engaged in important expeditions should be accompanied by a Military Bridge system, or Pontoon Train, to ensure its efficiency as affording the best, and indeed only, means of passing these obstacles.

*Requisites of an efficient Bridge Train.*—The Bridge Train generally proceeds with the Infantry, under whose protection it is laid; when the time arrives for the formation of the bridge, it must proceed at a rapid pace to the front, carrying on its waggons the men who are to lay it. On arrival at the river the transit of the covering party is effected by means of row boats, which are next employed on laying and serving the bridge. After the passage of the Army and following, it has to regain its position by forced marches to the front.

It follows therefore that a perfect Military Bridge system should com-

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bine mobility to traverse difficult ground with ease, with quick means to pass armies over considerable rivers. There is at present no Bridge system in existence which perfectly fulfils both these conditions.

*Composition of a Bridge System.*—Every Bridge system is composed of superstructure and supports, the latter being both fixed and floating.

*Superstructure.*—To diminish weight and transport and consequently increase the bearing power of the supports, as well as to diminish oscillation, the roadway should be as narrow as is compatible with the proper passage of troops, and is determined by the order of march most convenient for the three arms. Four's for Infantry, two's for Cavalry, and Artillery in subdivisions, would find ample space on a way 9 or 9½ feet in the clear, and this would be also well sufficient for our Indian following.

In regard to the strength of the superstructure, this must be determined by the heaviest carriage that the bridge may be called upon to bear. If we assume a 24-pounder siege gun with carriage and limber to weigh 3 tons, we shall have about 1 ton on each gun wheel, and the breaking weight of the superstructure should be consequently three times, or 3 tons. This would also be ample for the passage of all other heavy carriages and even for laden elephants.

The present system that obtains in all armies of gradually building up this superstructure on the spot by means of Balks and Chesses, and then racking down these latter with cordage, is open to many objections. The Balks in most systems are apt to turn half round or get misplaced and thereby diminish the weight they are able to support. The Chesses and racking down are complained of by every body, as they have to be constantly relaid and renewed during the passage of troops. We lose at least 1½ feet in the breadth of roadway, with the attendant increase of weight in transport as well as that of the small balks, &c., used for racking down. The roadway being built up piecemeal without mutual support, it is necessary to have each Balk, Chess, &c., of a greater scantling and strength than would be necessary if they afforded each other mutual support; and any damage to one of these would render it necessary to relay an entire bay.

*Supports, floating.*—The row boat is a fundamental necessity for a Military Bridge system, as by its aid alone can we effect the transit of the covering party, and perform the services of all kinds afterwards required, such as laying the bridge itself, performing the police of the river, both up and down-stream, &c. They give us the means of transport across

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any breadth and in all depths of water in any velocity of current; they are as stable as Pontoons and ride more easily at anchor. They form therefore the right form of support for Military Bridges wherever floating supports are used; and the troops, more especially the English, would sooner become accustomed to handle them.

In common with all floating supports their use is attended with oscillation and undulation, which wears the bridge and is a source of danger during the passage of troops. In heavy weather this may become so great as to interrupt the traffic altogether. In addition to these defects, which render the employ of fixed instead of floating supports a matter of necessity whenever practicable, it has been brought to notice in the writer's report to the Quarter Master General of the Bombay Army, that there are many cases in which floating supports cannot be used at all.

Wherever these supports *are* employed however, they must be of a stable section and of sufficient buoyancy to bear the heaviest weights that can come on to them. This ultimate buoyancy is found by calculating the greatest number of men that could be jammed into one bay, such as might occur in the event of a hurried retreat of troops, or during an impetuous advance. From 6 to 8 tons ultimate buoyancy would be ample in this connexion. They must also possess sufficient portability to be easily loaded and unloaded on and off the waggons, and carried some distance on mens' shoulders whenever necessary.

They should be capable of being easily and quickly repaired and bailed out, and of having their leaks readily stopped; they should be adapted to carry stores, men, horses, and even light Artillery, and must be constructed of durable materials to stand the hard wear and tear of active service. If made of cloth, canvass, leather, or any thing similar, they would be quickly worn out.

From what has been above stated, it would be clearly inadmissible to have these supports in the form of closed vessels, as two of these have to be rafted together before they can be used at all. By the use of canvass bulwarks and air-tight tubes as sister keelsons, which greatly strengthen the vessel, we secure our row boat from being suddenly swamped, and obtain all the advantages of closed vessels without any of their numerous and fatal disadvantages.

In considering the relative merits of the materials, wood and iron, to which we are reduced by these considerations, we must conclude that for

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India corrugated iron boats would be preferable to wooden ones, as in all our campaigns the long land carriage in the sun would split the planks and open the seams of these latter.

*Fixed supports.*—We now come to the consideration of fixed supports or trestles, which possess numerous advantages as already pointed out over floating supports.

The best form of trestle is that adopted in the Austrian service, and which is in process of introduction into most of the Continental services; a drawing of one of these has been already given.

It is not necessary to persue this subject further, as it will be readily conceded from the remarks that have been made on the nature of Indian rivers, that a system which carries floating supports for Siege Artillery for half the bays in the bridge, and floating supports throughout for Cavalry and Infantry, will accommodate all the rivers met with on active service, as in the case of a river requiring floating supports for Siege Artillery throughout, it would be of such a nature that we should invariably find country craft ready on the spot to answer our ends.

*Selection of Bridge sites.*—In the selection of Bridge sites we are limited by strategetical reasons to a certain portion of the river's course. This part has to be again subdivided from a tactical point of view, and we find that a re-entering angle is the best position we can select for the passage, as the hostile bank is then swept from our side, which is also usually in this case the commanding ground. If the side from which we embank be wooded and undulating, or possessed of an affluent or island so as to mask our operations and diminish the breadth of the river, our great object of effecting the passage unknown to the enemy would be much facilitated, and we should be saved one of the most difficult and dangerous operations of war, that of forcing the passage of a river in face of an enemy.

The above are the principles which hold good in the selection of Bridge sites, both in advance and retreat, except that in the latter case we should endeavour to get a good start before the enemy, and have a *tête-de-pont* constructed on the hostile bank in which the Artillery remains to the last movement to hold the enemy in check.

The site is connected with the lines of communication in the vicinity in as efficient a manner as our circumstances will permit.

*Preparation and details of the passage.*—In effecting the actual passage of a river some ruse or stratagem is usually employed by which the

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enemy is deceived as to the site selected for crossing, and the train brought up as close to the river's bank as possible at night. After the Artillery have taken up their position to sweep the opposite bank the boats are put into the water and the passage of the covering party effected, during which operation the construction of the bridge may also proceed. Day-break is the proper time for this, and under a proper system of management a few hours should suffice to bridge the largest river.

It is usual in the Austrian and other Continental services to take a rough profile of the river, so as to determine at what places fixed and floating supports are severally required, boats being sent to each place and provided with trestles whenever necessary. A still more compendious method than this will however be indicated when endeavouring to propound a Military Pontoon Train which shall fulfil all necessary conditions.

*Carriage of the Train and distribution of the materials on the Waggons.*—In a country like India, intersected with nullahs and ravines, and where the few lines of made road are not in those provinces likely to be campaigned over, it is evident that the load of each carriage must be lighter by far than what is considered practicable in Europe, and to this conclusion we are also brought by a consideration of the inferior nature of the draught of the country, that of bullocks. Each carriage therefore should carry but little over a ton in weight.

In regard to the form of the carriage we are limited to 4-wheeled waggons as 2-wheeled carts cannot be used at all across country.* The best form of construction for these is to have the fore wheels capable of locking under the body of the waggons so that it can lock round on its own ground. In order to diminish draught the wheels should be near together, and of as large diameter as is consistent with stability. The gauge cannot be more than 5 feet for the outlying districts, as any one who has had much experience of country roads in India will readily concede. They should be furnished with springs to save the cattle, which are thereby enabled to draw greater loads (say one-third additional) with greater ease to themselves.

In regard to the actual distribution of materials on the Train, the best method of loading is obviously that by which one complete bay is carried

* Why not? Surely two-wheeled carriages are both more manageable and of lighter draught over bad roads. They are used in the Bengal Pontoon Train.—[Ed].

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on one waggon, and consequently each can be detached separately. By making each waggon carry its own share of tools, &c., every small detachment is quite independent of the others and capable of availing itself of the local resources and materials on the spot. Any loss or delay of any of the waggons would not affect the remainder of the train in the least.

As against this view it has been argued that a Train should be furnished with special carriages for each special portion of the train—such as store, trestle, balk and other waggons, as thereby the loads are more compact and the line of march of the entire Train shortened by a few feet. There is no doubt of these advantages, but they are trifling when compared with those above enumerated, which greatly increase the value of the Bridge system. Moreover, this system of special waggons complicates much the construction, maintenance and drill of the Train; and has the still more fatal objection, that the loss or delay of any such special waggon, cripples to a certain extent the remainder of the train, and may even do so to the extent of rendering it totally useless.

*Construction and details of a perfect Bridge system, which fulfills all the necessary conditions.*—We now come to the most important part of our subject, and if the remarks contained in the above discussion be well founded, we find that the following are the chief and indeed essential elements of a bridge system.

1. Easy adaptability to the beds and banks of all sorts of rivers.
2. Stability and firmness as a bridge during the passage of large bodies of Men, Horses and Artillery, &c.
3. Strength and durability as an article of equipment.
4. Capability to transit the covering force, and at need the Army itself, when the obstacle is too considerable to be bridged over.
5. Mobility to follow the movements of an Army in the field, and portability for transport by the men at those places where the waggons cannot be taken.

We shall now proceed to bring forward a system fulfilling the above conditions to a perfect extent.

*Superstructure.*—Instead of the Balks, Chesses, and Racking Down arrangements, which constitute the superstructure of all Military Bridges at present, a little consideration shows us that these should take the form of two Platforms about 4¾ feet broad and 20 feet long with a breaking strength of 8 tons. Each of these on the outer sides would be provided

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with a light steel chain suspended on uprights sunk in angle iron to keep the carriages on the roadway. In addition to these, which would form the way for the passage of the army and following, there should be a small service platform or way running along side the main road, constructed from the ways by means of which the boats and platforms are loaded on and off the waggons. These ways would be an important improvement on the usual Bridge system; they could be used by the Sappers for all the services of the bridge without interfering with the general traffic, would enable orders to be conveyed to either side of the river, and also a stream of foot soldiers or others in Indian file could be passed at any time from either side to the other, in a direction contrary to the general march.

These Platforms would be strongly keyed on to the capsills or piers; their weight need not exceed 4 cwt. each.

The advantages gained by this system are, greater stability and solidity, which would be more especially useful in perilous circumstances, such as the retreat of an army or an impetuous advance. The weight is reduced at least 40 per cent., and the bearing capacity of the supports is proportionately increased, the points of junction are fewer, and being of iron, would be less likely to wear and get out of order. We have also greater simplicity and quickness in construction.

*Floating Supports.*—As the row boat has been conclusively shown to be a normal and fundamental necessity for a Military Bridge, it only remains to show how these are attached together to form floating supports for the bridge. By bringing two boats together, stern to stern, they can be formed into one support by means of iron shackles and other fastenings. Two boats thus joined would form a support about 40 feet in length and be much less liable to oscillation than two of the Byrago pontoons. In stability also they would be fully equal to those pontoons, as during the passage of heavy Artillery, the bow and the stern would become gradually immersed and diminish the undulation.

*Fixed Supports.*—The form already indicated as the Austrian is the best form of trestle that can be adopted, and is the one proposed to be incorporated with the present system. The mortices at the ends of the capsills would be made of boiler plate, and the legs or standards strutted with iron, so as to combine strength with lightness.

*Carriages.*—The carriages will be very similar in construction to the

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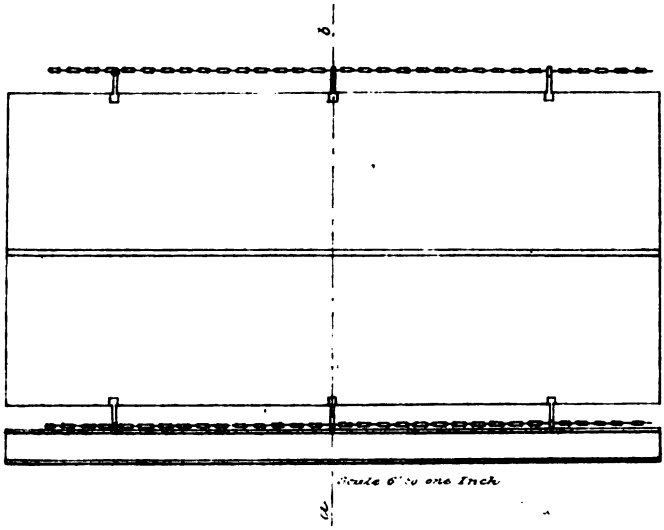
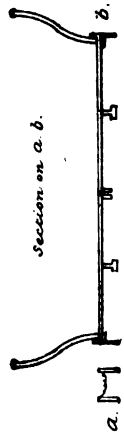
# MILITARY BRIDGES.

## *Proposed Pontoons.*

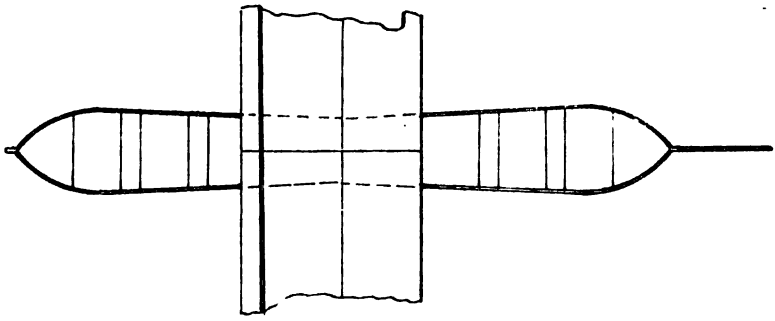
*Plan of Platforms and Way.*




*Floating Supports for Siege Artillery.*

*Plan*



*Elevation*

*Scale 12' to one Inch.*

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Austrian trestle carriage. They would, however, be furnished with springs and have a larger gauge as well as larger wheels, the fore wheels being 4 feet in diameter and the hind wheels at least 5 feet. The load of each carriage would be as under, carrying each 20½ feet of bridge.

| Numbers. | Items. | Weight. Cwt. | Qrs. | Lbs. | Remarks. |
|---|---|---|---|---|---|
| 1 | Boat, ... ... ... ... ... | 6 | 0 | 0 | Of corrugated iron, weight, inclusive of oars, rowlocks, rudder and boat-hook. |
| 2 | Platforms, ... ... ... | 8 | 0 | 0 | Of angle iron and corrugated iron. |
| 1 | Way, ... ... ... ... ... | 1 | 0 | 0 | Used as construction and service platforms. |
| 1 | Capsill, ... ... ... ... | 1 | 1 | 0 | These items form one complete trestle. |
| 1 | Standard, 8 feet, ... ... | 0 | 1 | 2 | |
| 1 | „ 12 feet, ... ... | 0 | 1 | 22 | |
| 2 | „ 16 „ ... ... | 1 | 0 | 0 | |
| 1 | „ 20 „ ... ... | 0 | 2 | 7 | |
| 2 | Wedges, ... ... ... ... | 0 | 2 | 0 | |
| 2 | Shoes, ... ... ... ... | 0 | 1 | 12 | |
| 2 | Suspension chains, ... ... | 0 | 1 | 6 | |
| 1 | Screw-jack, ... ... ... ... | 0 | 1 | 8 | |
| 1 | Anchor and cable, ... ... | 1 | 2 | 0 | |
| 1 | Mallet, ... ... ... ... | 0 | 0 | 4 | |
| 1 | Canvass bulwark and sticks, | 0 | 0 | 8 | |
| 1 | Scoop, ... ... ... ... | 0 | 0 | 2 | |
| | | 21 | 2 | 15 | |
| | Proportion of artificers' tools, say, ... ... ... | 1 | 1 | 13 | |
| 21 | Total, ... ... | 28 | 0 | 0 | One ton three hundred weight. |

On the forge waggon we should carry two platforms, one way, and the two landsills, on which the shore ends of the bridge rest, in addition to the necessary tools, &c.



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Our length of Train would be determined by the medium size of rivers of the 2nd class, which would be for India about 100 yards long. Fifteen waggons with one forge waggon would give us 328 feet of bridge or 109⅓ yards, and be well capable of covering 100 yards of waterway.

We shall have our waggons much more lightly loaded and more mobile than the Austrian, which latter we should find very difficult to move across country with the present bullock draught. To compare these two systems together as far as regards the weight per foot run, we have the following comparative table:—

| | Weight per foot run. | | | Remarks. |
|---|---|---|---|---|
| | Byrago. | Proposed. | Per centage of proposed system and Byrago's. | |
| Siege Artillery, ... ... ... | 179 | 118 | 0·61 | |
| Cavalry in Indian file and Infantry in file, ... ... | 96 | 59 | 0·61 | |
| Infantry in Indian file, ... | 77 | 39* | 0·51 | * Using some supports of circumstance. |

In the actual laying of this bridge the simplicity of the details would afford us great facilities for the construction by the method of booming out, as practised in the English service wherever the stream was sufficiently sluggish to allow of that operation. But when the stream was too rapid to permit of this system, our row boats would enable us to lay the bridge with ease and rapidity. Each boat as soon as slid into the water by means of the ways, (which would also be used in unloading the platforms, &c.,) would take on board a complete trestle and way; in fact the entire load of one waggon, except the platforms and artificers' tools. The first boat would take over a wire rope marked at intervals of 20½ feet (being the length of one bay) being assisted by one or more boats, according to the breadth of the stream, and the remainder would row up to their places at once and anchor there. Those boats that found the water sufficiently shallow for trestles, would fix them immediately, directly opposite the mark on the rope, and the light warps would then be thrown across from one pier to the other, and a communication for foot soldiers would be at once estab-

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lished between bank and bank. The boats that had fixed trestles would then proceed to those places where floating supports were required, and attach themselves to the boats already there. The platforms would be then brought on by hand from the shore by means of these warps and keyed on to the piers.

This system is evidently capable of performing all that is claimed for the Byrago Pontoon Train; with the exception that these new boats cannot be joined end for end like the Austrian; but as they would be far superior as rafts and flying bridges, we need attach but little importance to this.

To recapitulate therefore, and in conclusion, we may justly claim the following most important advantages over the Austrian system.

Greater mobility and capability of division, which would be more especially beneficial in a country like India abounding in nullahs on the line of march, greater stability and solidity and lateral stiffness, which would be of the highest value in perilous circumstances, and improved facility and quickness in passing Armies in the field over considerable obstacles. As all these have been attained with a great decrease in weight, being indeed a reduction of at least 40 per cent. on the Austrian system, it is trusted that a sufficient case has been made out to induce discussion by professional men.

ALEX. COWPER, LIEUT.-COL., R.E.

MHOW,
*1st January*, 1865.

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NOTE BY EDITOR.

The chief difference between the form of pontoon or boat advocated by Colonel Cowper and the Byrago pattern is, that he employs two separate boats fastened together, instead of two half boats. The Byrago bateaux can be used with or without the middle piece, and in the former case do not differ essentially from Pasley's Pontoons or demi-canoes, as now used by the Sappers in the Bengal Army, which are thus described by Sir H. Douglas (Military Bridges):—

"Sir Charles Pasley's pontoons, or canoes, are, each in its whole length, 22 feet long, 2 feet 8 inches broad in its greatest width, and 2 feet 8 inches deep. Except the deck, the vessel is formed of sheet copper, covering a wooden frame, and the deck is

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of wood. Each is formed in two equal portions and each demi-pontoon is divided by a transverse partition, in order to prevent the water from filling the pontoon, should a hole be made in it by accident; and a pump is provided for the purpose of drawing the water off. Light carts, with two wheels, each drawn by two horses, will convey two demi-pontoons with their stores; thus two carts will convey the two pontoons, with all the materials necessary for forming a raft, which, when put together, will constitute a portion of the bridge.

"When the banks are favorable for launching the pontoons, any number of rafts, with the complement of hands, can be put together and launched in a quarter of an hour; in another quarter of an hour the bridge can be formed. The bridge may be dismantled in 8 minutes; and in a quarter of an hour afterwards the rafts may be run ashore, taken to pieces, and the pontoons with their stores packed on the carriages."

Similar boats or bateaux, except that they are not divided in the middle, and which will be described further on, are used in the French service; and as no other Army except our own uses the cylindrical pontoon, the weight of authority and custom is certainly against it. For Civil Bridges, however, it is certainly preferable to the boat (*vide* Professional Papers, Vol. I., p. 209), but the conditions are very different from those now under consideration.

That the superstructure proposed by Colonel Cowper would be an improvement on that now in use when once it was laid, may I think be admitted. It would not of course be so portable or so handy.

With regard to Trestles, it is impossible I think to doubt their utility as adjuncts to the floating supports, in many cases of Indian Rivers, especially where the water is too shallow to admit of the boats floating properly. But the Byrago Trestle has been tried by the United States Engineers in the present American War, and appears to have been condemned, while the French system is strongly recommended as the best yet devised. As this experiment is the latest that has been made in actual war on a large scale, and the United States' Engineers are well known to be Officers of great ability, I give the following extracts from the "Report of Brigadier General Barnard, Chief Engineer with the Army of the Potomac, published at New York in 1863," which will be found full of interest (all the italics are in the original):—

"The engineer equipage consisted of about 160 bateaux or wooden pontoons of the French model, with the necessary balks, chess, anchors, cordage, &c. There were also a certain number (of which I do not now find any exact statement) of Birago trestles, and Russian canvas boats.

"As originally got up, this bridge equipage was organized in *trains*, of which there were six regular trains, consisting each of thirty-four French pontoons and eight Birago

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trestles, calculated to make a bridge of about 250 yards length; and an advanced guard train composed of Birago trestles and Russian canvas boats. The waggons for but four of the regular trains and for the advanced guard were provided.

"A word is proper here concerning the Chickahominy, which, at the season we struck it, was one of the most formidable obstacles that could be opposed to the advance of an army; an obstacle to which an ordinary *river*, though it be of considerable magnitude, is comparatively slight. The Chickahominy, considered as a military obstacle, consists of a stream of no great volume, a swamp, and a bottom-land.

"The stream flows through a belt of heavily timbered swamp, which averages three to four hundred yards wide. A few hundred yards below New Bridge is a short length of the stream *not* margined by swamp timber; but everywhere else between New and Bottom's Bridges, the belt of swamp timber is continuous and wide.

"Through this belt of swamp the streams flows, sometimes in a single channel, more frequently divided into several; and, when but a foot or two above its summer level, overspreads the whole swamp.

"The *bottom-lands*, between the swamp and high-lands, are little elevated at their margins above the swamp, so that a few feet rise of the stream overflows large areas of them. They rise very gently towards the foot of the highland slopes. These bottom-lands are generally cultivated, intersected by deep ditches, and their lower portions are, in wet weather, even when not overflowed, spongy, and impracticable for cavalry and artillery. The total width of bottom-land varies from three-fourths of a mile to a mile and one-fourth.

"The pontoon equipage which accompanied the army was got up (as already mentioned) by Lieut.-Col. Alexander, assisted by Capt. J. C. Duane. The former had acquired an enviable reputation as the builder of the Minot's Ledge Light-House; possessed great practical ingenuity, and had had the means of knowing the best results arrived at in other services in this branch of military art.

"Captain Duane possessed a more extensive and thorough practical and experimental knowledge of military bridges than any other man in this country.

"They gave, after full consideration of the subject, their preference to the French system. Even had they adopted this system blindly, *because* it was French, they would not have been without solid reasons, for the French have studied and *experimented* upon the best systems known to the world. Whatever may be said about the difference in the character of the country, roads, etc., the thing *to be done* here and in Europe (now that our armies have assumed European magnitude) is essentially *the same*.

"But these officers had before them the best *modern inventions* of Europe and America. The India-rubber pontoon they knew *thoroughly*; corrugated iron bodies, and countless other "inventions" of American genius, were before them, and the former experimented upon.

"My own prepossessions had been in favor of the Birago system of sectional pontoons, and "Birago" (so called) trestles.

"The experience we had, proved the wisdom which adopted the system in question. Not to advance, by any means, that nothing better can be found (the substitution of iron for wood was one of the probable improvements well understood by the officers named, but not, *at the time*, adopted, for substantial reasons), it is enough to say that the French pontoon was found to be most excellent, useful, and reliable for *all* mili-

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tary purposes. They were used by the Quarter Master's Department in discharging transports; were precisely what was needed for the disembarkation of General Franklin's division; constituted a portion of the numerous bridges built over Wormley Creek during the seige of Yorktown, and were of the highest use on the Chickahominy, while over the lower Chickahominy, some 75,000 men, some 300 pieces of artillery, and the immense baggage-trains of the army, passed over a bridge of the extraordinary length of nearly 650 yards; a feat scarcely surpassed in military history.

"The Birago trestles, of which I had formed so high an opinion, proved itself dangerous and unreliable; useful for an advanced guard or detachment, unfit, in general, for a military bridge. Of the American India-rubber and the Russian canvas pontoon we had no fair experiment. They may both be useful; but again, I think, not reliable for a "military bridge," considered in all its aspects and uses.

"The weight of the French pontoons is objected to, but a *certain flotation power is required* which it is not easy to get, nor are the ways unobjectionable which seek to get it with less weight; and the vehicle which carries it is not heavier loaded than other vehicles of an army train. *Less length* would certainly make it more manageable on our narrow roads, while, for advanced guards and dashing minor enterprises, greater lightness is requisite. Perhaps an iron sectional pontoon may be contrived which will meet these requirements, but prudence demands that the safety of an army shall not be jeopardized by giving it a bridge which experiment has not fully tested. American genius is fertile in this as in all other expedients, but no genius can provide for an object which is not understood.

"The numerous proposers of "flying" bridges forget that, if a military bridge is intended to be *carried with* an army, it is also intended to *carry* an army, its columns of men, its cavalry, its countless heavy waggons, and its ponderous artillery. It must carry all these, and it must do it with certainty and safety, even though a demoralized corps should rush upon it in throngs.

"No make-shift expedient, no "ingenious" inventions, not tested by severe experiment, nor light affair, of which the chief merit alledged is that it is light, will be likely to do what is required, and what the French pontoon has so often done."

The following description of the French Pontoon above alluded to is from an instructive Paper by Lieut.-Col. Lovell, C.B., R.E, in Vol. XII., of the R. E. Professional Papers:—

"The new pattern French pontoon or bateau (introduced in 1853) is 31 feet long, the bottom and sides being of fir planks about 1 inch thick, nailed to a framework of wooden ribs 3 inches by 2¼ inches. The bateaux are quite open and have a flare bow and stern, the latter being rather shorter than the former. As ordinarily arranged in bridges, these bateaux are placed at intervals of 19 feet 8 inches, when the bridge has a power of 644 lbs. per lineal foot, and is quite equal to any ordinary load. When required for extraordinary loads, the necessary power is obtained by diminishing the intervals between the pontoons. For transport, two pontoons and the material for the superstructure of two bays of the roadway are subdivided between three waggons, each drawn by six horses, and weighing about 4,670 lbs. (778 lbs. per horse). The anchors, of which one is allowed to each of these bateaux, weigh about 145 lbs. Finding that these batcaux, in consequence of their great length, are very unwieldly

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when loaded on their waggons, the French pontooners have lately proposed and made an equipment of demi-bateaux, each of which is just half the size of those which they at present employ, and with the buoyancy of which they express themselves as being perfectly satisfied."

The following table extracted from Col. Lovell's paper shows the comparative size, weight, and flotative power of the pontoons above described, to which I have added a column to include Colonel Cowper's, as far as I could determine the details:—

| | French, present general pattern, open wooden bateau. | Austrian Byrago present pattern, iron; open bateau two bows and one middle piece. | English, Pasley, copper; demi-canoes, with wood deck. | English Blanshard, cylinder, tin; hemispherical ends; open order. | Colonel Cowper's pattern. |
|---|---|---|---|---|---|
| Total length of pontoon over all, ft., | 30·93 | 39·41 | 25·0 | 22·5 | 40·0 |
| Width of do., greatest section, ft.,.. | 5·06 | 6·22 | 2·75 | 2·66 | 5·0 |
| Depth of do., midships, ft., .. .. | 2·58 | 2·59 | 2·58 | Diam. | 3·0 |
| Displacement do., c. ft.,.. .. .. | 321·04 | 530·16 | 140·5 | 108·56 | 170·0 |
| Ditto, do., lbs., .. .. .. .. | 20,065 | 33,135 | 8,781 | 6,785 | 16,625 |
| Weight of pontoon, lbs., .. .. | 1,323 | 2,532 | 778 | 482 | 672 |
| Do. of one bay of superstructure, lbs., | 1,830 | 1,969 | 1,325 | 1,120 | 896 |
| Power of support, total lbs., .. | 16,912 | 28,634 | 6,678 | 5,185 | 9,057 |
| Do. do. for load; three-fourths for open pontoon, nine-tenths for close do., lbs., .. .. .. .. | 12,684 | 21,476 | 6,010 | 4,667 | 6,793 |
| Interval in Bridge, ft., .. .. .. | 19·69 | 21·67 | 12·5 | 12·5 | 20·0 |
| Power per lineal foot of roadway, lbs., .. .. .. .. .. .. | 644 | 991 | 481 | 373 | 340 |
| Greatest possible load at 110 lbs. per foot (superficial), lbs.,.. .. | 1,082 | 1,026 | 1,100 | 1,100 | 1,045 |
| Greatest ordinary load, 560 lbs. per foot (lineal), lbs., .. .. .. | 560 | 560 | 560 | 560 | 560 |
| Width of roadway, ft., .. .. .. | 9·84 | 9·33 | 10·0 | 10·0 | 9·5 |
| Weight of Pontoon per cubic foot of displacement,.. .. .. .. | 4·12 | 5·49 | 5·83 | 5·43 | 3·95 |
| Area of greatest immersed transverse section of Pontoons per lineal foot of Bridge, when arranged to support, on each foot of a roadway 10 feet wide, a load of 1,100 lbs., .. .. .. .. | ·898 | ·615 | ·956 | 1·026 | |
| Do., do. do. do. 560 lbs., .. .. | ·472 | ·322 | ·513 | ·541 | |

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Although I have inserted the above table, it does not appear to give any satisfactory means of comparing the different patterns according to the work which each can perform. Some of the dimensions and weights too, differ from those in the text above.

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# No. LVII.

## PURTAPORE STONE QUARRIES.

By T. E. Owen, Esquire, *Assistant Engineer.*

A large amount of stone being required for the new Public Offices in Allahabad, it was considered advisable to open a Quarry, as the only means of breaking the monopoly hitherto enjoyed by the leading Mahajuns, who by making advances to zemindars and others, where stone was procurable, kept the supply in their own hands and naturally charged enormous prices.

The place fixed upon was at Purtapore, a village on the banks of the Jumna, thirty miles from Allahabad, where the valley of the river towards the south is narrowed by a range of low hills; the underlying strata of which, here and there, crop out into the bed of the river.

These hills form the outer scarp of the Vhyndian system, towards the north, and apparently belong to the lowest group of that great system, viz., the Kymore group; they are low irregular hills, partially covered with the scantiest jungle, and strewn with large boulders of white crystalline sandstone, generally capped with massive beds of the same material.

The quarries at Purtapore are worked in a small hill, about 160 feet high, slightly isolated from the range. This offers peculiar facilities for quarrying as it can be worked on any side, and its underlying strata, from which alone good stone is procurable, seem to be considerably raised above the level of the same beds, visible (and in some places worked) in the face of the scarp of the range. The strata worked is a fine grained compact sandstone, of a light reddish color; it is extremely homogenous, moderately



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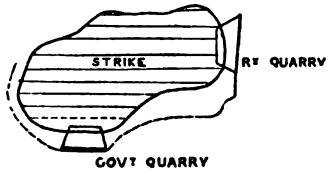
ard and suitable for every kind of work, from the large blocks of the Jumna bridge piers, to the elaborate carvings of a church.

When first quarried it is softer than it afterwards becomes when exposed to the air, owing probably to the deposition of the natural cements before held in solution. The hill is capped to a depth of from 40 to 50 feet, with massive beds of white crystalline rock, of flinty hardness, with a conchoidal fracture; its strike is about two points to the north of west: under this for a depth of about 40 feet, beds of soft friable sandstone are met with, crushed and distorted to a great degree; then from 4 to 6 feet of shales immediately above the workable stone. This stone lies in beds of from 6 inches to 8 feet in thickness; its strike is nearly due west; it has no apparent dip, and is extremely fissile in some beds, but has no cleavage, properly so called; the lower the beds, the further they crop out from the hill, and the more compact and homogeneous the stone, generally speaking.

The selection of a site is attended with great uncertainty, as the stone crops out from the hill very irregularly, but as a rule further in the direction of its strike. The sketch shows roughly the outline of the hill; with the underlying stone strata where known; and dotted, where supposed to lie; boring might often be employed with great advantage, where it is desirable to know how far the stone beds crop out from the hill, but a boring apparatus of great strength would be necessary to penetrate the hard boulders.




The Government quarry was commenced in June 1863, on the north side of the hill, where it was steeply scarped towards the top, which appeared to give a good face to work up to. For the first month, progress was merely nominal. Workmen were not easily procured for this kind of work; there were preliminary operations to be got through, such as building houses for an Assistant Engineer and Overseer, sheds for workmen, stores, bullocks, &c., for which all materials, except rubble, had to be procured from Allahabad. Cholera broke out at this time badly, the European Overseer being one of the first victims, so that it was not till October that an adit of 20 feet wide was cut into the face of the hill down to the stone beds; a considerable area to one side was also partially uncovered, unfortu-

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nately as it turned out, as the stone beds appearing to thin out in this direction, the present quarry had to be opened out on the other side. It is difficult to fancy any more tedious work than the excavation of this adit. First the large surface boulders had to be removed; then for a depth varying from 6 to 12 feet the work consisted in blasting and removing boulders and irregular beds of rock, imbedded and wedged in by small stones and a tenacious clay, so that stone-cutters had to be employed for blasting and cutting up the beds of the rock, bundanies for removing these and all boulders and stone above a certain size, bildars and coolies for excavating and removing the soil and rubbish. None of these would work without the others, and *having* to work together, but a few of each could be employed in the limited space; the rains too continually stopped the blasting, and consequently the whole work.

The adit having been opened down to the stone beds to an average depth of 40 feet, the most favorable direction for continuing the work was seen, and the clearing of 20,000 square feet of stone beds being sanctioned, a space 170 feet at top, 230 at bottom, was marked off; of this the greater part has been cleared to workable stone beds, and the remainder will be finished during October 1864.

The length of the quarry runs in the direction of the strike, and the stone beds are continuous the whole length, in almost perfectly horizontal beds, forming a most valuable quarry, from which stone of all dimensions can be rapidly and cheaply quarried now that the opening is completed; and the cost of such, being no longer indefinite, there can be no doubt of its great advantage and success in a pecuniary point of view. Supposing the quarry to be worked to a depth of 20 feet (the railway quarry has been worked to a greater depth), at least 2½ lakhs of ashlar and one lakh of rubble can be procured; the cost of opening the quarry will add less than 2 annas per foot on to this amount of ashlar, and the cost at per cubic foot will be—

| | R. | A. | P. |
|---|---|---|---|
| Opening quarry, . . . . . | 0 | 2 | 0 |
| Quarrying (with contingencies,) . . . . | 0 | 3 | 0 |
| Carriage to boat (including cost of tramway,) . . | 0 | 2 | 0 |
| „ by boat, . . . . . | 0 | 1 | 6 |
| „ to site of building, . . . . . | 0 | 1 | 6 |
| Total, . | 0 | 10 | 0 |

10 annas per cubic foot for ashlar of all sizes delivered at site; whereas

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the prices rating in Allahabad at the time the quarry commenced ranged from Rs. 1-2 to Rs. 2-4, per cubic foot, according to size.

From various causes, but chiefly from the delay in the sanction of the new Public Offices at Allahabad, the work was not pushed on so fast as it might have been until the month of April 1864, when every exertion was made and as many men placed on the work as could possibly work together; from twenty to thirty-five blasts were fired every day in this month, working on an area of 12,000 square feet; 80,000 cubic feet were excavated and removed, which gives in round numbers 6½ feet as the average depth of excavation per month for this description of work; of this at least 50,000 cubic feet were broken or loosened by blasts. The area of the quarry, within certain limits, signifies little, the number of workmen who can be employed being proportional to the space. This work has for sometime been done by contract at Rs. 16 per 1,000 cubic feet down to good stone beds, being Rs. 12 for excavation, blasting, and removal of rubbish, and Rs. 4 for the removal of the larger boulders by bundanies. The lead for spoil being on an average 200 feet, powder and tools being supplied by Government, the contractor also received Rs. 1-8 per 1,000 cubic feet for all rubble procured during the excavation. Up to the first of October 1864, 650,000 cubic feet have been excavated.

Up to the above date 2,400 lbs. of blasting powder have been expended, which gives 3·7 lbs. per 1,000 feet of excavation. Three sizes of jumpers were used—for hard boulders, 1½-inch; for loose sand-stone and shales, 2¾-inch; for shallow beds of the same, 4½-inch. They were 12 and 8 feet long, tipped at both ends; the 1½-inch taking ¼ seer of steel for both ends; the 2¾-inch taking ¾ seer; the 4½-inch taking 2¼ seers. In hard stone the 1½-inch, using both ends, would jump 3½ feet without being sharpened. The sandstones and shales vary so much that it is difficult to give a like average for the 2¾-inch jumpers. In hard stone, with 1½-inch jumpers, two men *could* jump a hole 3 feet in a day, but the average was not so good; with a 2½-inch jumper, they could not do more than 1 foot 8 inches.

In moderately hard shale, two men could jump two holes 2¾ inches, 3½ feet deep in the day, but not so much with deeper holes; in the friable sandstone, two men could jump 2 holes 2¾ inches from 8 to 12 feet deep.

At first, stone-cutters were employed for jumping, but afterwards beldars were taught and paid at the rate of 2½ annas per day. The charges for

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blasting were calculated on the "the cubes of the lines of least resistance," taking a 4 ounce charge for 2 feet as the standard; thus a 3 feet line of least resistance would require $3^3 : 2^3 :: x : 4$ ounces $\therefore x = 13\frac{1}{2}$ ounces. This was found to answer well for stone; and for shale $\frac{2}{3}$ of this was ample; but the loose sandstone took considerably more, though soft; the sand being cemented with a soft argillaceous cement, it was compressible and withstood the shock better.

The tamping was of clay, moderately dried in small rolls in the workshop. Cartridge paper soaked in a solution of 1 ounce of saltpetre and 4 ounces of water, was used for igniting the charges. Rammers with copper ends, copper needles, and long iron scoops were all made on the works.

No serious accident has occurred in the quarry or in blasting; twice men have been slightly burnt from carelessness in lighting the touch paper.

The tools used for quarrying are very simple; large hammers and wedges, which are supplied by Government, and small hammers and chisels, which the workmen themselves procure.

The large hammers and wedges are best made from the raw country iron; those made of English iron (as procurable in the Indian market) are very inferior and break or crack after a few days work; country iron being extremely tough scarcely ever breaks, and the hammers and wedges when gradually flattened by use can easily be made up again. The iron used here comes from Rewah on pack-buffaloes, in pieces of from 10 seers to 1 maund in the rough state. From a piece weighing $7\frac{1}{2}$ seers, 6 seers of iron was worked into a wedge, but the average is not so good, being about 60 to 70 per cent. The price of this delivered at the quarries is from Rs. 4-8 to 5 per maund.

The working of this from its rough state, of course involves a great deal of manual labor, and costs from Rs. 10 to 18 per maund, but the product is excellent, which may be attributed to the original quality of the iron, to the hand forging, or charcoal fuel, but probably to all three combined.

The stone lies in beds, through the breadth of which it is first necessary to chisel a trench, in order that blocks may be split off; a trench 28 feet long in a bed 2 feet 4 inches deep, cost Rs. 58. This trench was 1 foot 6 inches wide at top, 8 inches at bottom, giving a cubical content of 70 feet; this gives $13\frac{1}{4}$ annas as the cost of chiseling out per cubic foot, paying the men at the rate of 6 annas per day, but I think it *might* have been done cheaper than this.

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The method of working the stone is this; the dimensions having been marked off, holes are chiseled along these about 3 inches apart, from 3 to 6 inches deep, from 4 to 6 inches long and 2½ inches wide, into which wedges are put, and struck from end to end of the line with heavy hammers, until the stone is split. This is precisely the same method as that in use in England, and was probably known in India before England existed as a nation; old Bhur forts near shewing marks of smaller wedge holes.

The rates I am now paying for quarrying are—

| | R. | A. | P. |
|---|---|---|---|
| For ashlar, 1 to 20 cubic feet, per foot, . . . | 0 | 2 | 0 |
| „ 20 to 40 „ „ . . . | 0 | 2 | 6 |
| „ flags, two inches thick, „ . . . | 0 | 3 | 0 |
| Rough dressing the ashlar, „ . . . | 0 | 1 | 0 |
| For large rubble, per 100 cubic feet, . . . | 3 | 14 | 0 |
| „ small „ „ . . . . | 1 | 8 | 0 |

The ashlar is rough dressed before it is taken out of the quarry; this has been found to save ¼ths of the carriage.

The Establishment at present consists of—One Assistant Engineer—an English writer—Two Moonshees—One Jemadar—A police guard of one head and four men. Head stone-cutters and head bundanies receive from Rs. 14 to 16 per mensem, stone-cutters from annas 4 to 6, bundanies annas 4½ per day.

A double line of tramway leads from the quarry to the river; two derricks will soon be erected in front of the quarry, as soon as these are completed, all ashlar will be hauled out of the quarry on to the trucks, (which will run along the face of the quarry) at once, and propelled by coolies to the river bank. In the dry season when the river falls 40 feet below the level of the end of the tramway, it is proposed to lower the laden trucks (which at the same time pull up the empty ones) by a chain passing round a drum, with a brake, on a tramway running on a rubble embankment pier, 450 feet long, with a slope of 9 in 100, and a 200 feet level at the end. The total cost of the tramway 2,500 feet long, with thirty trucks, including five lakhs of earthwork, will be about Rs. 14,000. The probable rates for leading and loading, with the tramway will be

Ashlar, 1 to 20, at 8 Rs. per 100 cubic feet.
„ 20 to 40 at 12, „ „
Large rubble and flags, at 4 Rs. per 100 cubic feet.
Small „ „ 1 „ „

The East Indian Railway Company work a quarry 380 feet long by

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about 120 feet broad, from which a great portion of the large ashlar for the Jumna Bridge has been procured. They have a single line of tramway to the river at a very low level; this saves the necessity for steep gradients, but is useless during the rains and for a month after, being covered for several hundred feet with a deposit of silt from 4 to 10 feet deep. When the work was first commenced a masonry pier was built into the river, but was unfortunately swept away during the ensuing rains; a temporary earthen pier is now made every year to carry on the work during the dry season. This is a very fine quarry, and has beds 7 feet thick in many parts.

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*Tramway.*—The tramway from the quarries to the high bank is 2,400 feet long, with a descending gradient from the quarry, in some places ·5 in a 100, in others 2 in 100; it has three sharp curves running into each other, whose radii are respectively 425, 300 and 225 feet. The loaded trucks run with considerable velocity down the 2 in 100 gradient, but are sufficiently checked and easily brought up, without a brake, on the gradient of ·5 in 100 of the end. According to the formulæ for raising the outer end rail in curves, *i. e.*, $\frac{R - r}{R \times r} \times W\,8^2 \times \cdot 782 =$ super-elevation in inches.

Where R = least radius (in this case 1,200 feet).
„ $r$ = radius of curve.
W = width between rails.

and taking 8 miles per hour as the greatest velocity; the outer rail in the sharpest curve, *i. e.*, 225 feet, would only require to be raised nearly ½ inch.

But, practically, this was not found enough; probably the smaller flanged wheels and the less perfect laying down of a tramway require a modified formula. A super-elevation of 2 inches in the outer rail was found necessary. The formation level was made 20 feet wide to allow for a double line of tramway 8 feet from centre to centre, and a pathway along one side.

The transverse sleepers were laid upon a 6-inch bed of ballast about 9 feet apart, they were 7′ × 6″ × 4″; over these the longitudinal sleepers were laid, their joints meeting over the transverse sleepers, and fixed in position by chucks of wood on each side, secured on the outside by two

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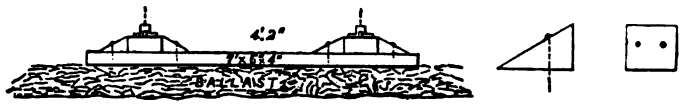
6-inch nails, on the inside by one do. The chucks were easily and cheaply made out of the ends of the sleepers, which had to be cut to uniform lengths.



The rail is a small bridge rail, weighing 14 lbs. to the yard; generally in 10 feet lengths, fastened by 4-inch nails to the sleepers; in each length there are 10 nails. No drill holes are required for these in the timber, but they penetrate much better if wetted before being driven in; in very dry weather they are apt to jump back when struck without this precaution.

The line being ballasted up to the top of the sleepers, it was found that a 2-inch layer of fine gravel or budgeree over this was of great service in binding down and so consolidating the ballast, as to fix the longitudinal sleepers immoveably and prevent any vibration.

The trucks are of two sizes, the larger 8 × 8 feet for the carriage of rubble, the smaller 7 × 4 feet for ashlar; they run up on 2 feet 3 inches wheels with 2½″ axles, and are made of strong framed saul, strengthened by bolts and ties; the 8 × 8 feet trucks carry as an ordinary load 150 cubic feet of rubble, weighing about 1¼ cwt. per cubic foot = 188 cwts. = 9½ tons, nearly; five men are required to propel these loaded trucks with a descending gradient, and three men to push back the empty ones with an ascending gradient.

The ashlar is now lifted by an ordinary derrick out of the quarry, at once on to the trucks; no blocks over 25 cubic feet have yet been lifted.

The rates for earthwork (cutting) were, down to 6 feet, Rs. 3; from 6 to 12, Rs. 3-8; 12 to 16, Rs. 4; 16 to 20, Rs. 4-8; with a lead of 200 feet from the top of the slope.

For turfing slopes, 2 annas per 100 square feet.

For dressing „ 1 „ „

For breaking ballast to 2½″ gauge, 12 annas per 100 cubic feet.

For spreading ballast, with an average lead of 1,000 feet, 8 annas per 100 cubic feet.

The woodwork was bought at 4 annas per cubic foot; in every 100 running feet of single line there are 11 transverse sleepers = 11 × 7′ × 6″ × 4″ = 13 cubic feet, and 200 running feet of longitudinal sleep-

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ers, $6'' \times 5'' = 96$ cubic feet; total 109 cubic feet. Add $\frac{1}{10}$th for wastage in cutting, which gives 120 cubic feet per 100 running feet of tramway. The cost including carriage, would be nearly 5 annas per cubic foot.

Therefore the cost per 100 feet of line

| | | | | | |
|---|---|---|---|---|---|
| would be— $\frac{120 \times 5}{16}$ | = | 37 | 8 0 | 37 | 8 0 |
| The cost of laying was— | | | | | |
| Cutting 11 transverse sleepers, to 7 ft. length, | = | 0 | 8 0 | | |
| „ 22 longitudinal sleepers, to uniform lengths, ... ... ... ... ... | = | 1 | 0 0 | | |
| Making 44 chucks,... ... ... ... | = | 0 | 12 0 | | |
| Drilling 132 holes in ditto, ... ... | = | 0 | 6 0 | | |
| Laying transverse and longitudinal sleepers in position, ... ... ... ... | = | 1 | 6 0 | | |
| Hammering 132 nails in sleepers, ... ... | = | 0 | 4 0 | | |
| | | | | 4 | 4 0 |
| Total cost of woodwork per 100 r. ft. of single line, | | | | 41 | 12 0 |

*N.B.*—In curves (sharp) it costs $\frac{1}{3}$th more to cut the longitudinal sleepers.

The cost of laying the rails was very slight, except in curves where the rails had to be bent; this cost about Rs. 2 per 100 running feet of single line; it was done by beating the rails till nearly red hot in ooplah, then striking them with a mallet on a gauge bent to the required curve.

The rate for conveying rubble by the tramway, *i. e.*, loading, leading and unloading trucks, and stacking at ghât, is Rs. 1; for large rubble, Rs. 4.

The leading and loading of ashlar will probably be reduced next month to $1\frac{1}{2}$ annas per cubic foot, as the tramway is now in good working order.

The tramway itself requires 1 smith and 1 beldar to keep it in order.

T. E. Owen.

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## No. LVIII.

## RATES OF WORK IN BENGAL.

[The following Circular was addressed by the Editor in July last, to the Controllers of P. W. Accounts in the several Provinces—their replies as received will be published.]

*To the Controller and Examiner of Accounts, Public Works Department, ———— Circle.*

*Roorkee, 1st July 1864.*

Dear Sir—It has been suggested to me that it would be of essential service to Officers of the Department, generally, to collect and publish in the Engineering Papers which are issued quarterly from this press, the various rates of work obtaining in different parts of the country *at the same time;* and to enable me to do this I beg to solicit your aid.

I enclose a printed list containing most of the rates in ordinary use, with spaces for additions if necessary, and I would request the favor of your filling up the columns and returning the list to me at your early convenience.

I have, &c.,

J. G. M.

[In the following Tabular Statement received from Bengal, I have omitted those items which were returned blank.]

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## Works Department, in or about the month of MAY, 1864.

| | | Hazareebaugh. | Burrakur. | Burdwan. | Midnapore. | Balasore. | Cuttack. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| **Rates** | | | | | | | | |
| Mistrie Mason, | 0 0 | 12 0 0 | 11 4 0 | ... | ... | ... | 9 8 0 | |
| Skilled workmen, | 0 3 | ... | ... | ... | ... | ... | 0 4 0 | |
| Ordinary do., | 0 2 6 | ... | ... | ... | ... | ... | ... | |
| Mistrie Bricklayer, | 0 0 | ... | 9 6 0 | ... | 5 10 0 | ... | ... | |
| Skilled workmen, | | ... | ... | ... | ... | ... | ... | |
| Ordinary do., | | ... | ... | 0 3 0 | 0 2 0 | ... | ... | |
| Mistrie Carpenter, | 0 0 | 7 8 0 | 9 6 0 | ... | 7 8 0 | ... | 7 8 0 | |
| Skilled workmen, | 0 3 | ... | ... | 0 5 0 | 0 3 0 | ... | 0 3 6 | |
| Ordinary do., | | ... | ... | 0 5 0 | ... | ... | 0 2 9 | |
| Mistrie Smith, | 0 0 | 9 6 0 | 20 0 0 | ... | ... | ... | ... | |
| Skilled workmen, | 0 3 | ... | ... | ... | ... | ... | ... | |
| Ordinary do., | 0 2 6 | ... | ... | ... | ... | ... | ... | |
| | | ... | ... | 0 3 0 | 0 4 6 | ... | ... | |
| | 0 2 6 | 0 2 0 | 0 5 0 | 0 3 0 | ... | ... | ... | |
| | | 0 2 0 | ... | ... | ... | ... | ... | |
| Beldar, | 0 1 6 | 0 1 6 | ... | 0 1 6 | ... | ... | ... | |
| Mate coolie, | 0 2 0 | 0 2 0 | 0 2 6 | 4 0*0 | 0 2 0 | 0 2 0 | 0 2 6 | |
| Coolie, | 0 1 0 | 0 1 0 | 0 1 3 | 0 2 0 | 0 1 6 | 0 1 6 | 0 2 0 | |
| **Rates** | | | | | | | | |
| Stone, best quality at the quarry, | | ... | 1 1 0 | ... | ... | ... | ... | |
| Bricks (best), | 0 0 | 5 0 0 | 6 0 0 | 5 6 0 | ... | ... | ... | |
| Ditto (second), | 0 0 | ... | ... | 5 6 0 | ... | 2 8 0 | 3 8 0 | |
| Ditto (best), | | ... | ... | ... | ... | 2 8 0 | 3 8 0 | |
| Tiles, common, | | ... | ... | ... | ... | ... | ... | |
| Tiles, Goodwin, | | ... | ... | ... | .. | ... | ... | |
| Flooring tiles at kiln, ... | | ... | ... | 1 2 0 | ... | .. | ... | |
| Lime, best kunkur, | 0 0 | 8 12 0 | ... | 28 4 0 | ... | 18 0 0 | ... | |
| „ stone, | 0 0 | 23 6 0 | ... | ... | ... | ... | ... | |
| Chunam, for kiln, | | ... | ... | ... | ... | ... | ... | |

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| | Hazareebaugh. | Burrakur. | Burdwan. | Midnapore. | Balasore. | Cuttack. | Remarks. |
|---|---|---|---|---|---|---|---|
| **Rates of Mati** | | | | | | | |
| Soorkhee, pound | 0 4 0 0 | .. | 6 2 9 | .. | 6 4 0 | 8 0 0 | |
| Sand, clean, sh carried—mile | .. | .. | .. | .. | .. | .. | |
| Kunkur, for me | .. | .. | .. | .. | .. | .. | |
| Broken stone, fo carried—mile | .. | .. | .. | .. | .. | 3 1 0 | |
| **T** | | | | | | | |
| Saul, rough, in carried—mile | 0 .. | 1 8 0 | .. | .. | 0 12 0 | 0 8 0 | |
| Teak, do. | .. | 2 12 0 | .. | .. | .. | .. | |
| **C** | | | | | | | |
| 2-Bullock cart, | .. | .. | .. | .. | .. | .. | |
| **Rate** | | | | | | | |
| **I** | | | | | | | |
| Collection and s cluding cost miles. *a.* Ku | 0 .. | .. | .. | .. | 3 8 0 | 3 2 0 | |
| Consolidation o cubic feet of *a.* Kunkur, | 0 .. | .. | .. | .. | .. | .. | |
| **Ea** | | | | | | | |
| Earthwork, exc or sandy soil, up to 75 fe bank, .. | 0 .. | .. | 2 8 0 | .. | 2 4 0 | 2 2 0 | |
| Ditto, hard clay able stone or the pick occ in bank), | .. | .. | .. | .. | .. | .. | |
| **Fo** | | | | | | | |
| Excavation of I where no pum quired, .. | .. | .. | .. | .. | .. | .. | |
| Concrete or béto | .. | .. | .. | .. | 8 0 0 | 5 8 0 | |

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|---|---|---|---|---|---|---|---|
| (*All* | | | | | | | |
| Rubble, .. 0 | .. | .. | .. | .. | .. | .. | |
| Flagged floor 0 | .. | .. | .. | .. | .. | .. | |
| *A* | | | | | | | |
| First class B or dressed set in best ting joints 0 | 11 0 0 | 10 0 0 | .. | .. | 17 0 0 | 15 0 0 | |
| Second class best brick best mortar 0 | .. | .. | .. | .. | 13 0 0 | 12 0 0 | |
| Third class br good bricks 0 | .. | .. | .. | .. | 8 0 0 | 10 0 0 | |
| First class br dressed fac up to 16 fe 0 | .. | .. | .. | .. | .. | .. | |
| Undersunk br including 0 | .. | .. | .. | .. | .. | .. | |
| Best lime P walls, ½" .. 0 | 2 4 0 | .. | 1 12 0 | .. | 1 8 0 | 3 4 0 | |
| White washin 0 | 0 2 0 | 0 2 4 | 0 2 9 | .. | .. | .. | |
| Color washing 0 | .. | .. | .. | .. | .. | .. | |
| (*Exclusiv* | | | | | | | |
| Flat pucka course of fl | 10 0 0 | .. | 12 1 0 | .. | .. | 17 8 0 | * Inclusive of timber [work. |
| Thatched roo 0 | 5 0 0 | 4 8 0 | 1 9 0 | .. | .. | .. | † 6″ Thatching. |
| Tiled roofing, set in mud and mats, 0 | 8 0 0 | .. | .. | .. | .. | .. | |
| Ditto, ditto, layer of fla | .. | .. | .. | .. | .. | .. | |
| Corrugated Ir | 78 0 0 | .. | .. | .. | .. | .. | |
| Pucka terras over 2 cour 0 | .. | 4 0 0 | .. | .. | 16 0 0 | 23 0 0 | |

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| | Hazarebaugh. | Burrakur. | Burdwan. | Midnapore. | Balasore. | Cuttack. | Remarks. |
|---|---|---|---|---|---|---|---|
| *Flooring* | | | | | | | |
| Flat bricks or ti and laid on l | .. | .. | .. | .. | .. | .. | |
| Brick-on-edge rubbed or dre joints laid course of flat 0 | .. | .. | .. | .. | .. | 5 0 0 | |
| Slate floor, | .. | .. | .. | .. | .. | .. | |
| *Ti* | | | | | | | |
| Saul timber, wi roofs, bridg cluding nails clusive of bo 0 | .. | .. | 2 8 0 | .. | .. | 1 8 0 | |
| Pannelled Doo 0 | .. | .. | .. | .. | .. | .. | |
| *I* | | | | | | | |
| Best English Ir ges, bolts, str 0 | .. | .. | .. | .. | .. | .. | |
| Country bar iro | .. | .. | .. | .. | .. | .. | |
| *P* | | | | | | | |
| Painting Wood Red or Whit 0 | .. | 3 0 0 | .. | .. | .. | 2 0 0 | |

P. H. TROTTER,

*Deputy Controller and Examiner of P. W. Accounts, Bengal.*

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# LIX.

## BARRA BRIDGE — LAHORE AND PESHAWUR ROAD.

*Designed and Built by* Lieut.-Colonel, A. Taylor, R.E., *Superintendent Lahore and Peshawur Road.*

The Barra River, which meets the Lahore and Peshawur Road about 7 miles to the west of Peshawur, formed the chief obstacle to traffic on the Trans-Indus section of the road. Its drainage area can only be guessed at, as it runs for the greater part of its length through country which no European has ever visited; but it probably drains the greater portion of the mountainous district of Teerah, extending almost as far as Caubul. From the point where it issues from the Khyber Pass, at Fort Barra, to its junction with the Caubul River, it runs on a ridge which it seems to have raised for itself by successive deposits. This peculiar formation renders it very mischievous to the surrounding country, which, during the summer rains, it lays under water for miles.

A strut and strain timber bridge, resting on piles and wooden piers, had been originally sanctioned by the Government; but the unheard of behaviour of the river caused the design to be altered to the present plan. Every arrangement had been made for commencing the work; when the river put a stop to further proceedings by carrying off the pile engine in the middle of the night; and with it the Assistant Engineer in charge, who was unwary enough to be caught by the sudden rush of waters, which he describes as having come down like a wall. Engine and Engineer were stranded some six miles down the



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river, both coated with whip grass to such an extent, as to warrant the latter's opinion that wooden piers would never stand in the Barra. He thought no wooden framing could have stood the weight and vibration of such a mass of grass, branches, &c., as would certainly have caught in the *wales* and cross braces of the piers. So is experience acquired in India; and this little incident is a good commentary on the *Peculiarities of Indian Engineering*.

This opinion was confirmed by the great flood of July 1861, which happened only a few days later. The river on that occasion rose 18 feet in 5 minutes; and was observed to have a surface velocity of 15½ feet a second, or over 10 miles an hour. A timber superstructure was therefore decided upon, which should obviated the risk of the scour, consequent on checking such a current; and work was commenced upon the left pier foundation.

The soil consisted of alternate thin layers of very stiff clayey silt, and loose sand, for a depth of 18 feet; then came a bed of sand 8 feet in thickness, overlying a stratum of clay. It was therefore necessary to excavate down to the thick layer of sand by open foundation, and then, through it, to countersink masonry wells to the solid clay below, a total depth of 26 feet. Although the river was only ankle deep at the time, the soil was so saturated with water, that the two pumps, which were alone available, were found quite inadequate to keep the foundations dry; and the work was stopped, until 12 churusses or water bags, each worked by 6 men, could be rigged up. A depth of 12 feet was reached by working night and day; when a land spring was tapped, which put an end to any chance there might otherwise have been, of doing the work by the help of churusses alone. A plan was then suggested, which succeeded so well in this case, and has since proved so useful in many similar works, that a short account may not be amiss. Two wheels were taken off a horse cart, and fixed 5 feet apart, on an axle projecting about 3 feet on either side. Battens were then lashed to the ends of corresponding spokes, projecting 2 feet beyond the tires, and forming a kind of drum. This machine, on being turned by 2 men stepping on the battens as on a tread-mill, brought up the water by means of two chains of pots, passing over the projecting ends of the drum and discharging into troughs placed on the axle; a cross bar on two up-rights being provided for the men to hold on

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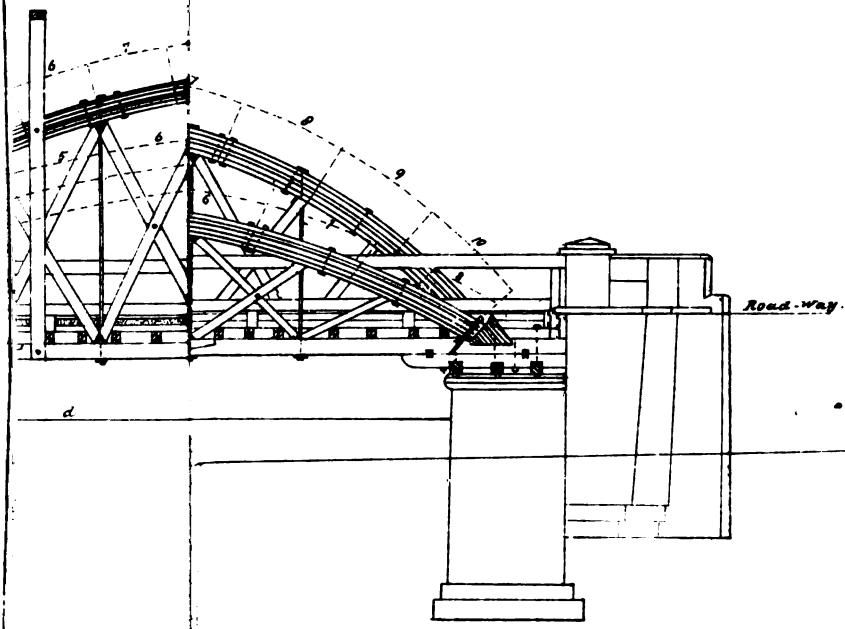
A BRIDGE

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by. This machine, requiring 4 men to work it during the day, and 6 men during the night, does more work than 6 churusses, and costs very little in making. By means of three such drums the water was kept under, and the western pier completed. The excavation was twice filled up, during the progress of the work, by floods in the river, which it would have been impossible to keep out by any means short of a regular cofferdam.

Work was now commenced on the eastern pier, which was completed in half the time, and at one-sixth of the expense of the western. A small irrigation canal which ran along the high bank of the river, was utilized into turning a water-wheel 12 feet in diameter, connected to a drum 7 feet in diameter, carrying two chains of very large pots. The chain was made in pieces of 4 feet in length, connected by hooks-and-eyes, so as to allow it to be lengthened or shortened with ease to suit the level of the water; an operation otherwise productive of much labor and waste of time. The wheel was found to work best, when doing from 8 to 9 revolutions in the minute, as a higher velocity did not allow the pots time to empty themselves properly into the trough. The work done averaged from 1,200 to 1,600 cubic feet of water raised 18 feet in the hour; and more might have been done, if required, by putting on a heavier chain of pots and turning on more water. The cost of setting up the whole machine did not exceed 70 Rs.; the wheel being very roughly made of slab planks and refuse wood; and the saving effected by it was over Rs. 2,000. Hence it appears, that in cases where much water is met with in foundations, it may often be true economy to spend even a considerable sum on obtaining water as a motive power to the pumping arrangements; either by damming up the river itself so as to obtain a fall, or by cutting a channal to bring the water from other sources. It may be said that this is a self-evident statement; but the little use made of the enormous water power available throughout India, shows that the self-evident truth will bear repeating, as it is so very seldom acted upon.

The springs which gave so much trouble by swamping the foundations, were of two kinds. The first, which looked exactly like, but were not really, land springs, were generally due to some local cause, such as water running near the excavation, &c. These could either be entirely stopped, or very much checked, by cutting a trench close to the

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supposed source of supply, and between it and the excavation; or if this did not succeed, by blocking up the spring; which, if of this nature, was seldom so strong as to force its way out in another place.

A few drainage cuts, in the high ground above the excavation, materially lessened the influx of water; an unlooked for result, considering the work was being done in the bed of a river.

The real land springs, which could always be recognized by the high temperature of the water, were much harder to deal with, and could only be checked in very hard clay soil. This was done, by driving pointed slab planks close together some 4 feet into the ground round the spring; then building a sort of masonry well as high as the water would rise, and filling it up with quick setting mortar and good clay. But this plan did not always succeed; and it was generally found best not to interfere with the land springs; as, if blocked up, they undermined and brought down the shores and planking supporting the sides of the excavation, and did a vast deal of mischief.

The wells were sunk in the usual manner, but were vaulted over with segmental domes connected by cross arches; a quicker method than filling them with concrete, and then building up solid, as usually practised. This would have required some fifteen days for the concrete to settle; and no stone slabs were procurable of sufficient size to stretch from one well to the other. The bricks for the domes were previously cut on a centreing on the ground. The tops of the wells were strongly bonded with hoop iron, to resist the thrust of the vaults and cross arches, which are shown in detail in the plan.

The centering for building the plank ribs, consisted of a number of long stout timbers (which were afterwards used up as roadway beams) laid at equal distances on the ground, in the direction of radii of the curve, and carefully levelled. Any short spare timbers, not less than 10 × 8 inches, that could be obtained, were then roughly dressed to the required radius on their outer side, and connected together by square lap joints so as to form one continuous curve. These were further kept together by $\frac{3}{4}$-inch bolts passing through the lap joints, and the extremities of the long timbers, into which they were slightly notched to prevent the bolts being bent by lateral pressure. The curved outer face of the short pieces was then carefully dressed and planed to the required ra-

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dius, and formed a centering, on to which the planks were bent with screw clamps. Notches were cut on the curved surface, opposite each joint in the rib, sufficiently large to admit a wrench, by which the nuts were screwed home. The same centering served for all the trusses; those of least curvature being built first. In such cases it would, however, always be better to raise the centering on brick pillars some 3 or 4 feet from the ground; as this would allow the workmen to fit the lower face of the rib as accurately as the upper. There would then be no need to turn the rib on itself to plane and adjust its lower face—a great advantage—as plank bows are very liable to be damaged by the strains produced by their own weight, if not very carefully supported at their extremities. They should be moved as little, and as carefully, as possible before being permanently fitted on to their tie-beams. To prevent the ribs from flattening out, they were kept screwed on to the centering, and thoroughly wetted, for a few days after being bolted together. As the low centering would only admit of this being done to the upper face of the bow, the unequal expansion caused it to warp; and it is very probable, that the tendency so occasioned, may spoil the look of the bridge, when time and weather have loosened the joints of the cross and side bracing.

In order to allow for the straightening of the rib when taken off the centering, the latter was built of a sharper curvature than the arch was intended permanently to retain. The tendency to flatten, is however much less than might be expected, and no difficulty was experienced in keeping the bows of the proper shape. The radii of the centerings were made shorter than the proper radii, by $\frac{1}{4}$ of an inch to every foot of the intended rise in the completed arch; and in every case this allowance was found to be quite sufficient. 35 feet 6 inches was found to be the least radius to which 3-inch deodar planks should ever be bent; as none but the very best would take that curve. 2$\frac{1}{2}$-inch planks would have been employed, were it not that the strength of a laminated arch, as compared with that of a solid rib, diminishes almost in the ratio of unity to the number of layers into which it is divided.

Many different methods were tried for bending the planks, but the following plan, which was very economical as not requiring a

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steaming apparatus, was found less injurious to the fibres of the wood than any other. The planks were wholly immersed in water for eight or ten days; then taken out, placed on edge before a bright chip fire, and oiled on both sides until well heated throughout. They were then bent on to a curved gauge, by means of a rack-stick and rope looped over their ends, without giving any signs of straining. On cooling, they retained the form so given them; and by soaking half an hour in water, and repeating the process of heating and oiling, could be fitted on to the centerings with the greatest ease.

It is doubtful, whether iron hoops shrunk when hot over the ribs, would not answer better than bolts to connect the layers of planking. Hoops would not, in practice, be as convenient as bolts, if it were necessary to take out or renew a plank, and might not make so stiff an arch; but they would not weaken it by bolt holes near the joints. A combination of both would perhaps be best—hoops for the outside and bolts for the inside joints. The joints of an outside plank can never, by means of bolts alone, be prevented from starting from each other and from their underlying planks, after a little exposure to the weather. A broad strap over the joint would quite prevent this; and the rib would not be weakened by four bolt holes, passing through it at its weakest points.

The following points were noticed in the construction of the tie-beam, which may be of some use. The scarf shown in the drawing might with advantage have been altered to a plain fish-joint with stout strap irons. This was actually done in one of the smaller ribs; and was found on trial to act better than the scarf, which showed a great tendency to split up at its angles. Hard wood keys, 1½ inches square, introduced at intervals between the two pieces of the tie-beam, prevented their sliding on one another under unequal strains, and took the lateral pressure off the connecting bolts. The corners of the notches, cut for the reception of the hard wood abutting blocks, were secured from splitting up under the thrust of the arches, by pieces of angle iron let into the wood.

The bridge was tested by a dead load of (it is believed) 200 lbs. to the superficial foot of roadway; which it bore without injury. Owing, it is supposed, to the strength of the arched ribs not being at

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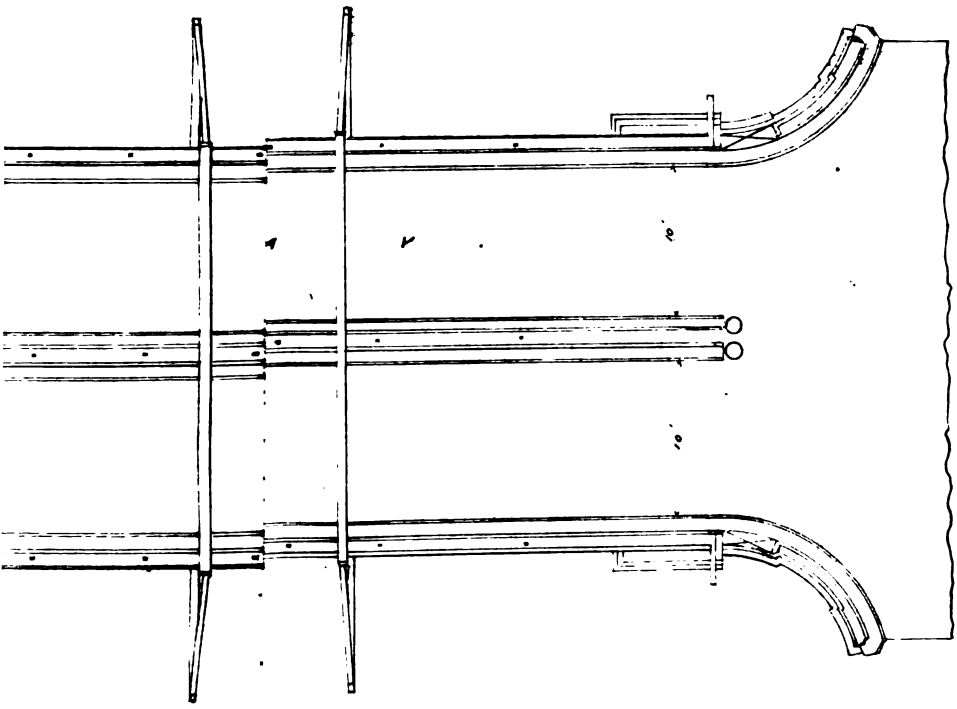
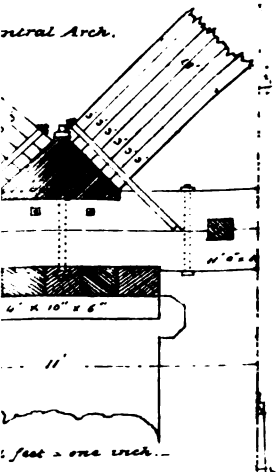
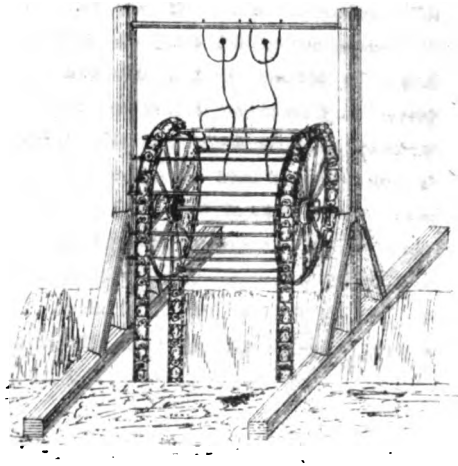
PESHAWUR RC





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UNIV. OF MICH.

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first, fairly brought into play, the deflection under the half, was greater than that under the whole of the load.

All the timber in the bridge, with the exception of the sheeshum abutting blocks, was obtained, at great trouble and expense, from the deodar forests of Kashgar; a wild and unexplored country, some 150 miles north of Peshawur. The timber trade so created, although entirely in the hands of native merchants, is now very extensive, and bids fair ere long to rival that on the Jhelum and the Chenab.

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SPECIFICATION.

The Bridge consists of 3 spans. The two end ones having a clear waterway of 53 feet, and the centre span a waterway of 74 feet. The piers and abutments are of brick-work founded at the depth shown. The timber work to be entirely of deodar free from sap wood.

*Wall Plates.*—The lower pieces are 10 × 6 inches scantling. The upper pieces rest on them and are 10 × 8 inches scantling.

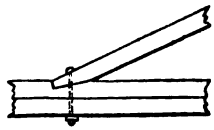
*Corbels.*—Are notched out and let down on to the wall plates to the extent of 2 inches. The keys connecting the corbels and tie-beams are of seasoned sheeshum or Kow wood.

*Tie-beams.*—Are shown in the drawings in full detail. All trenails are to be baked before they are used.

*Abutting blocks.*—Against which the arches and the cross braces abut, are of seasoned sheeshum.

*Roadway Beams.*—Are let on to the tie-beam to the depth of 2 inches. The beams which project and carry struts to steady the vertical frames are to be secured to the tie-beams by ¾-inch bolts. All other roadway beams, excepting the last over each abutment, merely rest on the tie-beams. They are kept in place, by the 2-inch deep notches at each of their ends, and by the planking which is spiked on to them.

*Weather Bracing.*—None is provided for in the two end arches; in the centre span two timbers 8 × 6 inches are introduced at each end, secured to the tie-beams by 1-inch bolts and proper joints, as shown; and supported each at its centre by a bolt passing through a roadway beam.



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*Roadway Planking.*—The spikes to be 9 inches long; two spikes to be used at each end of every plank. One spike is to secure each plank to every roadway beam that it crosses.

*Wheel-guard.*—Different lengths to abut against each other with square ends.

*Cross Braces.*—To be stepped into the hard wood blocks with tenons 2 inches square and 1½ inches deep, and to be secured to each other, where they cross, by a ½-inch bolt.

*Arches.*—Full details are given in the drawings. The surface of the planks to be tarred before they are finally put together in the arch.

*Railing.*—Is secured at intervals to the cross braces and arches.

*Vertical Frames.*—The posts are bolted to the tie-beams and to the arches, and fit into the cap pieces, with mortice and tenon joints secured by an iron strap.

*Painting.*—The railings, railing posts, and struts, are to be painted.

*Tarring.*—The beds of the hard wood blocks, all touching surfaces, where not exposed, surfaces of junction between corbels, wall plates, and tie-beams; and touching surfaces of tie-beam itself, &c., to be tarred.

*Tie-Rods.*—The heads to rest on the tops of the arches over an iron washer. Under the nut, a piece of hard wood 12 × 6 × 4 inches, is inserted to distribute the support over the tie-beam. A washer to be inserted between the nut and the hard wood.

*Stone Posts.*—To protect the ends of the central arch over the abutments; two stone posts of 9 inches diameter are let into the ground.

ABSTRACT OF ESTIMATE.

| c. ft. | | RS. | A. | P. |
|---|---|---|---|---|
| 1,15,480· | Excavation of dry soil, at Rs. 4 per 1,000, | 461 | 14 | 9 |
| 61,200· | „ wet soil, at Rs. 40 per 1,000, ... ... ... ... ... | 2,448 | 0 | 0 |
| 169·3 | Deodar neem chuck, at Rs. 2-4 per c. ft.„ | 380 | 14 | 10 |
| 191·2 | Well sinking, 8 ft. dp., at Rs. 25 per 100, | 172 | 12 | 10 |
| 13,000·60 | Brick-work, at Rs. 24, per 100, ... ... | 3,120 | 2 | 3 |
| 12,778·08 | Superstructure, &c., at Rs. 24 per 100,... | 3,066 | 11 | 10 |
| 1,090·75 | Stone capping and guard blocks, at Rs. 1 per ft. ... ... ... ... ... | 1,090 | 12 | 0 |
| 5,574·08 | Wood-work deodar, at Rs. 2-4 per. ft., | 12,541 | 11 | 3 |
| 131·65 | Hard wood work, at Rs. 4 per ft., | 526 | 9 | 7 |

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ABSTRACT OF ESTIMATE.—*(Continued.)*

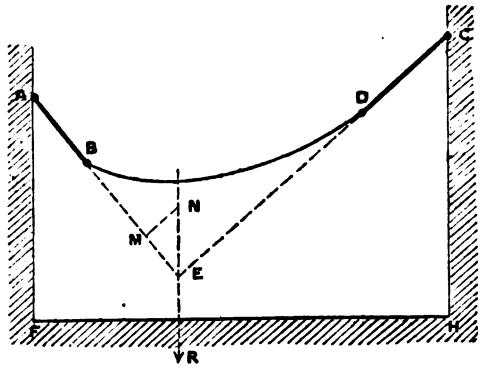
| lbs. | | RS. | A. | A. | | | |
|---|---|---|---|---|---|---|---|
| 6,588·24 | Iron work, at Rs. 20 per 100 lbs., ... | 1,317 | 10 | 4 | | | |
| s. ft. | | | | | | | |
| 31,363·31 | Tarring, at Rs 2 per 100, ... ... | 627 | 4 | 8 | | | |
| 2,432· | Painting, at Rs. 5 per 100, ... ... | 121 | 9 | 7 | | | |
| | Allowance for work commenced on former designs, but unavailable for this one, ... ... .. ... ... | 130 | 0 | 0 | 26,006 | 1 | 6 |
| | Add Contingencies at 5 per cent., ... | | | | 1,300 | 4 | 11 |
| | Grand Total Rupees, ... | | | | 27,306 | 6 | 5 |

ALEX. TAYLOR, LIEUT.-COL., R.E.
*Supdt. L. and P. Road.*

## CALCULATION OF THE STRAINS ON THE DIFFERENT TIMBERS IN A BOWSTRING GIRDER.

The conditions of equilibrium of a rib, are exactly similar to those of a chain; both being under an uniform vertical load. Most of the calculations on such chains or ribs may be said to depend on the following property, which can be proved mathematically, but will now merely be stated.

AB, CD, are two straight weightless rods moveable round hinges




at A and C, in the walls AF, CH. Let BD be a cord attached to their extremities, and loaded either with constant, or with variable loads. In the position of equilibrium of the system, the rods AB, CD, will be tangents at B and D to the curve assumed by the cord whose tensions at those points, will act in the direction of AB and



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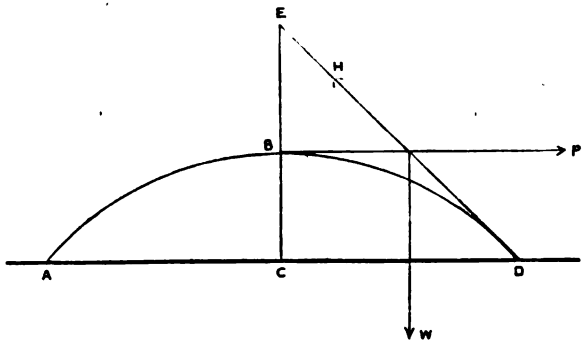
CD. The resultant of all the forces acting on the cord BD will pass through the intersection of the tangents at E. The tensions and resultant are also represented in magnitude by the sides of a triangle drawn parallel to their directions, such as NME.

From this property it can now easily be proved, that the curve of equilibrium under an uniform load is a parabola; such that ED being




a tangent at D (see figure) EB = CB. The triangle CED will also represent the magnitude and direction of the forces keeping the arch in equilibrium.

If then W be the weight of the loaded half arch, P the pressure at B, H the pressure at D in the direction of the tangent ED, we have—

$$W : P : H :: EC : CD : DE$$

$$\therefore P = \frac{W.\,CD}{EC} \text{ and } H = \frac{W.\,DE}{CE}$$

($\alpha$) $\therefore$ Pressure at the crown $= \frac{W.\,CD}{EC} = \frac{W.\,CD}{2\,CB}$ and tension of the beam = horizontal component of H = H cos EDC $= \frac{W.\,DE}{CE} \cdot \frac{DC}{DE}$.

($\beta$)..... $= \frac{W.\,CD}{2\,CB}$ also.

The rib and the tie-beam should therefore be of the same scantling, were it not that the latter besides tension is acted upon by a cross strain.

To allow for this cross strain, the scantling of the tie-beam is calculated from the formula,

$$f' = \frac{H}{b\,h} + \frac{6\,M}{b\,h^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (\gamma)$$

Where $f'$ = The safe crushing weight of the wood used.

H = Tension of tie-beam.

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$b \times h$ The scantling of tie-beam.

M = Bending weight on each section of the tie-beam.

To apply these results to determining the scantling of the main rib of the centre span of the Barra Bridge, we have—

Width of roadway, 10 feet.

Length of roadway, 74 feet.

Weight of roadway per s. foot, 280 lbs.

Height of truss, 16 feet.

∴ Whole weight on centre truss

= 74′ × 10′ × 280 lbs. = 2,07,200 lbs.

and W = Weight on half arch = 1,03,600 lbs.

∴ From ($\alpha$)

Pressure at the crown

$$= \frac{W.CD}{2CB} = \frac{103600.37}{32} = 119{,}787 \text{ lbs.}$$

and a square inch of deodar can resist a pressure of 700 lbs.

$$\therefore \text{Area of rib} = \frac{119787}{700} = 171 \text{ square inches.}$$

But, as 700 is rather a high co-efficient, the scantling of the rib is made, 18″ × 10″ or 180 square inches.

Again, from equation $\beta$,

Tension of tie-beam = 1,19,787 lbs.; and the weight on each section between the suspending rods

74′ = × 10′ × 280 lbs. = 20,720 lbs.

which is equivalent to a bending weight of 10,360 lbs. at the centre of the section. Let the depth of the tie-beam = 10 inches, then if $b$ be its width in inches, equation $\gamma$ becomes

$$700 = \frac{119787}{10\,b} + \frac{610 \cdot 360}{100\,b}$$

$$= \frac{1260030}{100\,b}. \text{ whence}$$

$b$ = 18 inches and 20 × 10 inches, is actually given to compensate for bolt holes, weak joints, &c.

For the diameter of the suspending rods; 220 lbs. being assumed as the weight per superficial foot of roadway, exclusive of the weight of the rib.

Weight on each rod

= 220 lbs. × 10 feet × 7·4 feet.

= 16,280 lbs.

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and tensile strength of wrought-iron being 12,500 lbs.

Required section of iron $= \frac{16280}{12500} = 1{\cdot}3$ inches.

For the dimensions of roadway beams, 2 feet from centre to centre, and 11 feet 6 inches long. The severest probable test on these joists, would bring a weight of $1\frac{1}{2}$ tons on a foot run of the bridge. Hence the joists should be able to support a weight of $1\frac{1}{2}$ tons at their centre. If the joist were 8 inches deep, the breadth $b$ would be found by the equation

$3360 = \frac{b \cdot \delta^2}{11' 6''} \cdot 115$ (co-efficient for transverse strength of deodar).

Whence $b = 5{\cdot}25$ inches; and the scantlings may for safety be increased $\frac{1}{4}$th, or $10 \times 6$ inches, the dimensions actually given.

For the scantlings of the diagonals, the following formula is used—

$$T = \frac{w' s}{k} \cdot \frac{n(n+1)}{2N}$$

Where

$T$ = Greatest thrust on diagonal.

$N$ = Whole number of divisions of roadway.

$n$ and $n + 1$., The numbers of the rods between which a diagonal is situated.

$s$ = Length of brace.

$k$ = Difference of level of its ends.

$w'$ = Greatest travelling load on the post.

To determine the proper scantling for the centre diagonal braces, we have—

$N = 10$.

$n$ and $n + 1 = 4$ and 5, respectively.

$s$ = 17 feet.

$k$ = 16 feet.

$w' = 1\frac{1}{2}$ tons $= 3{,}360$ lbs., the greatest likely travelling load acting on the brace.

Hence

$$T = \frac{3360 \cdot 17}{16} \cdot \frac{4 \cdot 5}{2 \cdot 10} = 3570 = \text{thrust on the diagonal.}$$

The brace being 34 times as long as its thickness; the co-efficient of crushing should be for deodar about $\frac{700}{4}$ or 175 lbs.

Hence proper sectional area $= \frac{3570}{175} = 20$ square inches; or rather less than the section $6'' \times 4''$ which is actually given to the braces.

J. Browne, Lieut., R.E.

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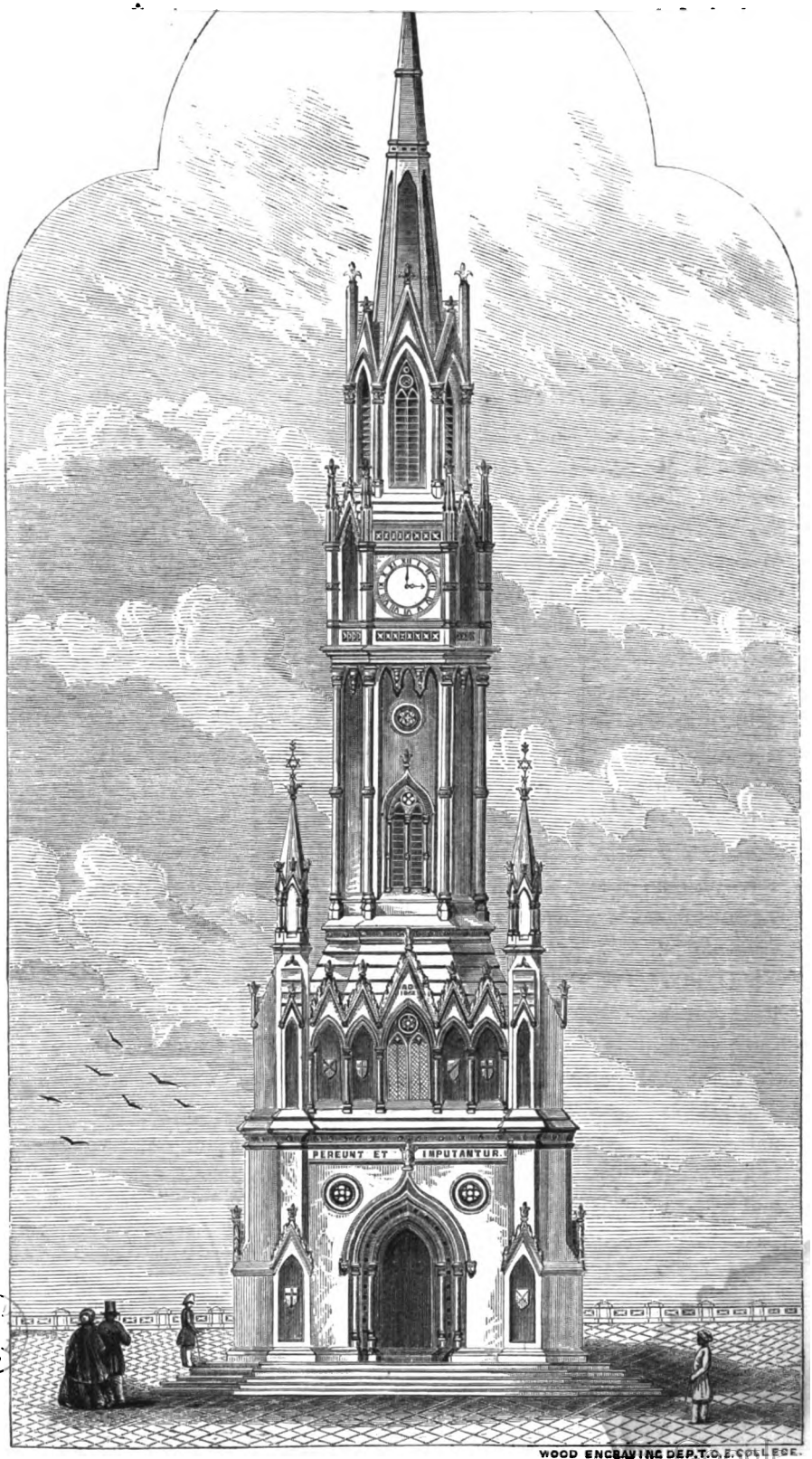


WOOD ENGRAVING DEP.T.O.C.COLLEGE.

THE CLOCK TOWER—UMRITSUR.

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# INDIAN BARRACKS.

In an article on Anglo-Indian Architecture, in Vol. I., I expressed an opinion that the style of building usually adopted in the Upper Provinces for our dwellings, was ill adapted to the climate. Having lately been called upon to act as member of a Committee on the Ventilation and Cooling of Barracks, I have been led further to consider the question of the best form of barrack, and now venture to offer the following suggestions on the subject.

The general fault of all Barracks that I have yet seen is, that they are very hot in summer, and cold and *draughty* in winter—that there is no proper system of ventilation;—that the men have virtually to live in their bed rooms, in an uncomfortable fashion, and without any privacy;—that they are very expensive and exceedingly ugly.

Now, there is little doubt that the present fashion of barracks arose from our first tropical stations being on or near the sea coast, in which numerous doors are required through which the refreshing sea breezes may sweep through the building. But it is *primâ facie* unlikely that buildings erected after the same fashion in a totally different climate such as that of Hindostan, should answer their purpose. For several months in the year it is necessary in these provinces to exclude the external air all day long, and (but for the sake of ventilation) through the night too, and when to the heat is added the abomination of a dust-storm, not to mention the normal plague of *flies*, the discomfort of the present arrangement is indescribable. The best fitting door will hardly exclude the dust, and half the doors won't shut, while the other half have broken panes of glass.



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It would, therefore, in the first place seem desirable to reduce the number of *Doors*, to what is absolutely required for ingress to, and egress from, the barrack; so that there should be as few entrances as possible for the hot air in summer, and the cold air in winter; upper windows or sky-lights being employed for light. These may be made to open, and should be defended from the direct rays of the sun by venetians, but they are primarily for light and not for ventilation, which should be independently arranged.

Next, as to the *Walls;* if the cost were not too great, I would make them 8 or 10 feet thick, so as to be absolutely impervious to the external heat. But I believe the same end may be answered by using walls of the ordinary thickness, only *making them hollow.* This is so common a construction now in England, where its advantages in excluding damp are well understood, that it is surprising it has not been tried in India for excluding heat as well as damp. Hollow walls may be made of ordinary bricks, or with the help of bricks specially moulded,* as shown in the annexed plate, the latter arrangement being copied from the Civil Engineer's Journal for 1862, where its use is explained in the construction of the Dover Railway Station. Hollow *bricks* might also be tried, as nothing but actual experiment can determine which is the coolest construction.

Whether open verandahs can or cannot be dispensed with for such walls must also be settled by trial. The principal use of verandahs is undoubtedly to shade the doors, but it is proposed to dispense with most of these; they do certainly defend the lower part of the walls from the sun, but it is *only* the lower part; and as for convenience, it is well known that in the hot weather they are far too hot to be used.

On such walls I would not put an ordinary wooden trussed roof covered with thatch or tiles; the one is inflammable, the other leaks —both are perishable. A hollow arched masonry roof would be

* I have had some of these bricks made and burnt at Roorkee without any trouble. Perforated bricks are also common in England, the perforations being simply to secure a more uniformly burnt brick by allowing the flame to reach the inside through the perforations.

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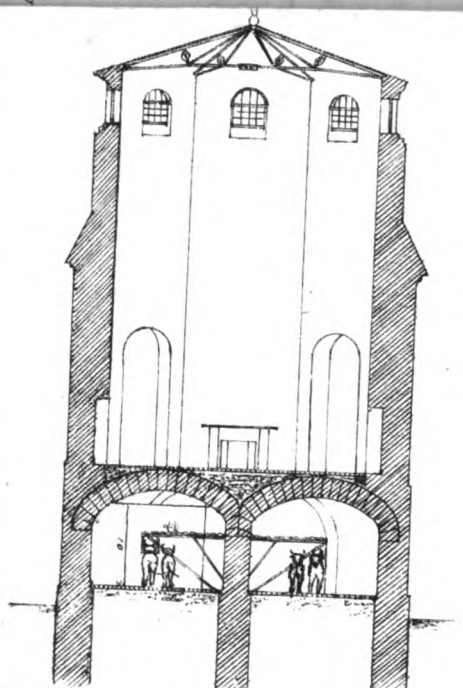
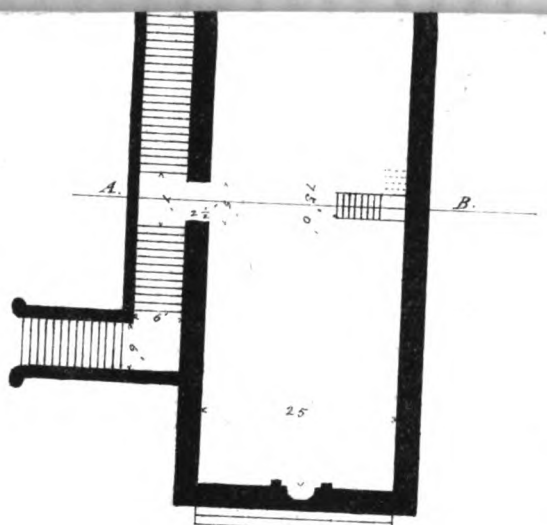
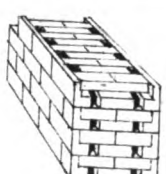
# DESIGN FOR A BARRACK IN UPPER INDIA.

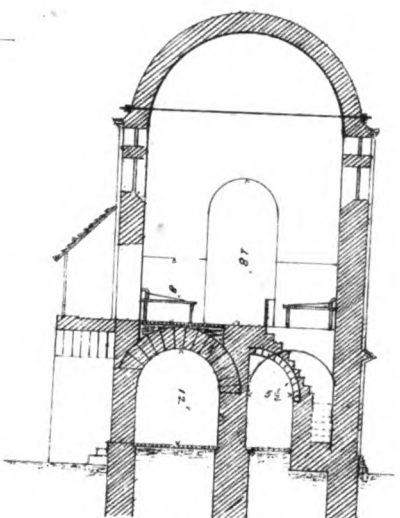


Section on E.F.



Section of Wall.




Section on A.B.

PLATE XV.

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better than either, and the Syrian roof, or the improvement on it, used in Scinde by Col. Fife, (see p. 411, Vol. I.,) might be employed with advantage.

For ventilation, let the floors be *hollow*, the plinth of the building being raised above the ground on arches, forming a basement story,* which might be used for Wash-houses, Privies, and Store-rooms. In the centre of this basement may be placed thermantidotes or fans, by which a continuous current of air will be forced up through perforations in the floor, the foul air being allowed to escape through the domed roof, or by a perforated cornice at the springings, aided if necessary by ventilating shafts with furnaces or exhaust fans (*see* "Ventilation of Barracks" in the present Number.) Of course the fresh air will be cooled, when necessary, by passing it through tatties, or it may be warmed if required.

So much for the construction of the barrack. As to its arrangement, there should be a central dining hall, which would also be the reading room and general living apartment. In the long sleeping wards, I would have wooden and canvass partitions, 8 feet high, giving each man a small room which he would feel was his own (Addiscombe readers will know what *kennels* are). In the cold weather there could be no objection to them. In the hot weather, they might, if necessary, be removed, but I do not think with the ventilation I have proposed, that they would be objectionable. If punkahs are used it might be better to lower the partitions to 7 feet; but punkahs could I hope be dispensed with in such a building. They are expensive and troublesome, and give the men sore eyes, and all that is necessary is to employ thermantidotes of sufficient power below, to blow in a proper quantity of fresh cool air. The Barrack Commission in England give 20 cubic feet per man per minute as the quantity required. For a whole company barrack then 2,000 cubic feet per minute are wanted, which would be supplied by an ordinary 6-feet thermantidote, making 60 revolu-

* The basement might perhaps be partly sunk with advantage below the ground level for the sake of coolness; forming a series of *tackhanahs*, such as are common in Native Forts; they are very cool in hot weather.

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tions per minute.* The Agra jail is ventilated in this manner, and the arrangement is said to be highly successful.†

The arrangements recommended above are shown in the accompanying design. I don't say it is a very handsome building, and doubtless it might be improved, nor would it answer for a climate different from that of Hindostan, where the thermometer ranges from 30° to 130°, where the night is often as hot as the day, and where dust-storms and hot winds are common. The addition of verandahs might also be found necessary, and I have partly shown the arrangement I would in that case propose, but I believe for a barrack in Upper India such a construction would be cooler, healthier, more comfortable, and more durable, while it would at least be not uglier than its predecessors.

*Specification.*—Each Barrack to accommodate a whole company, (nominally 100 men,) to consist of four Wards 75 × 25 feet, radiating from an octagonal Dining Hall 30 feet wide. The Walls to be of hollow (brick) masonry, 2½ bricks thick, the Roofs semi-circular arched, and also hollow except that of the central hall, which will be of large tiles supported on iron trusses. The Basement story to be as shown in section, and to carry the flooring of the wards and hall on semi-circular arches, perforated to allow of a free current of air passing up. Below the central hall will be powerful Thermantidotes, driven by bullocks, to blow air down the passages under the floors; ‡ and from this central space below, the punkahs (if required) can also be pulled. In the basement below the wards, will be situated the wash-houses, baths, privies, and store-rooms.

If Verandahs are required, an ordinary arched masonry verandah

* The Reform Club in London has a similar apparatus driven by a 5-horse power steam engine, and supplying 11,000 cubic feet of air per minute.

† I think it is worth a trial, whether the ordinary form of thermantidote might not be superseded by a piston and cylinder to drive in cool air, as mines are ventilated in England, and furnaces are usually blown. A steam engine of 3 to 5-horse power, ought to do this and pull punkahs as well, and even if bullock power be employed, the arrangement might be adopted if more efficient than the usual one.

‡ If the central pillar, on which the groined arches abut, should interfere with the working of the ventilating apparatus, iron girders might be substituted to carry the floor of the Dining Hall.

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will be provided for the basement story, supporting cast-iron pillars with a tiled roof for the upper story, as shown in the plan.

Stair-cases where shown in the plans. The upper windows to be fitted with venetians,* and a louvred ventilator to be provided all along at the level of the cornice. A fire place is shown at the end of each ward, but in winter the thermantidotes might be employed to drive in warm instead of cold air.

The Cost of such a Barrack will of course chiefly depend on the price of brick and mortar; the barracks at Nowshera (see Vol. I., p. 132) cost Rs. 72,447, besides the cost of the Iron roofing, which if added would swell the total probably to Rs. 90,000. Nor do I think that barracks of the ordinary kind could be built as a rule under Rs. 800 per man, besides the wash-houses and privies, which are usually separate. At an average rate for masonry all through of Rs. 22 per 100 cubic feet, (and there would be a great saving of bricks by the hollow construction), the cost of the proposed design would be Rs. 50,000 (500 Rs. per man) without verandahs, or Rs. 60,000 with verandahs.

---

Since writing the above, I have seen the suggestions for Indian Barracks, prepared by the Barrack and Hospital Commission in England. The general form of double-storied barrack there given, would doubtless be very good for a West Indian station, or for a place on the Indian sea-coast; but for the climate of Upper India its numerous large windows and doors would make it as objectionable as those generally constructed. Nor would the ventilating shafts work, when the external air is hotter, and therefore, lighter than the foul air which is meant to be extracted. Under such a condition, a powerful artificial current is necessary in aid of the natural currents through the ventilators. Regarding the methods of cooling the air, the Commissioners say—

"The thermantidote is correct in principle, but of all the methods of moving air, that by means of a fan wheel used in the thermantidote is the most costly, on

* The glazed frame inside should be moveable on a central hinge; the venetians must also be workable from the inside.

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account of waste of force. Dr. Arnott's ventilating air pump, either in the form of a light metal gasometer, or of a large light piston swinging like a punkah in a fresh air chamber, with suitable valves for ingress and egress of air and means of cooling, would be the nearest approach to an economical and effective thermantidote. The expenditure of force required to move large masses of air by Dr. Arnott's contrivance is very small indeed.

"The cheapest source of cold for cooling air in India is evaporation. And air so cooled should be allowed to enter barrack rooms and wards, not in rapid currents, but in large slow moving masses. The cheapest mechanical method for moving large masses of air is Dr. Arnott's ventilating air pump.

"We would suggest this whole subject for consideration in India, where improved methods of cooling air could be tried to an extent for which there are not facilities in this country."

The kind of Roof recommended, consisting of tiles laid on boarding, would be objectionable in this part of the world—the extreme changes of temperature would certainly warp the boarding and crack the tiles, and make the roof leaky. One object in the design above given is to dispense with a perishable material like wood in all the essential parts of the building.

The recommendations given for hollow walls and a basement story correspond with what is proposed above, but the use of the basement for ventilation as well as for dryness is not suggested. Indeed, the recommendations of the Commissioners lay such stress on the evils of dampness, that it is clear they had the climate of Bengal in view, rather than that of Upper India. Giving every credit to the value of many of the suggestions in the Report, it does not appear that the specialities of the climate of Hindostan have been taken into account,* and that the best kind of barrack to suit those specialities remains still to be devised.

J. G. M.

* Judging from the names it would appear that only one Member of the Commission has ever been in this part of India, and his attention was always directed to totally different subjects.

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# No. LX.

## UMRITSUR CLOCK TOWER.

*Estimate framed by* J. GORDON, ESQ., C.E., *Executive Engineer, Civil Works, of the cost of erecting a Clock Tower in the City of Umritsur, and improving the site by a terrace wall and steps.*

### REPORT.

THE first plans and estimates for this work were prepared without reference to any particular site, and nothing more than a plastered brick-work building was contemplated.

The present conspicuous site having been determined on, it was considered advisable to enlarge the base of the tower so as to allow more space in the lower part of the building, and afford a more convenient spiral stair; which necessarily increased the height in proportion, adding thereby very considerably to the expense of the work, but insuring a very superior structure.

The total outer width of base on the first plan was only 24 feet, and the proposed height 100 feet. On the present plan the width (at the lower buttress) is 32 feet, giving in the same proprtion a height of 133 feet.

The site being the highest point in the city, about 10 feet above the surface of the country, the total height of the tower above the marble tank will be—

| | | |
|---|---|---|
| Height to stone finial, ... ... ... ... | 133 | feet, |
| „ of gilt finial, ... ... ... ... ... | 4 | „ |
| „ of site above level of ground, ... ... ... | 10 | „ |
| Total height, ... ... ... | 147 | „ |

being about 6 feet higher than any of the city buildings.

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The foundations of the tower are unavoidably heavy, as the ground is artificial and unsound for a depth of 12 feet, this circumstance also adds considerable to the extra cost of the building.

It is proposed to construct the building of the *finest description of brick-work*, with dressings and ornamentation in red sand-stone, this being the only practicable way of producing a work worthy of the site, and in harmony with the surrounding objects.

The stone work will be the most costly item in the estimate;* but I feel confident that the result will give satisfaction, as the stone-cutters are very skilful workmen.

The plan of site shows the proposed terrace wall, with flights of steps 32 feet wide, leading to the terrace and tank.

It is considered that this will produce a very improved effect, and give a finish to the entire place, as a frame to a picture.

An arched verandah,† for visitors and spectators on occasions of illuminations, has also been introduced, which will command a good view of the temple and towers. On the opposite side of the terrace, a house in the same style is being built from the plans prepared recently.

The steel bell and new dials have been shipped from England; the bell being 3 feet diameter, will be heard at a distance of four miles. The dials are of the most improved plan, having the figures and hands enclosed between two plates of glass (one semi-transparent) by an iron ring, which arrangement completely prevents injury from dust or rain.

The motto selected for the clock is "pereunt et imputantur," taken from Exeter Cathedral, and suggested by Mr. L. Griffin. White marble tablets will be inserted in pannels in the doorways for any names, records, &c., which may be considered necessary.

As a finish to the design, I hope to be able to get sanction for four figures for the niches round the faces of the clock, which can be done after completion of the building. The Lahore Exhibition may produce some work of art which will perhaps assist in carrying out this idea.

A great difficulty having been experienced in procuring first class bricks, necessary for the face work of the tower, the working establishment has been for some time engaged in the preparation of cut stone dressings and pillars for the lower section of the building, which is in a very advanced state.

* The cost of undressed stone at Umritsur is from Rs. 3 to 3-8 per cubic foot.

† This verandah will conceal an unsightly blank wall.

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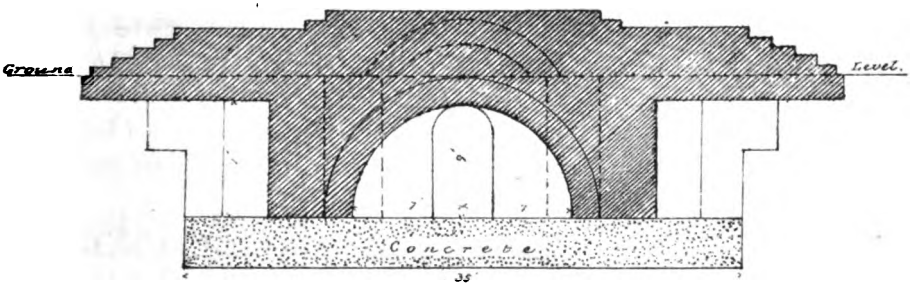
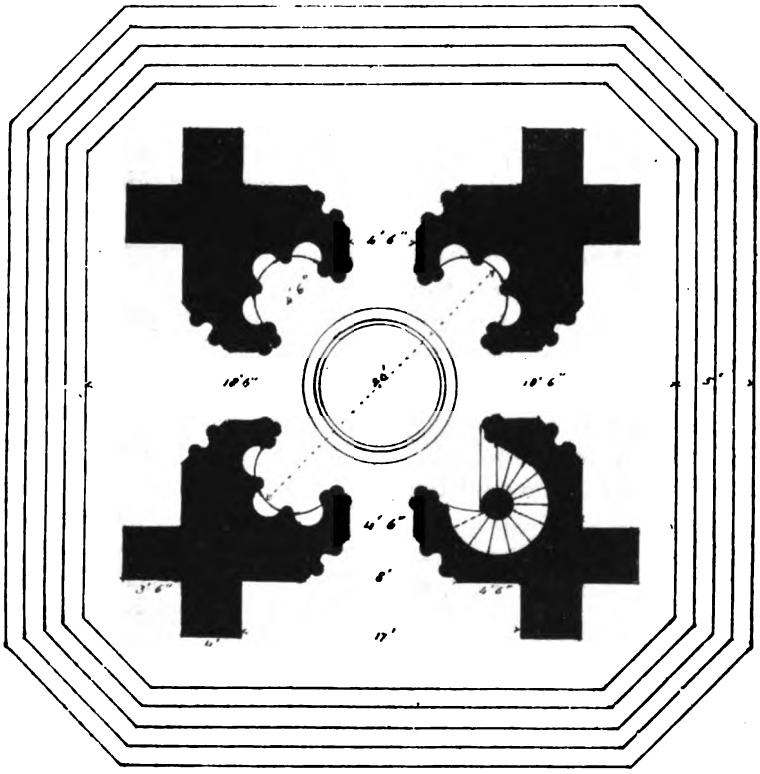
# UMRITSUR CLOCK TOWER.

## SECTION OF FOUNDATION




## PLAN




Scale 12 feet = 1 inch.

LITHO: T. C. PRESS

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Red sand-stone has been procured, in great part in the city of Umritsur, and I apprehend no difficulty in procuring a sufficient quantity for the entire work.

A Clayton's brick compressing machine has been procured for the manufacture of face bricks for city works, and bricks are now being moulded with it, which will be ready in a few weeks.

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ABSTRACT OF ESTIMATE FOR TOWER.

| c. f. | | Rs. | A. | P. |
|---|---|---|---|---|
| 15,068 | Excavation for foundations, at Rs. 5, .. .. .. | 75 | 0 | 0 |
| 3,483 | Concrete in foundation, at Rs. 8, .. .. ... | 103 | 0 | 0 |
| 10,231 | Pucka masonry in foundation, at Rs. 20, .. .. .. | 2,064 | 0 | 0 |
| 4.616 | „ dressed in steps, at Rs. 25, .. .. | 1,154 | 0 | 0 |
| 260 | „ brick-on-edge, at Rs. 30, .. .. .. | 78 | 0 | 0 |
| 27,738 | „ superstructure, including scaffolding, at Rs. 35, | 9,708 | 0 | 0 |
| 1,142 | Cut stone dressings and finials, at Rs. 7, .. .. .. | 8,008 | 0 | 0 |
| s. f. | | | | |
| 3,684 | Plastering part of interior and painting ceilings, at Rs. 5, .. | 184 | 0 | 0 |
| 300 | Encaustic tiles for floor, at Rs. 0-8-0 per foot, .. .. | 150 | 0 | 0 |
| 8 | Marble tablets, at Rs. 10 each, .. .. .. .. | 80 | 0 | 0 |
| | Lettering 8 tablets and cutting 8 shields, at Rs. 12 each, .. | 96 | 0 | 0 |
| s. f. | | | | |
| 363 | Windows, including painting wood work, at Rs. 1-4-0, .. | 454 | 0 | 0 |
| 150 | Timber flooring, at Rs. 50, .. .. .. .. | 75 | 0 | 0 |
| r. f. | | | | |
| 77 | Iron spiral ladders, at Rs. 2-8-0, .. .. .. | 192 | 0 | 0 |
| 10 | 1½-inch iron for spire,.. .. .. .. .. | 50 | 0 | 0 |
| 20 | ¾ „ „ for pinnacles, .. .. .. .. | | | |
| 1 | Iron ring (1½-inch), 36 feet circumference, .. .. | | | |
| 5 | Iron finials, gilt, at Rs. 30, .. .. .. .. | 150 | 0 | 0 |
| 100 | Brass letters, gilt, at Rs. 1 each, .. .. .. | 100 | 0 | 0 |
| | | 22,703 | 0 | 0 |
| | Contingencies at 5 per cent., .. .. | 1,135 | 0 | 0 |
| | Total Rupees, .. .. | 23,838 | 0 | 0 |

*Estimate for Four Glass Dials, 5 feet diameter, and Steel Bell, 3 feet diameter.*

| | | | | |
|---|---|---|---|---|
| 4 | Dials, .. .. .. .. .. .. | 1,250 | 0 | 0 |
| | Packing, .. .. .. .. .. .. | 150 | 0 | 0 |
| | Freight and insurance, .. .. .. .. | 820 | 2 | 8 |
| | Bell, including carriage, &c., .. .. .. .. | 450 | 0 | 0 |
| | Total Rupees, .. .. | 2,670 | 2 | 8 |



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*Terrace Wall, Steps and Arcade.*

| c. f. | | Rs. | A. | P. |
|---|---|---|---|---|
| 7,861 | Pucka masonry in steps and terrace wall, at Rs. 25, .. | 1,965 | 0 | 0 |
| 18,800 | Earthwork, at Rs. 4, .. .. .. .. .. | 75 | 0 | 0 |
| 5,866 | Pucka masonry in arcade, at Rs. 25, .. .. .. | 1,450 | 0 | 0 |
| s. c. | | | | |
| 2,160 | Plastering, at Rs. 5, .. .. .. .. .. | 108 | 0 | 0 |
| | Total Rupees, .. | 3,598 | 0 | 0 |
| | Total cost of Tower, Rupees, .. .. | 23,838 | 0 | 0 |
| | Dials and Bell, including freight, &c., .. .. .. | 2,670 | 0 | 0 |
| | Terrace Wall, with steps and arcade, .. .. .. | 3,598 | 0 | 0 |
| | Grand Total Rupees, .. ... | 30,106 | 0 | 0 |

J. GORDON, C.E.

*September*, 1863.

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REMARKS BY DEPUTY COMMISSIONER.

The design is most chaste and beautiful, and will be as perfectly executed by Mr. Gordon, though not within the period which was first anticipated. The estimate exceeds very much what was first expected. It has been considerably increased by the unexpected cost of ten clock dials, and the bell. These have been underestimated by at least Rs. 1,000, which may be added to the aggregate sum. The bill for customs duties and carriage, viz., bullock train and steamer up-country, has not been included. From letters I have received from Messrs. Grindlay and Co., I am prepared for these charges, amounting to at least Rs. 1,000.

T. W. MERCER.

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## No. LXI.

# THE INDUS TUNNEL.

(2ND ARTICLE.)

*Abridged from a Report upon the Indus Passage at Attock, prepared agreeably to the orders of the Government of India.* BY LIEUT.-COL. ALARIC ROBERTSON, *Superintending Engineer.*

I WILL now refer to the *modifications* which could be made in the scheme for a Tunnel, by which to reduce the first cost, and which would provide fair, though modified facilities, for the traffic, should the cost of the entire scheme as above submitted be considered too great.

The simplest form to which we could reduce the Tunnel, would be that proposed by the Secretary to the Government of India, (Col. Strachey, R.E.,) viz., to complete the *river* section, either as a single or a double roadway; work the traffic through that, either by our own cattle or machinery, and hoist it up and lower it down Shafts constructed for the purpose. And to this arrangement, much consideration has led me to believe that our operations should be limited for the present, leaving the approaches to be dealt with hereafter.

In the details of this scheme the first point is the *width*. A present saving might be effected by reducing the width of the main tunnel, but not only with regard to present arrangement, but to the future possibility of completing approaches, this I think would be bad economy; as reducing the traffic to a single line, would add much to the delay incidental to the proposed mode of lowering and raising the heavy traffic, and would make this objection permanent, except at great cost, which would be in-

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curred by the construction of a second line of tunnel, while the immediate saving would not be large.

The next point is the *Shafts* on both banks. I agree in opinion with Colonel Strachey, that in this modification of the scheme, extraordinary floods should be disregarded. With the pumping engines I propose, *i. e.*, about 30-horse power, the whole tunnel and shafts, if filled, could be cleared under nine days; so that the engines being in a place of safety, the only inconvenience would be the stoppage of the traffic for this time, and with fair warning, temporary precautions might be taken for even preventing the tunnel being filled.

The shafts at present are, one on the left bank, of 10 feet diameter, designed as the pumping shaft in the complete tunnel, and therefore situated on one side of the line, the centre of it being 24 feet from the centre of the line of tunnel. This shaft I would propose to leave exactly as it is, and use it for the purpose originally designed, viz., for pumping and for the gas mains.

On the right bank, the shaft at present is 9 feet diameter, and is situated within the ordinary floods, as shown in the section, and is now raised in a masonry column 24 feet high, which is beyond ordinary floods. This shaft I would purpose also to retain, as an air or ventilating shaft, and for working, while the others which I propose, were being sunk. But small saving would be made by enlarging this shaft, as all the masonry column and brick lining would have to be removed, and we should have to suspend all work below while this was going on.

The *Lift Shafts* I propose to make 28 feet internal diameter, and line them with 1 foot thick of brick masonry, and in these shafts to work two lifts—an ascending and descending one—a single lift might be considered sufficient, but the saving is so small that I recommend the two. The machinery must be the same for one as for two, and in lieu of the second we must have a counterpoise weight, so that the only saving would be the mere cost of the lift frame and a small decrease in the size of the shafts.

The lifts I propose to make 13 × 8 feet interior dimensions, the side frames 6 feet high; this size of lift is sufficient for the accomodation of a 12-pounder field gun, which I think enough. I attach drawings of the lifts and the lift machinery, and also of the timbering of the lift shafts. The lifts will work along guide rails, and there is a set of safety levers, to prevent the descent of the lift in case of the breaking of the rope.

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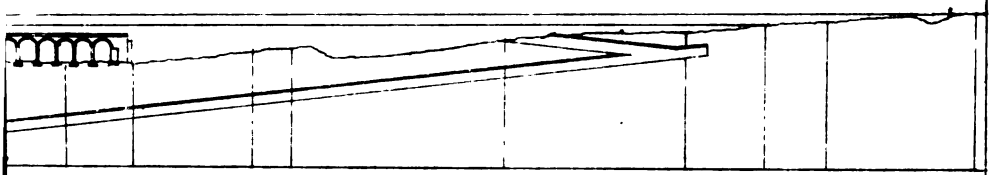
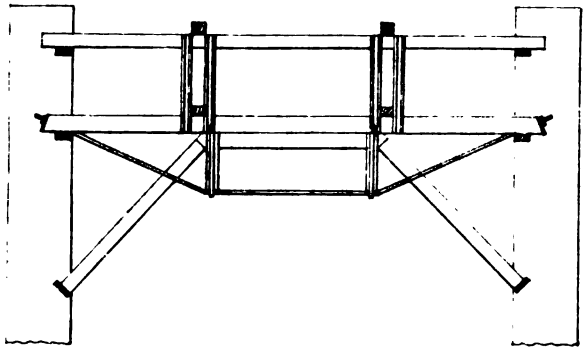
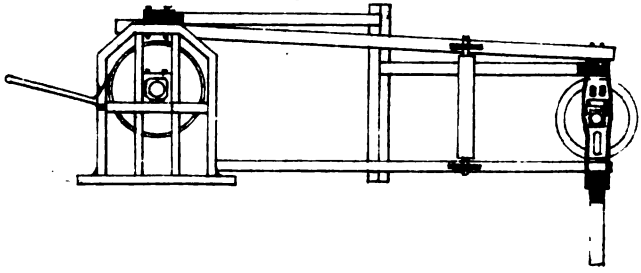


Elevation of Framing over Lift Shafts.



Elevation of Rope Drum and Framing connecting it with Framing over Shafts.



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On the rope drum there are two powerful friction bands, (two instead of one, in case of accident to one,) by which the lift will be lowered, and the cattle will only be required in raising.

The machinery, to be worked by six pair of bullocks, has a fast and slow motion. By the former, the amount it will raise will be about 4,400 lbs., or 2 tons, at a speed of the rope of about 54 feet a minute; by the latter, the weight about 13,200 lbs., at a speed of rope of 18 feet a minute.

I propose cattle for the lifts in lieu of steam power, as more economical; the heavy traffic is small, and of course irregular, for days there will not be a cart, and then a large convoy. With steam power, steam would require always to be kept up; with cattle, keeping only one set available for work, we may employ the others on other duty.

On the left bank I propose to place the lift shaft, just on the edge of the Lahore and Peshawur road, and at once accessible from it. The machinery above on the high ground.

On the right bank I place the shaft, just behind the present shaft, and only sufficiently far from it, to avoid injuring it in the excavation of the new shaft. This shaft being within the ordinary floods, must be raised well above them, and be connected with the high ground by a viaduct. The arrangement is all shown in the accompanying plan and section.

The actual length of the river section of the tunnel I make 1,175 feet. On the Attock side the distance to the lift platform is 165 feet; this I make at a grade of 1 in 20, with a 20 feet level platform in front of the lift. On the Khariabad side, the distance to the lift platform is 90 feet, and the level space in front 30 feet, or a total length of tunnel of 1,480 feet.

To take cattle and foot passengers up by the lift, would not only be inconvenient but expensive, I therefore propose a path at a inclination of 1 in 10 for this purpose; the path I would make 14 feet wide, and 12 feet high, so as to allow of the passage of an elephant unloaded. I would divide the path into an 8 feet road for animals, and a 6 feet footway for foot passengers. By this way, all animals would pass; even many of the loaded animals would use it. Carts would be drawn to the edge of the lift by their cattle, the cattle would go down by the path, and find the cart at the bottom; the cattle would again drag the cart to the other lift, and be taken up the path to find the cart ready for removal above.

The cost of the paths would only be Rs. 95,952; and I think their

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value would be saved in the working expenses of the lift. By making a large shaft, say 60 feet diameter, a path might be constructed round it, but I think the cost of this originally would be little less than that of the path, while the wear and tear would be considerable. The path once made may be almost said to be permanent. There are also other objections, previously stated, to a large shaft.

With regard to this scheme, there is another point to consider. Might it not be advisable to continue the tunnel on the right bank to the high ground, and there form the lift, and save the viaduct and masonry round the shafts? The original cost would be more, and the current expenses higher in lighting; 600 feet more of tunnel would cost Rs. 46,139, and the cost of masonry and viaduct is about Rs. 17,728. There would be some small saving in the path-way, but of very trifling amount.

In this scheme I would still use gas for lighting; it is the only efficient means. The pumping engines as provided for the full tunnel I would not propose to alter in any way, but the gas apparatus would be much reduced.

Full detailed estimates of original cost and maintenance are attached. The former amounts to Rs. 5,51,042·011, and the latter to Rs. 16,499·9,* this includes cost of cattle for lifts, &c.

We might consider next, the completing the tunnel with much steeper slopes, such as 1 in 6 or 7, and working the traffic through by machinery; using half the way for animals and foot passengers, and half for carriages of all kinds, transported on trucks on a tramway; but I think the plan above detailed is so far preferable to this, that it is scarcely worth considering.

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ESTIMATE showing probable cost of MAINTENANCE for complete Tunnel, and for Tunnel under river only, with Lifts and Footway.

This may be divided into PUMPING and LIGHTING.

### PUMPING.

The water has to be raised 194 feet; working the engine to 10-horse power, night and day, the results should be 1,633 cubic feet, or 10,206 gallons per hour, or 49192· cubic feet, or 2,44,944 gallons, in the 24 hours; more I think than we are likely to have to dispose of.

The expenditure per horse power of fuel in a Cornish engine, taken at

* Rate per yard run, Rs. 1,117.

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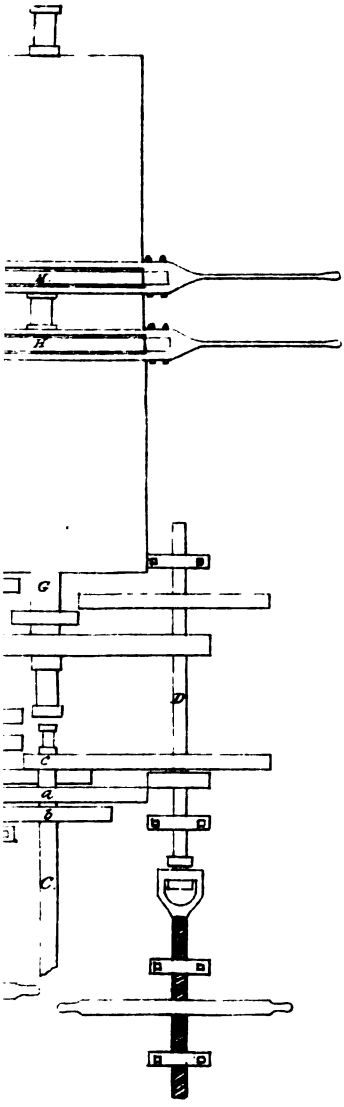
MACHINERY

Plan.




## DESCRIPTION.

C. Main Shaft driven by a 5' spur wheel off the toothed circle on the frame of the jib 19 diameter not shewn. On the shaft C. there is a 6' spur wheel, a, a pinion 2 diameter, c, and a spur 4' diameter, b. All these dimensions are at the pitch circle. On D, the intermediate shaft, there are 2 two feet pinions, and 2 six feet spurs, engaging corresponding wheels on the main shaft, C, and the drum Shaft, G. This intermediate shaft is traversed by the screw F, so that either pair of wheels can be put in action or all thrown out of gear. When the intermediate gear on the right is as shewn in the plan the motion of the drum is very slow, when the other pair of wheels are in gear, the motion of the drum is the same velocity as the main shaft.

The intermediate gear on the left is exactly the same as that on the right, only an extra shaft I, is introduced to change the direction of the motion so that the cattle in the jib may move always in the same direction, whichever lift is being raised, - the direction of the rope being regulated by the intermediate gearing used.

H H. The friction bands for regulating the descent of the lift.

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a very high rate, is 4lbs. per horse power per hour; 3½ would be a fairer average, but I take a high rate, $24 \times 4 \times 10 = 960$lbs. coal per 24 hours for the engine.

Now the value of wood to coal is as 10 to 4, $\frac{960 \times 10}{4} = 2{,}400$ lbs. wood or $\frac{2400}{80} = 30$ maunds, and at 8 maunds per rupee, (the present road rate in the Attock division,) we have, Rs. 3-12-0 per day, or per annum, Rupees, .. .. .. .. .. .. .. .. 1,368·75

Stores and repairs, may be taken according to an average of the London Water Works, at one-fourth the cost of fuel, Rupees, 342·18

Four stokers, and four assistants in the engine room, at Rs. 8 and 12, respectively, Rupees, .. .. .. .. .. 960·

One European Engineer, at 150 Rupees, .. .. .. 1,800·

Annual cost of Pumping, Rupees, .. .. 4,470·93

LIGHTING FULL TUNNEL.

$\frac{7200}{50} = 144$ lights.

Ventilation; 9 sun burners, 144 lights, workshops, &c., equal to 4 lights, day and night, as for the tunnel.

A fish-tail or bat-wing burner, will consume 1⅛ cubic feet of gas per hour, at full height; reduced at night to ½ cubic foot, or it may be much less. But assume ½ a foot; and take 12 hours at ⅛, and 12 hours at ½ $= 13{\cdot}5 + 6 = 19{\cdot}5$ in the 24 hours, for each lamp in tunnel.

$19{\cdot}5 \times 148 = 2886{\cdot}$ cubic feet per 24 hours for lighting tunnel.

Ventilation for 12 hours only, as the natural ventilation will act during the night; and allow each light in the sun burners 1 cubic foot per hour $144 \times 12 \times 1 = 1{,}728$ cubic feet per day, and it will be a full allowance, if we allow for ventilation by artificial means, for 3 months in the year.

*Cost of Lighting.*—The yield of gas from oil is variously stated in works on the subject. In "Brand's Dictionary of Science," it is given as 100 cubic feet from the gallon of oil; "Ure's Dictionary of Arts," 141; "Knapp's Chemistry Applied to the Arts," 150 to 175. The specific gravity of oil at home being ·92 to ·94, and the weight of a gallon 9·2 lbs. to 9·4 lbs.

I constructed a small apparatus, and tested the oils of the Punjab, and

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the rock oil, or Petrolium of Kalabagh. The common "Tara Mera," or wild mustard oil, (the cheapest in the market,) has a specific gravity of ·937, and weighs 9·375 lbs. to the gallon. Petrolium has a specific gravity of ·95, and weighs 9·5 lbs. to the gallon.

The yield of gas from mustard oil was 70 cubic feet to the gallon, from petrolium 80 cubic feet. In a large apparatus the yield would no doubt be much greater, as there is less waste and more economy of working, but I will take these results.

The cost of mustard oil is 6 seers per rupee; of petrolium, in the Attock godown, 3 Rs. per maund, or for 8·632 gallons, or Rs. 0-5-6 per gallon; but as the cost of carriage from Kalabagh to Attock by boat is only 8 annas, and the mere collection cannot be more than 8 annas in addition, 1 Rs. a maund would seem to be a full price; and I suppose the cost of barrels has been included; but I will take it in this estimate at Rs. 3, though it must be remembered that this is three times what it should cost.

$\frac{2886}{80}$ = 36·07 gallons of petrolium required for lighting for 24 hours.

$\frac{1728}{80}$ = 21·6 gallons for ventilation.

| | | Rs. |
|---|---|---|
| 36·07 at 5-6 = | .. .. .. | 12·4 |
| 21·6 at 5-6 = | .. .. .. | 7·42 |
| 12·4 × 365 days = | .. .. .. | 4,526 |
| 7·42 × 90 days = | .. .. .. | 667·5 |

In "Weale's Series," "gas lighting" fuel to produce 2,000 cubic feet of gas is stated as .. .. .. .. .. 560

"Ure's Dictionary of Arts," .. .. .. .. .. 416

"Cressy's Encyclopedia of Engineering," .. .. .. 261

and as Oil gas is produced more rapidly, and at a lower temperature than coal gas we may assume these quantities as excessive; but yet I will take the largest—

Value of wood $\frac{560 \times 10}{4}$ = 1,400 lbs. wood per 2,000 cubic feet gas.

$\frac{2886 \times 1400}{2000}$ = 2020 lbs. = 24·64 maunds, = Rs. 3·08.

$\frac{1728 \times 1400}{2000}$ = 1209 lbs. = 14·75 maunds, = Rs. 1·84.

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ANNUAL COST *for complete Tunnel.*

| | RS. |
|---|---|
| Petroleum for lighting, as above, at .. .. .. .. .. | 4,526· |
| „ ventilation, at .. .. .. .. .. | 667·8 |
| Fuel for lighting 3·08 × 365, .. .. .. .. .. | 1,124·20 |
| „ ventilation 1·84 × 90, .. .. .. .. .. | 165·60 |
| Four stokers and four attendants, at Rs. 8 and 12, .. .. | 960· |
| One European, at Rs. 150, .. .. .. .. .. .. | 1,800· |
| Repairs, .. .. .. .. .. .. .. .. | 800· |
| Two lamp cleaners, at Rs. 6, .. .. .. .. .. | 144· |
| Rupees, .. .. | 9,687·60 |
| Cost of Pumping as above, .. | 4,470·93 |
| | 14,158·53 |
| Contingencies at 5 per cent., .. .. | 707·92 |
| | 14,866·45 |
| Add for petty repairs to tunnel shafts, &c., .. .. | 1,000· |
| Total Rupees, .. .. | 15,866·45 |

If the supply of petroleum were to fail (which is unlikely) and oil be used, the annual cost would be Rs. 23,529.

Broad streets are well lighted at home with lamps at 100 feet intervals. In the tunnel, whitewashed, it may most likely be found that this amount of light is sufficient, which would at once reduce the cost one-half.

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For *Tunnel under River only, with Lifts and Footway*, the ANNUAL COST for LIGHTING with petroleum, would be Rs. 11,780, and with oil, Rs. 15,261.

### EXPENSE OF LIFTS.

6 pair of bullocks to each lift, for full work; and as the lift will never be worked for more than 4 or 5 hours, except on extraordinary occasions, if we allow 2 pairs for reliefs and sickness, it will be enough.

| | |
|---|---|
| 14 pair bullocks, at Rs. 17 a month each, .. .. .. | 238· |
| 6 breaks-men at lifts, 2 men at platforms, and 2 men below, 2 spare, 12 men, at Rs. 6, .. .. .. .. .. | 72 |
| Per month, .. .. | 310· |
| Per annum, .. .. | 3,720· |
| Repairs, oil, ropes, &c., .. .. .. .. .. .. | 1,000· |
| Total Rupees, .. .. | 4,720· |



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| | Rs. |
|---|---|
| Lighting and Pumping, .. .. .. .. .. .. | 11,779·9 |
| Total cost of Maintenance of Tunnel with Lifts, .. .. .. | 16,499·9 |
| Extra cost, if petrolinm failed and oil had to be used, .. .. | 3,481·82 |
| Grand Total Rupees, .. .. | 19,981·22 |

A. ROBERTSON, MAJOR.

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MEMO. BY THE LIEUT. GOVERNOR OF THE PUNJAB.

I visited the Tunnel at Attock on the 30th April, and, as the work is one that excites considerable interest, I propose briefly recording what I saw. I asked Lieut. Chalmers, Assistant Field Engineer, who accompanied me, for a memo. showing the progress made, and the present state of the works. His memo. is so full and complete, that I prefer transcribing it for the information of the Supreme Government.

I can add, that the work is being carried on most vigorously—night and day—and that there does not appear to exist in the minds of any, a doubt as to the success of the work. The deepest portion of the channel has been passed, and the rumbling of boulders overhead, carried along by the rapid rush of the current, has been occasionally heard.

Major Robertson, the projector, has gone to England, and will purchase such machinery as is required. Captain Sandilands is supervising the work in his absence, but the hard work of excavating falls on Lieut. Chalmers of the 24th Punjab Infantry, and his gallant Muzbee miners, aided by six European miners. All are indefatigable, and work with the greatest spirit.

The natives of the country are greatly interested in the work, and think far more of it than the Railway works or system of Telegraph lines. Many come from distant places to visit it, especially from beyond the Khyber.

(Signed) R. MONTGOMERY.

*Hurreerpore, 6th May*, 1861.

*Memorandum referred to above.*

The first blast for sinking the shafts on this work were fired in March 1860, in presence of the Governor General and Commander-in-Chief, but

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as sometime was subsequently taken up in preliminary arrangements, it can hardly be considered to have fairly commenced before the end of April in that year.

A shaft had to be sunk on each side of the river, which is here 1,505 feet 6 inches between its banks. That on the east side is 168, and that on the west side is 93, feet deep, besides 8 feet extra on each side for drainage.

The shaft on the east bank went on steadily at a rate varying from 3½ feet at first, to 7½, 8, and, on one occasion, 11 feet per week, as the men became better acquainted with the work. Until it was within 20 feet of its full depth we met with no difficulties beyond the extreme hardness of the rock, in every foot of which powder had to be used; but, at this point, having got below the bed of the river, the sides of the shaft were subjected to the action of water; masses of rock were detached at times, causing extensive and most dangerous slips, whilst a constant shower of smaller stones wounded, more or less seriously, the men employed. Fortunately, however, no fatal, or even very serious, accident occurred, and the shaft was pushed on without delay to its full depth, although in one week upwards of 20 wounded men were sent into hospital.

It was now considered advisable to line the shaft at once with brick masonry, instead of postponing this operation until the completion of the tunnel, as was at first intended; and, although this caused us some delay, there can be no doubt but that it saved many accidents, and possibly some lives.

From the bottom of the shaft two galleries proceed straight northwards to a distance of 25 feet. They are each 6 feet high and 3 feet wide; and at their further ends are met by the main drift, which crosses the river westwards, and is of the same dimensions.

This drift has, at its furthest point reached, on this date, a distance of 160 feet and is completed to 150 feet, with a railway for the removal of the material excavated; it has a rise of 1 foot in 300 for the purposes of drainage, which at present is very trifling, being only about 7 or 8 cubic feet per hour.

At the level of the Lahore and Peshawur road, a gallery has been driven in to meet the perpendicular shaft; by this, water, and the rock excavated, are now removed, saving a lift of 42 feet to the top of the bank.

The whole amount of work executed on this side, during the past year,

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is as follows:—Shaft, 176 feet; double galleries to northward, 50 feet; drift gallery, to cross river, 160 feet; gallery from the Lahore road, 50 feet; being in all, 176 feet of shaft, and 260 feet of gallery, all through solid rock; besides 160 feet of brick lining to the shaft, during the execution of which, the excavation, although not altogether stopped, was materially delayed.

The number of men employed is seven below, and eight above, ground. Those in the gallery work four hours in the twenty-four, and those in the windlass eight. There are three European miners of H. M.'s 94th Regiment, who assist and instruct the natives. The work has gone on without intermission by night or day, since its commencement.

The west shaft, or that on the Peshawur side of the river, is situated close to the river's edge, and much below the summer level. A hollow pier of masonry had therefore to be built up 24 feet, to keep out floods, and this, with a delay of two months during the last rains, from the insufficiency of the means available for keeping down the water, has thrown the progress on this side considerably behind that on the east or Attock bank.

The shaft is excavated to a depth of 93 feet, with 8 feet extra for drainage—102 feet in all—and the gallery has, to-day, reached a distance of 243 feet, of which 235 feet are completed and fitted with a railway. This gallery falls at a rate of 1 foot in 300 towards the Attock side, to which all drainage will eventually be directed. At present a deep drain is cut at one side of the gallery to bring the water back to the well in the shaft.

The principal difficulty on this side has been our very limited means of removing the water, although we have also had to encounter very dangerous slips in the shaft. This is about to be obviated by a horse-power chain pump ordered from Roorkee; and as we are now well past the deepest part of the river, and into a ridge of very solid rock, between which and the east bank the river bed is always dry in the cold season. I think there is reason to hope that our main difficulties are over, and that on the arrival of the Roorkee machinery our means of keeping the works dry will be ample.

Our progress for the last two months, has, on this side, averaged 60 feet per month, and has steadily increased from the commencement. The same number of men are employed here as in the east gallery, and their

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hours of work are the same; they have a similar amount of European instruction and assistance, and the works on both sides are under the superintendence of an officer of the corps.

The shaft on this side has also been lined with brick masonry, to prevent accidents, and likewise to diminish the leakage from the river. The water is drawn up by bullocks in relays of two pairs at a time.

It may be considered that the number of hours the men work below ground is small, but it must be remembered that they have excessively severe labor to perform in a very dense and oppressive atmosphere; that they are wet through from the time they descend the shaft until they return to their lines; and finally that they are soldiers, and must be kept in a fit state for active service at any moment. The health of the detachment employed on the work has been most excellent; there are at present only 2 per cent. in hospital, and a part of this number are in with bruises or slight injuries received on the work; and contrary, I believe, to general expectation, the six Europeans employed, although hard worked both by night and day, have enjoyed almost uninterrupted good health; one man was three days in hospital last year, and one has been two days sick this season.

The work has been hitherto singularily free from accident, indeed much more so than I recollect of any similar undertaking at home. With one exception there has been no loss of life or limb. That was a case of a man, who in coming up the east shaft, became suddenly giddy, let go his hold of the rope, fell to the bottom, and was killed on the spot. Since that time an arrangement has been contrived by which a man can at once secure himself to the bucket rope.

The whole work has been performed by a detachment of the 24th Punjab Infantry, under one of their own officers, and I feel assured that such employment must in every point of view be of the greatest utility to the corps, and they are now without doubt, the very best miners in the country, a qualification which of itself may prove of great advantage to them as soldiers; but in addition to this, the constant healthy employment, and habitual exposure to no mean amount of risk and danger, must, besides keeping them out of mischief, preserve both their minds and bodies in the very best state for active service.

JOHN CHALMERS, LIEUT.,
*24th Punjab Infantry.*

*2nd April*, 1861.

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# No. LXII.

## RAWUL PINDEE AND MURREE HILL ROAD.

*Memo. on Rawul Pindee and Murree Road from Barakow to Murree.*
By Major H. Rose, *Executive Engineer.*

The road enters the hills at 14½ miles from Rawul Pindee. For 9 miles it passes through low hills and then descends into the valley of the Korung, which it crosses close to Salgram villages; it here enters the higher range, and ascends gradually to Murree. Up to Sunny Bank, which is close to the station, it runs in a north-easterly direction. There are only four short zig-zags at the 23rd mile below Trait, above Shamli, and at the 36th mile. There is a Dâk Bungalow at Barakow, close to the entrance to the hills, and another at Trait, 12 miles distance. There is an experimental Government Garden at Chutter at the 29th mile, another above Shamli, in the 30th mile. The new station of Nund Kote is above the 27th mile; the new road to it turning off at 27½ mile. The Murree Brewery is close to the road at the 33rd mile; and the Lawrence Memorial Asylum on the crest of the hill above; the detachment of Native Infantry is at present located at Sunny Bank.

*Width of Road.*—As far as the Brewery the road has an average width of 20 feet, exclusive of side drain; from this to Sunny Bank the width has just been increased from 12 to 18 feet; for the rest of the distance it is only 12 feet.

*Available for Wheeled Traffic.*—The mail cart has been running regularly during the past season as far as the Brewery. Next year it will be able to go up to Sunny Bank. The horses are posted at the 17th, 22nd, 25th, 28th and 30th mile. Carts of all kinds use the road as far as the

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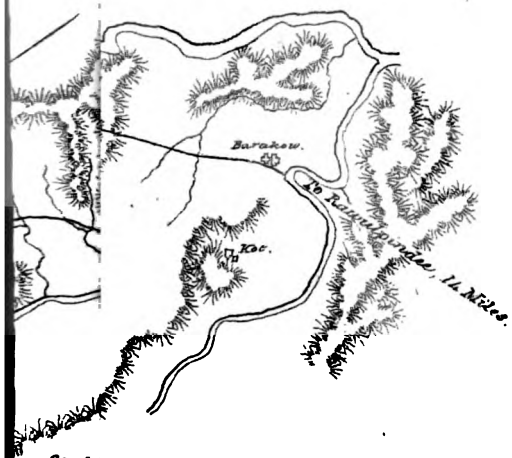


Scale

14 Miles from Rawalpindee.

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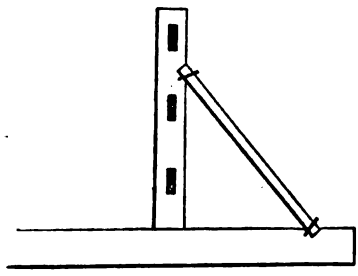
Brewery, and at the end of the season a considerable number went all the way up to Murree.

*Gradient of Road.*—As far as Salgram the ascents and descents alternate, but beyond that place the gradient of about 1 in 20 is continuous. At a good many places where corners have been cut off, and the road shortened, the gradient has been slightly increased.

*Formation of Surface.*—Cross sections are given to show the general form of road. In most places it is now higher in the centre than at the sides; when it was first made, and the width was only 12 feet, it sloped inwards. From the experience of last season, when the rains were heavy and wheeled traffic considerable, it is evident that the rise in the centre is much better than having the highest point at the outside, even with a slope of 1 in 15, which it would have been difficult to give. In many places, it was found impossible to keep the surface of the road in tolerable order, but where the road had been made with the rise in the centre, and the earth had settled, it remained comparatively speaking dry and firm.

*Bridges.*—There are only five bridges of any size, and those are all timber. Plans, &c., of them are forwarded. The first is just at the entrance to the hills; the second and third in the 16th and 17th mile, respectively; the fourth close to the Government Garden at Chutter; and the fifth at Salgram.

*Road Drainage.*—There is a drain 2 feet wide on the inside of the road. Annexed is a list of drain bridges with their width, &c., &c. There are no catch-water drains: these are required in many places where, owing to the want of them, the ground is constantly slipping; the side drains are kucha. The drain bridges are principally of dry stone masonry abutments, with covering of jungle wood beams; some are of pucka masonry and arched.



Up to the Brewery the outside of the road is protected at most of the dangerous places by railings made of undressed jungle wood; the uprights are about 6 × 4 inches let into sand sills, and with a strut on the outside. At a few places in the 23rd and 26th miles, there are masonry parapet walls, but they do not stand well, and as they decrease the width of the

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road by 1½ feet, railings appear preferable; railings are in course of erection from the Brewery to Sunny Bank, where the road is being widened to 18 feet.

STATEMENT OF DRAIN BRIDGES BETWEEN BARAKOW AND MURREE, ON THE RAWUL PINDEE AND MURREE ROAD.

| Mile. | WIDTH—FEET. | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 15 | 8 | .. | .. | 2 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 16 | 15 | .. | 2 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 17 | 13 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 18 | 19 | 4 | .. | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. |
| 19 | 19 | 2 | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. |
| 20 | 17 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 21 | 23 | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 2* | .. |
| 22 | 23 | .. | 2 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 23 | 18 | 4 | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 24 | 13 | .. | .. | 5 | 7 | .. | .. | .. | .. | 1 | 1 | .. | .. | .. | .. | .. |
| 25 | 12 | .. | 3 | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. |
| 26 | 17 | 6 | .. | 2 | .. | .. | .. | .. | . | .. | .. | .. | 1 | .. | .. | .. |
| 27 | 6 | 7 | .. | 12 | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 28 | 14 | .. | .. | 6 | 1 | .. | .. | .. | 1 | .. | .. | 1 | .. | .. | .. | .. |
| 29 | 15 | .. | 3 | 6 | .. | 2 | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. |
| 30 | 19 | .. | .. | 4 | .. | 2 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 31 | 11 | .. | 1 | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 32 | 7 | 3 | 2 | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. |
| 33 | 15 | 2 | .. | 2 | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. |
| 34 | 20 | 1 | 1 | .. | .. | .. | .. | 2 | .. | .. | .. | .. | .. | .. | .. | .. |
| 35 | 25 | .. | .. | .. | 2 | 1 | .. | 2 | .. | .. | .. | .. | .. | .. | .. | .. |
| 36 | 26 | .. | .. | 2 | 2 | 1 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 37 | 24 | .. | 3 | .. | 3 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 38 | 22 | .. | .. | .. | .. | 2 | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 |
| Total, | 401 | 80 | 17 | 43 | 16 | 9 | 1 | 6 | 4 | 2 | 1 | 1 | 2 | .. | 2 | 1 |

* Bays.

The following specification for the Salgram Bridge, the largest on the road (see plan) erected by Capt. Glover, R.E., in 1855, may be found useful:—

The *Bridge* to consist of one span 60 feet wide, the abutments to be built up solid, their foundations resting on the rock on each side. The faces of the abutments to be of dressed stone of the largest size procurable, the backing to be of rubble stone, the whole laid in the best mortar. The sides and front of the abutments to have a batter of 1 foot to 6 feet in perpendicular height, and to be 27 feet wide at the level of the top of the beams.

All timber to be dressed, square edged, free from knots or shakes, and of the dimensions given.

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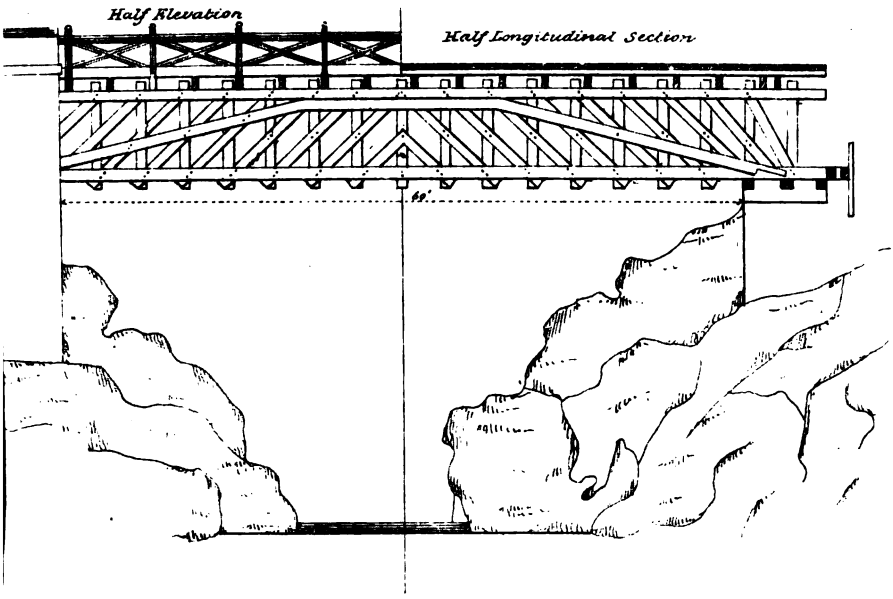
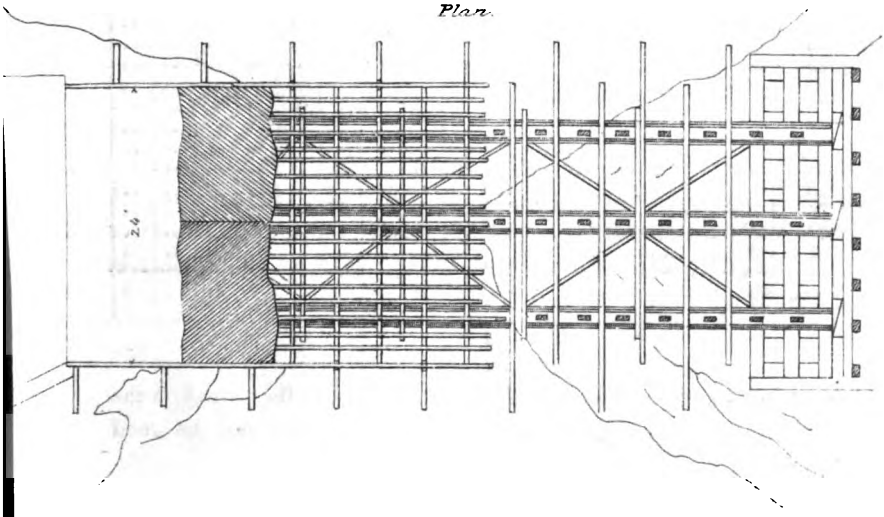
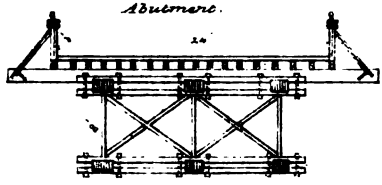
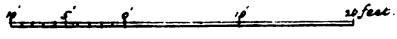
# Salgram Bridge.

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The *Trussed Beams* to consist of two chords placed 8 feet apart from inside to inside, and connected by upright ties and diagonal braces, and further strengthened by arch braces. The whole of the timbers where they cross one another to be firmly connected by treenails of hard wood, firmly driven with a little oil, and to be driven till the planks fit close to one another, their heads also to be well wedged.

The *Treenails* to be octagonal, 2½ inches diameter, and to be driven into holes slightly smaller in diameter.

The *Upper Chord* to consist of four layers of plank, 14 inches by 3 inches, laid two and two together, with a space between, sufficient for the admission of the vertical ties and braces. The upper chord to be joined where necessary by a simple abutting joint; the ends of each plank to be fitted with great precision, and to have a fair bearing, and to be well driven home until they fit close; in case of opening between the joints, wedges of hard wood should be firmly driven in between the ends of the planks. The joints to be broken so that no two joints come together, they are to be further secured by four treenails, two to be driven on each side of the joint.

The *Lower Chord* to consist of four layers of plank, 14 inches by 4 inches, laid together in a similar manner. The joints of the lower chords should be further strengthened by iron straps, 3 inches by ¾-inch, firmly bolted with 1¼-inch iron bolts; the space between the chords to be filled in with a solid block of wood wherever a joint occurs. Care should be taken that no two joints come together and the joints should, moreover, be made as far from the centre of the bridge as practicable. The planks of both upper and lower chords should be as long as can be procured.

*Upright Ties*, 12 inches by 3 inches, to be placed at intervals of 2 feet 9½ inches from inside to inside, and perpendicularly between the upper and lower chords, the two last ties at each end near the abutment to be placed 2 feet 11½ inches apart. The ties to be connected with the chords by treenails of hard wood.

*Diagonal Braces* consisting of double planks, each 10 inches by 2½ inches, and placed one on each side of the upright ties, to be added, they will be so laid as to connect the top and bottom of each alternate tie.

The whole of the braces and ties to be firmly connected with the upper and lower chords, and also with one another where they meet, by treenails of hard wood. The treenails to be driven till all the planks fit close, and their heads to be well wedged.

The truss to be further strengthened by *Arch Braces*, 12 inches by 6 inches, one on each side of the vertical ties and braces. The joint of the braces and straining piece to be accurately fitted, and to be further secured against dropping or slipping, by small pins of hard wood driven into their ends. The lower end of the braces to be let into the lower tie. The arch braces to be secured to the vertical ties and braces where they meet by treenails.

The three trusses to be firmly fastened together by horizontal ties, laid 9½ feet apart, above and below both the upper and lower chords, and firmly bolted together with 1-inch iron bolts, with screws and nuts driven into ¼-inch auger holes. They are to be further strengthened by vertical bracing, consisting of small beams, 6 inches by 5 inches, laid diagonally, and abutting against the upper and lower chords. These braces to be fastened together where they meet by treenails.

The upper chords to be further connected by a *Weather Bracing* laid horizontally, and consisting of timbers 6 inches by 5 inches, diagonally laid across the bridge. These braces to abut against blocks of hard wood, let into the upper chord to a depth of ¾-inch, and fastened to it with 1-inch iron bolts, with nuts and screws.



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The *Roadway* to be laid on the upper chords, and to be supported by roadway beams, 10 inches by 6 inches, laid transversely, 3 feet 3½ inches apart; these beams to be placed as close to the upright ties as possible, and not in the bays between them, so as to have the advantage of the strongest part of the upper chord. Each roadway beam to project alternately on each side of the roadway 3 feet 9 inches, so as to afford a support for a diagonal brace for the support of the railing.

*Joists*, 6 inches by 4 inches, to be laid longitudinally, 16 inches apart from centre to centre: one joist to be laid over the open space between the upper chords of each beam, and to be firmly fastened by an iron bolt with screws and nuts, 1 inch diameter, to a piece of hard wood, 4 inches by 9 inches, laid across the under side of the upper chord of the trussed beam, so as to connect the roadway firmly with the trussed beams.

The roadway to be 24 feet wide inside the railings, and to consist of planking 3 inches in thickness laid diagonally across the bridge, and abutting end to end at the centre, and firmly spiked down to the joists.

The *Railing* is made 3 feet high from the flooring planks to the top of the handrail. To consist of a handrail 8 inches by 6 inches, laid horizontally, supported and also tied to the bridge by double uprights placed over every alternate roadway beam; these uprights are cut out and fixed round the joists with an iron bolt and nut, and are again cut out at their upper ends to allow them to pass round the handrail, when they are again bolted, diagonal pieces are placed between these uprights and mortised into them, to prevent them falling out in case of shrinking of the wood. In order to give stability to the railing, the roadway beams over which the uprights are fixed are prolonged, and a slanting brace is abutted against the roadway beam at one end, where it is fixed by an iron strut, and against the upright at the other, where it is fixed by an iron bolt and nut.

The *Wall Plates* are formed by longitudinal beams, 8 inches by 12 inches, laid on the flat longitudinally with the bridge on the abutments, 8 feet apart, and on these other beams of the same dimensions are laid transversely with the bridge, along the face of the abutment on which the three trussed beams are laid: these beams should run transversely across the whole abutment.

As the lower chord, from (the nature of the strains upon it, which are tensile, thereby causing a tendency to open in the joints by which means the whole section of the timber does not came into play as in the upper chords) is the weakest point in the construction, it should be as far as possible relieved by giving the ends firm abutting points, which in this case can be very easily effected on account of the very solid abutments, by driving in wedges of hard wood in rear of the ends of the trusted beams, thus transferring their strains to the abutments. This can be effected by placing upright beams, 8 inches by 12 inches, at every 8 feet apart, and about 6 feet in length, at the ends of the lower chords; their centres being in the same level as the chords, and against these another beam, 14 inches by 8 inches, is laid horizontally across the abutments, and about 8 inches distant from the ends of the lower chords; in this interval strong wedges of hard wood should be firmly driven, thus giving a fair bearing to the chords, whose strains will be thus transferred to the abutments, and be distributed over them by means of the upright beams.

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## No. LXIII.

## FLOOD DISCHARGE OF RIVERS.

*Note on the Flood Discharge of Rivers and Streams with reference to determining the Size of Bridges from Drainage Areas.* By Lieut.-Col. C. H. Dickens, R.A.

Let M = the number of square miles of drainage area of any river or water-course, no matter how small.

Let D = its discharge at highest flood, in cubic feet per second.

$$\text{Then } D = 825\ M^{\frac{3}{4}}.$$

Or in logarithms—

$$\text{Log } D = \log 825 + \tfrac{3}{4} \log M.$$

This formula is, of course, only applicable to cases within a certain average of annual rain-fall—say of 36 inches in the year. It may, however, be considered to hold approximately to all cases from 24 to 50 inches of average annual rain-fall; as the heaviest fall of rain varies less in proportion than the total annual rain-fall.

The manner in which this formula was arrived at is as follows:—

Let it be granted, first, that over a small area, say of 8 acres, the rain-fall may be as much as 4 inches in an hour. I have myself measured 3·98 in 68 minutes; and I think Lieut. Greathed, R.E., in his Report on the Drainage of Delhi, gives 4½ inches in the hour, as an actual case. In the case of these very heavy falls of short duration, the whole will drain off at once if the ground be previously wet.

Next, take Sir P. Cautley's rule of ½ an inch in the hour for small rivers, and assume it exactly applicable to cases of 50 square miles of drainage area.

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Then, we have the well-known case of the Damoodah; drainage area, 7,000 square miles, and flood discharge equal to $\frac{1}{8}$-inch per hour of rain-fall.

Lastly, take the Soane; 27,000 square miles of drainage area, and a flood discharge in extreme cases equal to $\frac{1}{10}$-inch per hour over the whole area.

Arrange these in a table, and add fourth root of the drainage area, and the product of this into the rain-fall drainage, thus—

| Square miles of area. | Rain-fall drained off in inches. | Fourth root of the area. | Product of the two last. |
|---|---|---|---|
| $\frac{1}{50}$ | 4 | $\frac{1}{2}$ | 1·88 |
| 50 | $\frac{1}{4}$ | $2\frac{1}{2}$ | 1·25 |
| 7,000 | $\frac{1}{8}$ | 9 | 1·13 |
| 27,000 | $\frac{1}{10}$ | 13 | 1·30 |

Thus it appears that the rain-fall drained off per hour is inversely as the fourth root of the drainage area—that is in a rough way; and so we obtain the formula $\frac{5}{4\,M^{\frac{1}{4}}}$ to give us the rain-fall per hour in inches which a certain drainage area will discharge in the heaviest floods.

To convert this into cubic feet per second—

$$\frac{5}{4\,M^{\frac{1}{4}}} \times \frac{M \times 5280 \times 5280}{12 \times 60 \times 60} = 806\,M^{\frac{3}{4}}, \text{ nearly.}$$

Instead of this I take as above, $D = 825\,M^{\frac{3}{4}}$, so as to give a little margin on the safe side.

Remembering all the differences of soil, declivity of drainage basin, and rain-fall, it is evident that such a formula cannot be anything better than a rough approximation. But still I think it will be found safer in most cases than the mere determination by reputed flood levels, or by flood marks in jungly tracts. At all events it affords a good method of testing the results arrived at by the former method, and a means therefore of detecting errors which otherwise might have escaped knowledge.

To make use of this formula it is necessary, first, to have the usual data of sections, transverse and longitudinal, of the river's bed. Then determine by a few trials the flood level which would give the discharge required

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by the formula. This may be compared with the reputed flood level. If they differ materially, the latter should be again investigated. After this it will be safe to adopt whichever determination gives the highest flood level.

For small drains, it will be quite safe to fix a velocity such as the soil will bear, and allow waterway enough to discharge the heaviest flood as determined by the formula from the drainage area.

The following table, computed on assumed velocities, and assumed proportions between depth and width of streams, shows, in a general way, the results of this formula in determining the size of bridge necessary for a given drainage area.

| Drainage area. | Discharge, cubic feet per second. | Assumed velocity, feet per second. | Square feet of Water-way. | Bridge for common cases. | | |
|---|---|---|---|---|---|---|
| | | | | No. of spans. | Span in feet. | Height of piers or abutments. |
| 1 acre, | 6½ | 5 | 1½ | 1 | 1½ | 1 |
| 2 „ | 11 | 5 | 2¼ | 1 | 2 | 1½ |
| 3 „ | 15 | 5 | 3 | 1 | 2 | 1½ |
| 5 „ | 22 | 5 | 4½ | 1 | 3 | 1½ |
| 8 „ | 31 | 5 | 6 | 1 | 3 | 2 |
| 16 „ | 52 | 5 | 10½ | 1 | 4 | 2½ |
| 40 = 1/10 sqr. M. | 103 | 6 | 18 | 1 | 6 | 3 |
| ¼ square mile, | 173 | 6 | 29 | 1 | 7 | 4 |
| ½ „ | 292 | 6 | 49 | 1 | 10 | 5 |
| ¾ „ | 490 | 6 | 81 | 1 | 12 | 7 |
| 1 „ | 825 | 6 | 137 | 2 | 12 | 6 |
| 2 „ | 1,888 | 7 | 300 | 3 | 12 | 6 |
| 3 „ | 1,881 | 7 | 270 | 3 | 14 | 7 |
| 5 „ | 2,760 | 7 | 400 | 3 | 16 | 8 |
| 7 „ | 3,550 | 7 | 507 | 3 | 18 | 9 |
| 10 „ | 4,640 | 7 | 668 | 3 | 20 | 11 |
| 20 „ | 7,804 | 8 | 975 | 5 | 20 | 10 |
| 30 „ | 10,577 | 8 | 1,322 | 5 | 24 | 11 |
| 50 „ | 15,605 | 9 | 1,734 | 5 | 30 | 11½ |
| 100 „ | 26,094 | 9 | 2,899 | 5 | 40 | 14½ |
| 200 „ | 43,884 | 10 | 4,388 | 7 | 40 | 15½ |
| 300 „ | 59,481 | 10 | 5,948 | 9 | 40 | 16½ |
| 500 „ | 87,255 | 10 | 8,725 | 9 | 50 | 19 |
| 1,000 „ | 146,737 | 10 | 14,673 | 15 | 50 | 19 |
| 2,000 „ | 246,780 | 11 | 22,434 | 15 | 60 | 24 |
| 3,000 „ | 334,487 | 11 | 30,406 | 20 | 60 | 25 |
| 5,000 „ | 490,636 | 12 | 40,886 | 20 | 75 | 27 |
| 10,000 „ | 825,000 | 12 | 68,750 | 30 | 75 | 30 |
| 20,000 „ | 1,387,746 | 13 | 106,749 | 40 | 75 | 35 |
| 30,000 „ | 1,870,962 | 13 | 143,920 | 45 | 80 | 40 |
| 50,000 „ | 2,695,690 | 14 | 190,256 | 50 | 90 | 42 |
| 100,000 „ | 4,639,274 | 15 | 309,285 | 60 | 100 | 50 |

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These figures will I think be found useful in testing in a rough way the soundness of projects.

But if any of the correspondents of the *Roorkee Professional Papers* would take the trouble to send comparisons of the application of the above formula with any well *ascertained* cases of extreme floods, giving the area of sections, fall per mile, drainage area, and rain-fall of the district, we may be able not only to ascertain within what limits to rely on this formula, but perhaps to substitute a better, and to deduce rules as to the change of co-efficient for different rain-falls. In Lower Bengal, perhaps 1,000 might be written for 825. But for Mahabuleshwur or Cherrapoonjee, some much larger co-efficient would be necessary.

C. H. DICKENS.

27*th February*, 1865.

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## No. LXIV.

# BRICK-MAKING IN INDIA.

Although the practical Engineer can lay his hands upon several excellent Treatises on Brick-making, as pursued in England and other places, there are not very many which tide him entirely over the minor difficulties he is likely to encounter when starting a brick field in out of the way parts of India, where for ages, and even at the present day, simple processes are found to answer best. We are far from sanguine that the following description will prove equally useful in all localities, because such extreme differences in both soil and climate are met with, as to render it impossible to adhere to a form of rules in every case with advantage; or it may happen that a better class of brick is wanted than our mode of procedure is calculated to furnish; still since the leading operations are universally the same, it is fair to presume from having experienced a certain degree of success in one instance, that our suggestions will be of some service to Indian Engineers and Contractors.

Where cheapness is an object and the work is not of special importance, Engineers have usually been contented with the ordinary bricks of the country, only turning brick-makers themselves if apprehensive of the supply falling short towards the close of the season, which to their great annoyance and discomfiture will sometimes occur. The quality of this common article depends upon whether the soil of a district is rich or poor in clay, more than upon the amount of care bestowed upon the manufacture of the bricks, and the difference is often considerable; but it will be conceded after glancing over the following account of the way they are made, "passim," that it is needless to look in this direction for really sound or durable bricks. Natives do no more than excavate a few

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cubic yards of surface mould from the nearest piece of waste land, and after wetting and turning it over for a few minutes with their hoes, transfer the mud, pebbles, grass, roots, and all, lump by lump at a time, to a double wooden mould, pat it in, strike off with their hands superfluous clay, then raise the mould, leaving two parallellopipeds of semi-fluid mud adhering to the ground; each moulder completing a daily task of about 2,000. These soon dry in the sun, and are ready on the following day to turn over, and in a few days to be burned, either in rude kilns or clamps, according to local custom. Any that survive cartage to site unbroken, owe their preservation to a sloppy way of moulding compensating for deficient tempering, and to the large modicum of sand they contain which reduces shrinkage. They are uncouth in shape, not uniform in size or thickness, and should never be tolerated if it is possible to procure Bench-made bricks.

*Bench bricks* require a certain preliminary outlay of capital, but are neither difficult nor expensive to manufacture in India, where several months of dry weather can be calculated on, and there is no frost. As is the case with every innovation on the customs of Orientals, a person would find a good deal of friction at first starting, but the people employed should in six weeks' time give no trouble. The first step to be taken is to select the best earth in the neighbourhood, near water, and as free from stones or grit as possible; then to collect the requisite labor, tools, and plant; and erect kilns and sheds. It is of the three latter items we desire to speak.

The pattern of Mould recommended is shown in Figs. 1 and 2, and can be easily put together by an ordinary blacksmith. It is drawn to a scale of 4 inches = 3 feet; interior dimensions being, length, 9 inches; breadth, $4\frac{1}{4}$ inches; and depth, 3 inches. The sides are formed of $\frac{1}{2}$-inch board, lined with $\frac{1}{16}$-inch sheet iron secured by rivets, while the ends are formed wholly of $\frac{1}{4}$-inch iron-plate, rivetted as before. Thin strips of $\frac{1}{16}$-inch sheet iron are screwed down over the edges of the side boards, on both the upper and the under sides of the mould, to save the wood from abrasion, and the whole is neatly finished off by filing. The Stock Board is of wood 2 inches thick, and for $\frac{1}{2}$-inch in depth is shaped to fit the mould accurately but easily. The surface is protected by a thin plate of $\frac{1}{16}$-inch iron, 9 × $4\frac{1}{4}$ inches, screwed down. The raw brick turned out is therefore 9 × $4\frac{1}{4}$ × $2\frac{1}{2}$ inches; or when burnt, say $8\frac{3}{4}$ × $4\frac{1}{4}$ × $2\frac{1}{2}$

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*Fig. 1.*

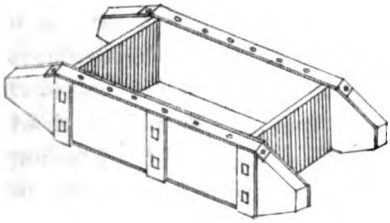


*Fig. 2.*

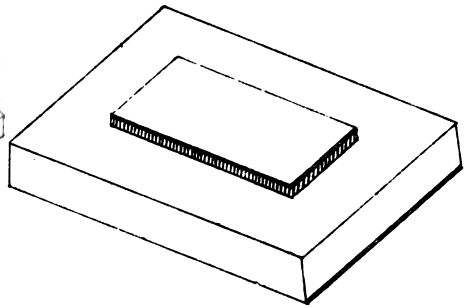


*Fig. 3.*

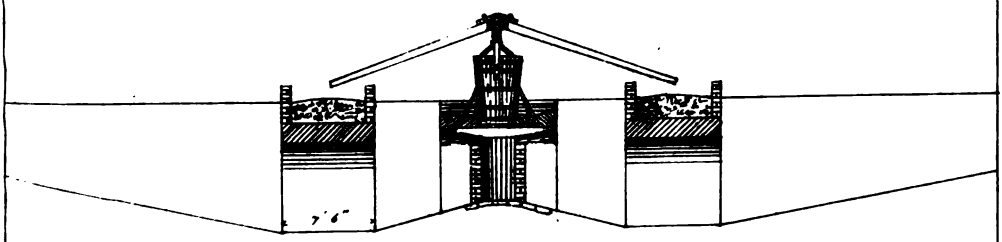
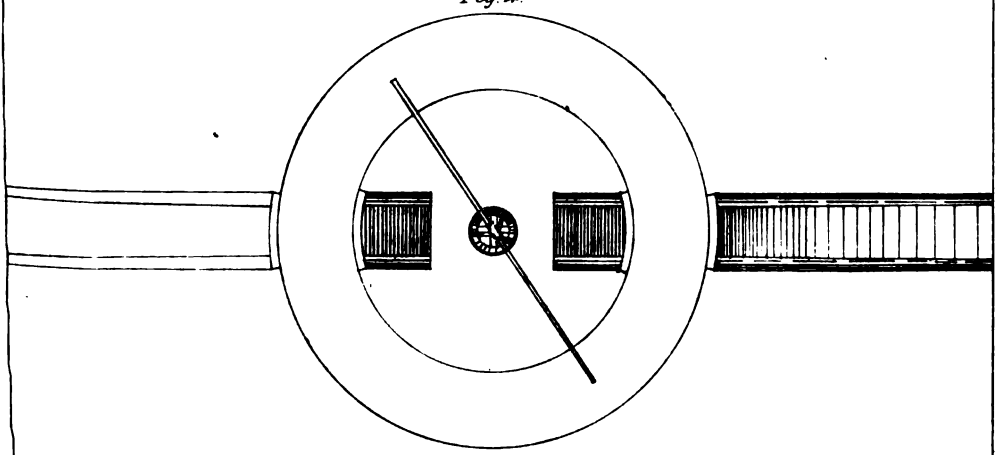



*Fig. 4.*



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inches, the length exceeding twice the breadth by the thickness of a mortar joint—which ensures good bond. These moulds are found to last a long time, and are not too weighty to handle. For an intended out-turn of 15,000 a-day, 20 moulds ought to be made up. The Moulding Bench is depicted at one end of the shed in Fig. 5. It consists of a board about 4 feet long and 2¾ feet wide, by 1½ inches thick, supported at each end upon pillars of brick in clay, the tops of which are levelled off so as to give an even surface 6 feet long.

The *Page* is also of brick in clay with a piece of wood, let in at the top for the pallet boards to rest upon, 4½ feet long. Upon the bench are placed the stock board, a trough for water, and at the right hand side, the Sand Bin. Books prescribe wooden supports, but the masonry ones do equally well, and are more expeditiously and cheaply constructed in India. The Shed in the sketch is supposed to be large enough to accommodate one moulder, and has hacks for two days moulding, at 1,500 per day. It is 15 feet wide and 90 feet long, and the height of the centre poles is 11 feet, of the eaves 4 feet. Each of the hacks is 70 feet long, and 6 feet wide, and a passage is left down the middle of 3 feet. It is true economy to provide at the beginning a sufficient number of sheds, which may be either thatched or tiled as opportunity permits. The better the clay the more obligatory to allow the newly moulded bricks to remain under cover for the first day. They are generally hard enough to lift by the second, if the air is moderately dry. It is possible, should the clay contain much sand, to conduct the drying in the sun without great risk, but if it is at all strong, nearly every brick will be broken from the violent contraction which takes place. This will also befall them if hot winds are let drive through the sheds.

Before going on to enumerate the rest of the Plant it is desirable to obtain, we have a few words to say regarding the provision of sand, and the treatment of the clay prior to being moulded.

As the moulds must be plied with sand, the finest sort should be collected, and cleared of small stones by sifting through wire gauze sieves. Coarse sand imparts a rough appearance to the brick, and clogs the mould.

The *Sieves* may be shallow wooden boxes with gauze at the bottom, about 18 inches square, and are better suited to the work, as also more lasting than those made of rattan. The state of the sand bins ought



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to be looked to from time to time. If not watched the people use any gravel that comes to hand.

In England, where frost tries building materials to the utmost, and the walls of houses are thinner and loftier, as a rule, than they are in India, great pains are taken with the preparation of brick earth, which is dug and weathered for many months before being finally tempered for the moulder. Here, however, in the absence of frost we can dispense with a good deal of this weathering, so that if the clay is excavated during the monsoon, and moulded in the dry season, it is perhaps sufficient.

There is usually a higher per centage of sand in our clays than enters into the composition of marls and loams at home. Dobson sets down 50 per cent. as representing the amount of silica in brick earth, but we are probably not far wrong in asserting, that as much as 70 per cent. will be discovered in fair specimens of Indian brick earth. Its presence to such an extent makes the bricks friable and weak, except lime or alkalies accompany it to act as fluxes, which they do in some places.

The writer having a poor clay to deal with, containing mere traces of those adjuncts, added 2½ per cent. of slaked lime; but the result did not compensate for the expense involved; so the addition was discontinued. A higher temperature in burning, and double the allowance of lime, might have gained the object, but the composition was too caustic for even a laborer's horny hands to manipulate.

In localities where cotton soil prevails, a far more dangerous enemy than sand is met with, which is so minutely interspersed with the clay, as to defy extraction by picking—we allude to nodular limestone. A small fragment, no bigger than a pea, involves such a stream of carbonic acid gas, when heated as to tear open any brick it may lie in. The only expedient is to crush the earth between iron rollers, and thus powder the limestone; for, pulverized, it is not merely comparatively harmless, but acts as a flux to bind the particles of sand together. It is understood that Messrs. Clayton and Shuttleworth furnish a one horse rolling mill for this purpose, at a cost of £35, which a brick-field so situated ought undoubtedly to be provided with, as it is impossible to extemporize an efficient substitute; indeed in all brick-fields its use would be attended with advantage.

The clay has now to be tempered, and upon this operation being thoroughly performed, the soundness of the brick mainly depends. Where

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# BRICK-MAKING IN INDIA.

Fig. 6.

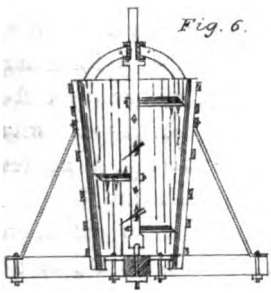


Fig. 5.

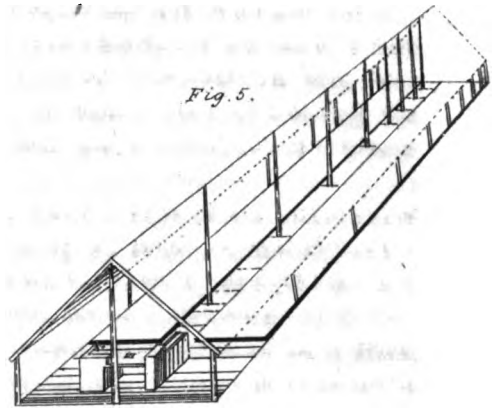


Fig. 7.

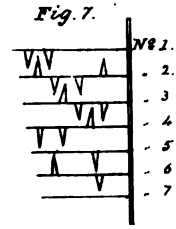
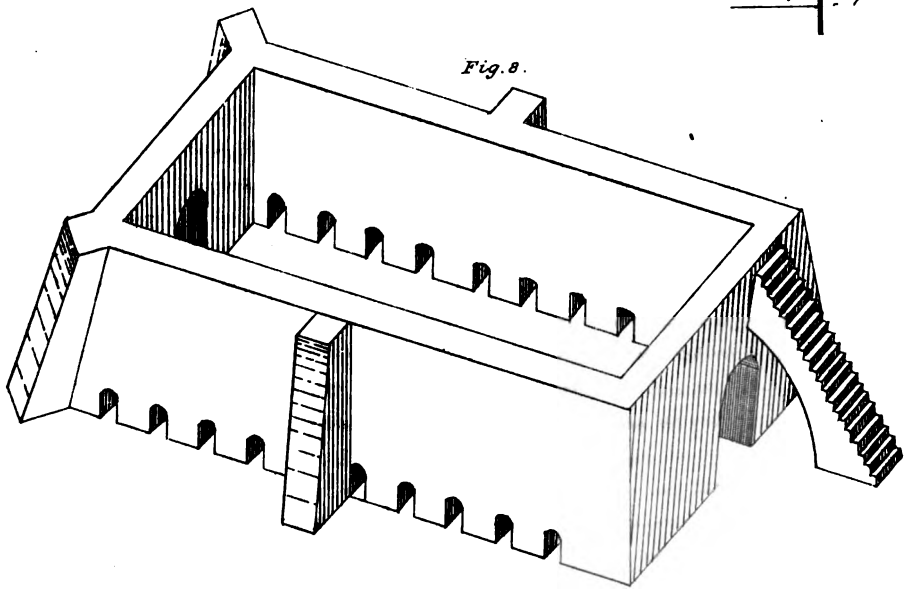



Fig. 8.



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labor is abundant and cheap, men can tread it out with their feet, but if the out-turn is to be considerable, we cannot too strongly advocate the employment of a *Pug-mill*—it will repay itself in the long run.

Fig. 6, is a drawing of one the writer recently had made up under his own eyes, by very ordinary artificers, on a scale of 6 feet to an inch. It is of the London pattern, discharges at the bottom, instead of at the side, and has considerably exceeded anticipation in the quantity of clay it is capable of pugging if mounted as in Figs. 3 and 4. The tub is of wood, $3\frac{1}{2}$ feet wide at top, diminishing to $2\frac{1}{2}$ feet at bottom, (interior measurement,) while it stands $5\frac{1}{2}$ feet high. The staves are about 5 inches wide at top, and 2 inches thick throughout. There are six iron hoops on the tub, 2 inches broad and $\frac{1}{2}$-inch thick. The spindle is of 3-inch square iron, and should be about $7\frac{1}{2}$ feet long; at the lower extremity a cup is formed for the pivot upon which the spindle revolves, and at the upper end, a collar is shrunk on and welded, to prevent it from rising through the bearings. The pivot is of brass, terminating in an iron bolt and nut, to secure it to the transoms; and the bearings are likewise of brass. They are held in their place by a cross head, with three arms, of not less sectional area than 2 × 2 inches. This cross head is in two pieces, and was found by far the most troublesome part of the machine to make. Before commencing to forge it an exact model should be got ready in wood to guide the workman. Each arm is fastened to the tub by a flange, 2 inches wide, and $\frac{3}{4}$ to $\frac{1}{2}$-inch thick, carrying a couple of bolts and nuts, and should have a piece of stout sheet iron 3 inches wide by $\frac{1}{4}$-inch thick as a washer inside. The tub is set upon two timber transoms and steadied by iron clamps and stays which it is needless to waste space in describing. The stairs ought to be carried down some 3 inches below the level of the top of the transoms, to assist in keeping the tub rigid. The entire machine must be well tarred. As regards the knives, they are seven in number, and 4 inches wide except the lowest, which has no teeth, and is 6 inches wide. The teeth are for the purpose of breaking up clods, and require to be set in a particular manner, as shown in Fig. 7. They may be either screwed or rivetted to the knives. No. 7 blade is inclined at an angle of 55° to the horizon, and all the rest at 45°, affording a strong propelling force downwards, which, slightly opposed, owing to the conical shape of the tub, is partly converted into a kneading action, most valuable in tempering the clay.

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The Pug-mill completed, it must be properly set to obtain the maximum effect. A mode which answers admirably, is shown in plan and sectional elevation, in Figs. 3 and 4, to a scale of 15 feet to an inch, where it is placed over a masonry well 3 feet in diameter and 5 feet deep. The transoms are built into the masonry, which is carried up 2 feet high on the tub. Access is gained to the well through openings at the opposite sides, about 3 feet wide and covered with rather flat arches. This arrangement allows the people who fill the machine to walk all round. From the well the clay which falls through, is conveyed away along an excavated passage, and under the bullock walk, by means of bridges, to a 1 in 5 ramp, direct to the surface. This passage and the bridges need be no wider than 4 feet, but any thing less will give too little room, while their construction completely obviates the inconvenience of even stopping the cattle except for rest. Pug-mills are often driven by a single lever, but we decidedly recommend the employment of two as in the drawing, otherwise the iron tripod is sure to be shaken loose. They are each 14 feet long and slightly drooping.

A mill, such as we have sketched, will temper enough clay per diem to keep fourteen or fifteen moulders going, only to do so it must be continuously and cautiously fed. Earth for one day's consumption should be deposited in a heap near it the day before, and be thoroughly watered, and turned over once with hoes or shovels; on no account must it be cast into the tub dry and then wetted, or the knives will assuredly be bent or broken. Of the four quadrantal openings at the bottom two are permanently closed, the others deliver the clay in a very plastic state ready for the moulder. A man in practise will turn out 1,000 a-day with ease, and is capable of making half as many again without distressing himself. He is allowed two men and two boys to assist him, and should be paid at so much per thousand, and not by the day. He is required to keep the hacks clean and level, and to see that the raw bricks are carefully laid in rows upon their sides, because a great deal depends upon judicious handling at this stage. They harden rapidly in this country, and may be lifted off the floors and stacked on the third day, but are let remain exposed to the sun and wind for a week or more before being placed in clamps or kilns.

The former way of burning has its advantages, since the clamps demand no attention after setting and firing till cool, but when time has to be saved, and there is a heavy call for bricks, it is well worth while using

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kilns. A large clamp takes weeks to become cold, and unless the bricks are perfectly dry when put in, they are found risen in all directions when the clamp is opened. Kilns on the other hand render it a matter of indifference whether they are wet or dry, since the heat can be regulated so as to drive off the water in steam before the actual burning begins, and the draught which circulates through the flues on the fires being raked out quickly cools the mass down.

A simple kind of kiln is given in the accompanying isometrical drawing, (Fig. 8,) to a scale of 15 feet to an inch. Its length is 41 feet, and width 16 feet, interiorly, and it is 12 feet high. The side and end walls are 4 feet thick at the base, and 2½ feet at top, with a batter on the outside. They are strengthened by buttresses at the four corners of any convenient shape, and by one or more at the sides; but it is necessary to remark that for clearness two corners are shown plain in the drawing, and one of the stair-cases has been suppressed. The side walls are respectively pierced by ten flues, 15 inches wide and 2½ feet high, to the crown of the arches; the end walls have each a doorway, 4 feet wide, flanked by stair-cases by which to reach the top. These doorways are bricked up while the kiln is burning. The masonry may be brick in clay throughout, and only the outer courses need have been burnt, the rest may be sun-dried brick. In fact the rubbish of the yard should be utilized in building them.

Sufficient breadth is allowed between the flues, for laying these bricks end to end, with the space of half a brick to spare, for it was ascertained that having the flues wider and loftier inside than the apertures in the walls, conduced to the more perfect combustion of the wood. When the flues are vaulted over, the piling of the raw bricks on their thin sides is continued solidly to the top, but a few passages 4 inches square are left to augment the draught, and lead off smoke (two or three to each flue suffice.) The last course had better be ground bricks, as it is not possible to burn it through, and on no account ought earth to be heaped on by way of keeping in the heat, till it is time to bank the fires. Steam is given off to the very end of the burning, and must have free vent. After three days and two nights stacking, the flue holes may be closed, and the fires permitted to die out. In this climate, when the rays of the sun are nearly as hot as the contents of the kiln, they can be opened again next day, or that following, to rake out the embers, and admit the air, which

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cools the bricks down in about five days time; as a rule, however, the process of annealing should be slow.

Two kilns of the size we have indicated, if half a kiln or fire flues are lit at a time, will yield an uninterrupted supply of 10,000 a-day.

Gauged bricks for arches and pillar bricks, are just as easily made on the bench as common bricks. For the latter sort, it is advisable to divide the circles into five sectors, instead of into quadrants. The mould has radii of $\frac{1}{8}$-inch sheet iron, rivetted to a circular segment, composed of wood lined with $\frac{1}{16}$-inch plate as before, the extremities of which form laps for the hands to grasp.

The depth of the mould is 3 inches, and the stock board is shaped to fit as already described, so that the bricks are turned out $2\frac{1}{2}$-inches thick. The pallet boards should be sectors, and a couple of inches larger every way than the pillar bricks. These last are laid on the drying hacks upon their radial and not upon the flat side, which is the only precaution to be noted.

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# LXV.

## THE SUTLEJ CANAL.

*Project for an Irrigation Canal from the River Sutlej; abridged from a Report drawn up under orders of the Government of India.*
By Capt. James Crofton, R.E.

The irrigation of the parched tract of country bounded by the Jumna and the Sutlej to the east and west, the Chittung to the south, and the line of the Himalaya to the north, has long been a desideratum, and has been the subject of several able and valuable reports, containing suggestions and projects for its improvement by Col. Baker, Capt. Cunningham, and others; all of which, however, have hitherto remained in abeyance.

Before adverting to the projects for irrigation, it may be as well to describe briefly the features of the country. The watershed line between the Jumna and Sutlej rivers, or as it may be called, the watershed of Hindoostan, runs close to the valley of the former, commencing from a spur of the low hills about 16 miles to the westward of the point where the Jumna debouches into the plains; thence it runs along the high edge of the valley of the Sombe, (a mountain torrent discharging itself into the Jumna a short distance below the permanent head of the Western Jumna Canal,) continuing along, or close to, the edge of the Jumna valley, to some distance below the town of Kurnaul.

The source of the Sursoottee is situated to the west of, and close to, the northern limit of this watershed; whence it takes a southerly direction, and is joined by the Chittung below the town of Bilaspore, about 16 miles from its source; thence onwards for another 16 miles the stream seems to be called indifferently by either name, till near the town of Ladwa a separation takes place, the channel to the westward retaining the name of

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Sursoottee, that to the southward the Chittung, which after its junction with a small drainage channel from the eastward, called the Rakshee, takes a south-westerly direction through the districts of Jheend, Hissar, and Beekaneer, till it joins the Cuggur about 22 miles below Bhutneer. This river then, or rather its valley, may be considered as the actual boundary to the eastward and south, of the tract of country with which we have to do. From Dhatrut in the State of Jheend, to Bahaderah in the Beekaneer territory, the centre of its course is occupied by the Hansee branch of the Western Jumna Canal.

Between the Chittung and the Sutlej, numerous drainage channels intersect the country, running for the most part in a south-westerly direction, some of which must evidently, from their size, have been rivers carrying large volumes of water in bygone ages, though now dry, except during periods of heavy rain. How and when the supply of water was discontinued have long been, and are still, disputed questions, the constant process of degradation of matter from the up-lands near their sources being sufficient, in the opinion of some, to account for the phenomenon, while others considered that the bunding across of the channels for the purposes of irrigation, so extensively practised on the Cuggur and other streams, was the main cause; others again have considered the effect due to the joint operation of both causes and are probably nearer the truth. Whatever the cause of the desiccation may have been, there is now a perennial stream in very few of these channels. The Cuggur and Markundah, the sources of which lie in the valleys of the low hills forming the southern face of the Himalaya, do indeed carry a small supply into the plains all the year round, but this in the case of the Cuggur does not extend ordinarily after the month of April, further down than Chut, about 15 miles from the foot of the hills: while in the Markundah and Sursoottee it is still less, and more uncertain. To the west of the Cuggur the channels are dry except during rain.

The Jumna and the Sutlej are the only streams connected with this tract of country, deriving their supply from the snows of the Himalayas, and which is therefore uninterrupted all the year round.

It seems unnecessary here to give a detailed description of the country with reference to its present state of cultivation and its capabilities if only water could be supplied to it, the able authors of the reports above alluded to, as well as many others, having given very full and com-

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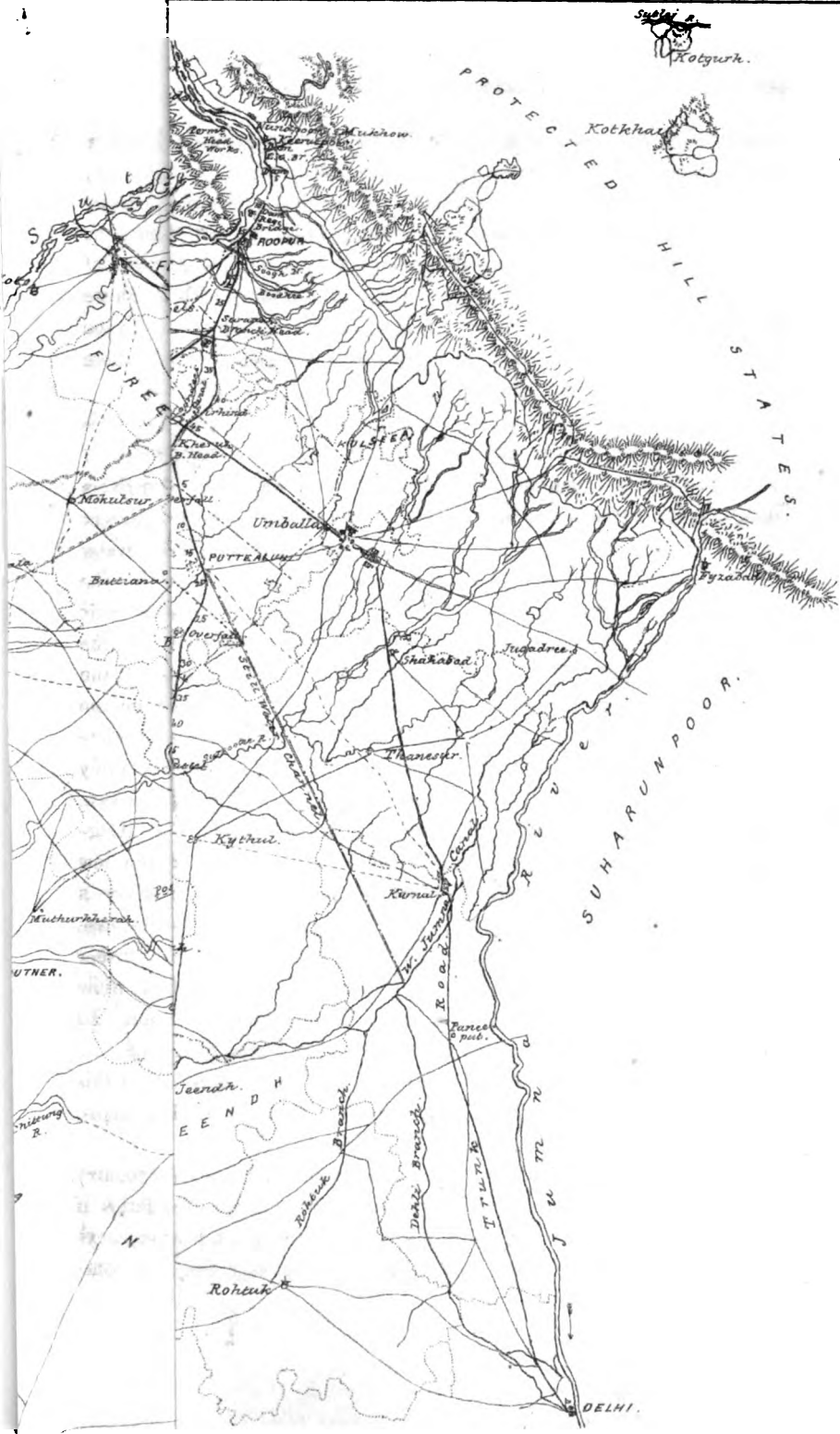


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prehensive information regarding it; suffice it to say that from the line of the Grand Trunk road downwards, there are few spots where irrigation is not urgently required; the need increasing as we proceed southward, where rain is scanty in quantity and of comparatively rare occurrence. Northward of the above indicated line, the influence of the proximity of the hills is felt in the regular and copious supply of rain, sufficient in ordinary years for all the purposes of a luxuriant cultivation.

From the above description it will be seen that there are three sources from which a supply of water for irrigation can be drawn.

1*st*.—From the Sutlej, which would be constant all the year round, though very limited considering the extent of country to be benefited.

2*nd*.—From the Sutlej or Jumna, or both, for the autumn crop, which would be constant only for six months in the year, say from April to September, the snow fed rivers usually commencing to rise in March and not materially decreasing till October.

3*rd*.—From the floods of the rainy season in the channels of the drainage lines between the Jumna and Sutlej, which, however, are very uncertain in their periods of occurrence and variable in quantity.

Projects for the delivery of a supply from each of the sources I have enumerated have been from time to time submitted by various Officers, of which those by Col. Baker and Capt. Dyas, were the most complete, and afforded valuable data for the present project. The object of all these projects was restricted to the benefit of British territory exclusively, and their execution was deferred from want of funds, but in 1863, the Puttiala Raja, having requested that the subject might be reconsidered with the view of supplying irrigation to his own territory, and having offered to defray the expenses of the Survey by British Officers, I was appointed to this duty by the Punjab Government.

Colonel Baker's levels having shown, as he observes in his report, that there was little inducement to follow the line of the old Mahommedan Canal,* and the objections to fixing a head for a permanent Canal anywhere below Roopur, being, as he clearly demonstrated, insurmountable; the only other proposal to be re-examined was that of Captain Dyas, who projected a line from the Sutlej about two miles above Roopur to run in a southerly direction, until the edge of the high (or *bangur*) land was

* Known as Mirza Koondee's, and running from Roopur to Sirhind.



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reached near the town of Chumkour, whence it could be carried along close to the foot of the high bank until the level of bed would admit of turning into the high land with a moderate depth of excavation, his levels on the high land having shown that the depth of excavation for a channel on that line would be excessive; with a longitudinal slope of bed of 1 in 7000 only "the depth of digging 30 miles from the head would be 22½ feet," and in one place "at the 11th mile as much as 58½ feet." Our subsequent levels show that the depth of a channel with the same slope of bed drawing its supply from this head would be at least 31½ feet at the Grand Trunk road near Barah, even if carried along the most direct line, which of course would be considerably greater were the line lengthened so as to sweep round by the edge of the high bank bounding the Khadir of the Sutlej. The object to be attained is in fact altered; any Canal from the Sutlej, intended, as in the present project, to irrigate the Puttiala territory must, it is evident, run considerably more to the eastward at its entrance into the high land, and as the direction of the drainage lines in that neighbourhood and the levels of the cross section along the foot of the hills, showed a steady rise in the surface of the country from west to east, it was manifestly necessary to carry the line across the Khadir on a higher level, and therefore to seek a head higher up on the river.

For the better elucidation of the details of the present project, it may be as well to describe briefly the physical features of this portion of the valley of the Sutlej. The accompanying map will assist in rendering the description intelligible. The Sutlej may be said to enter the plains close to the town of Roopur, whence its course for a long distance lies due east; above this its course is northerly, and a few miles below the town of Belaspoor, it forms a loop running north-west and south-east, about 40 miles in total length, while the width across the neck is not more than 6 or 7 miles; a ridge of hills, the highest point of which is 3,905 feet above sea level (by the Great Trigonometrical Survey) divides the two sides of the loop. On the north-east side the river runs in a rocky channel, but a little in advance of the point of the loop, enters a valley which continues down to Roopur, varying in width from 2 to 4 miles, the bed in boulders, decreasing in size as we proceed downwards as far as the Sarase Ghât, below which sand and shingle are largely intermixed, until stones are lost sight of in

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the sand, a short distance below Roopur. The river runs in one channel to Nungal Ghât a short distance below the point of the loop; immediately in advance of this, it divides into two main branches, one taking to the left edge of the valley skirting the low hills, until it rejoins the other at the Suraee Ghât, opposite the fort of Boongs; the larger branch to the westward, is broken up into several shifting channels which unite at the Thanna Ghât, opposite Nundpoor Makhowal, a noted place of Hindoo pilgrimage on the left bank of the river; below this it again separates, till at the Suraee Ghât, all the streams unite and pass onward past Roopur in one channel. The strip of land which divides the two branches is never flooded except in extraordinary freshes, and then only partially, as may be inferred from the number of villages scattered here and there over its surface. On the eastern side low hills skirt the valley, leaving generally a narrow strip of low sandy land reaching to the bank of the river; here and there however high spurs, as at Keerutpoor and Roopur, extend out to the edge of the running stream, that on which Keerutpoor is situated being not less than 200 feet in height; between Nundpoor Makhowal and Nungal Ghât, the stream washes the foot of a high table land.

From Nungal Ghât to Roopur, the valley is intersected by numerous torrents conveying the drainage from the neighbouring hills into the Sutlej; of these, the largest and most formidable are the Sursa, the Lohund, and that close to Nundpoor Makhowal; the Sursa drains the outer range of hills from the neighbourhood of Pinjor, its catchment basin has a more extended area than the Solanee, and its bed below its exit from the low hills is in pure sand; the Lohund drains the range of hills in the neighbourhood of Hindour, discharging itself into the eastern branch of the Sutlej close to the town of Keerutpoor; its floods bring down quantities of boulders, some of very large dimensions, but from the rapid declivity of its bed little sand is deposited.

Southward of the Roopur spur and between it and the high land, the Khadir is intersected by four nullas which carry off drainage from the southern face of the low hills, all in sandy beds and on steep slopes; the edge of the bangur here runs nearly east and west, except a triangular promontory about 3 miles in length, north to the village of Sulowra; between this point and Roopur, three of the torrents pass, the centre one, called in the Revenue Survey map, the Soogh, carrying the largest

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and most rapid stream. The Seeswan (so called from a town of that name situated on the outer range of hills, formerly a place of some note) runs a longer course and drains a larger area than any of the other three; its course for the most part lies in the high bangur land, from which it makes its exit close to the village of Balsinda, just where it was crossed by Mirza Koondee's Canal; a short distance above this, its channel, ordinarily not less than 250 feet in width, is suddenly contracted, in passing through a stream of kunkury earth for a length of a mile to 120 feet—at one place not above 100 feet. The banks of all these torrents to the westward of the old Mahommedan Canal are lined with sand ridges, mountains of sand I might say, showing very clearly the diminution of the slopes of their beds in that locality, and the velocity with which their flood waters must descend from the hilly country; above this line there is comparatively little sand visible except in the actual beds. All these channels from Keerutpoor downwards, are dry or nearly so, except during rain.

A reference to the map will show that the Seesooan torrent is the last of those draining directly to the west into the Sutlej. From its left bank the direction of the country drainage is nearly to the south-west, at right angles to its course, from the town of Khurr nearly to Chamkour on the high bank of the Sutlej. This converges to a point above Sirhind whence the floods pass off in the bed of the nullah passing close to that town: the Khurr nullah, which at the point where my levels crossed it, is about 400 feet wide and 5 feet deep, loses its defined section altogether 4 miles lower down close to the fort of Kulour, below which the floods find their way through some low ground to an extensive swamp in the vicinity of Railee, a village three miles north-west of Sirhind, whence they pass on to the Sirhind nullah meeting it just above the old Mahommedan bridge. To reach the watershed to the eastward of the Sirhind nullah therefore, this drainage must be crossed.

The course of any line for a Canal from above Roopur is thus confined within very narrow limits as to width of deviation. Now the Sursa being only three miles above Captain Dyas's proposed head, it is evident that little additional height is obtainable any where between those points—that torrent therefore must be crossed—and the most favorable place for a crossing whether above it, or on the level of its bed, is undoubtedly opposite the village of Majree, a little above the line of the old Mahommedan

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Canal. The direction of the stream is there perpendicular to the course of a Canal, the banks are less liable to change from the proximity of the low hills, and protecting works in bunds and spurs to confine its vagaries will be necessary only for about a mile above; the bed too is firmer than any where lower down. To cross it here, Colonel Baker's levels showed that we must seek a head of supply higher on the Sutlej than the point whence he commenced; that point also is unsuitable for the site of a permanent head, no unflooded firm ground existing on the right bank of the branch there on which a Dam might abut—it was necessary also to determine on a spot whence the whole dry weather supply of the river might be diverted into the Canal channel. Accordingly after a careful examination of the river and its banks, as far up as Nungal Ghât, I fixed on the Thanna Ghât (on the main stream) as the starting point, and carried a continuous line of levels thence, on a course which seemed practicable, to the Grand Trunk road near Barah, connecting with the upper cross section and the Great Trigonometical Survey bench-mark at the Barah encamping ground. This, with some collateral levels up the beds of nullahs, &c., gave a guide to the selection of the line now recommended—the level of the Sursa at the point of crossing determined in great measure the height at which the Canal must be carried both above and below.

For working out the details of the project certain data were assumed as follows:—

1*stly.*—*Discharge of the Canal.*—The discharge of the Sutlej at Roopur taken at its lowest, or nearly so, is stated by Captain Dyas to have been—

| | | | | |
|---|---|---|---|---|
| On the 21st January, 1856, | ... | ... | 2781 | cubic feet per second. |
| 12th February, 1857, | ... | ... | 3135 | „ „ |
| 26th January, 1859, | ... | ... | 4027 | „ „ |
| 20th December, 1859, | ... | ... | 4663 | „ „ |
| 21st January, 1861, | ... | ... | 3048 | „ „ |

By my own observations it was—

| | | | | |
|---|---|---|---|---|
| On the 22nd February, 1862, | ... | ... | 3152 | „ „ |

And at the Suraee Ghât—

| | | | | |
|---|---|---|---|---|
| On the 6th March, 1862, | ... | ... | 3122 | „ „ |

From these, I think, we may count with safety on a constant supply throughout the year of at least 3,000 cubic feet per second, and considering that the volume of the Sutlej is considerably more than this for eight or nine months in the year, and that water at *any* season is of incalculable

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value in the thirsty districts to the southward, it seemed to me advisable to make provision for the conveyance of a larger supply in at least the main channel to the first branch head on the high land. The extra supply has been assumed at 500 cubic feet per second (it might perhaps have been increased to 1,000 cubic feet with advantage) which therefore gives 3,500 cubic feet per second as the maximum discharge at the Canal head to be provided for.

*2ndly.—The longitudinal slope of bed and dimensions of channel.* These are, I need hardly say, points of paramount importance, the velocity of the stream being determined by their relative proportions. Information is unfortunately very defective as to the effect of running water on different soils. Captain Dyas, however, has given very valuable data in his Memo., taken from actual observation on the channel of the Baree Doab Canal, where the soil is if any thing worse than that of the Sutlej Khadir —he states that the Canal channel at Bheempoor on a curve (of 1 or 2 miles radius I believe) in deep excavation through sand, with a hydraulic mean depth of 4·21, and a longitudinal slope of 1 in 3333·3 seems to stand well, the mean velocity being 3·16 feet per second, or bottom velocity ($\frac{11}{11}$ × mean velocity) 2·42 feet per second—and adds his opinion that a greater mean velocity than 3 feet per second should not be given to a Canal channel in sandy soil. I have therefore fixed 3 feet per second as the maximum velocity for which the slope of bed and dimensions of the Canal channels are to be calculated, the soil in the Sutlej Khadir being very sandy, as well as a large proportion of that on the branch lines.

*3rdly.—Headway for bridges and superpassages.*—Assuming that the Canal is to be navigable, 10 feet above full supply level has been fixed as a full allowance for headway, and judging from the height allowed on English Canals, I think it will be sufficient for all the requirements of traffic here.

---

## Description of proposed line from the heads on the Sutlej to the Sursa Torrent.

The site selected for the permanent head works is at a point on the eastern branch of the Sutlej, immediately below the mouth of the Lohund torrent, the level of the bed there being sufficiently high to allow of a slope of 1 in 4800 being given to the bed of the channel down to the

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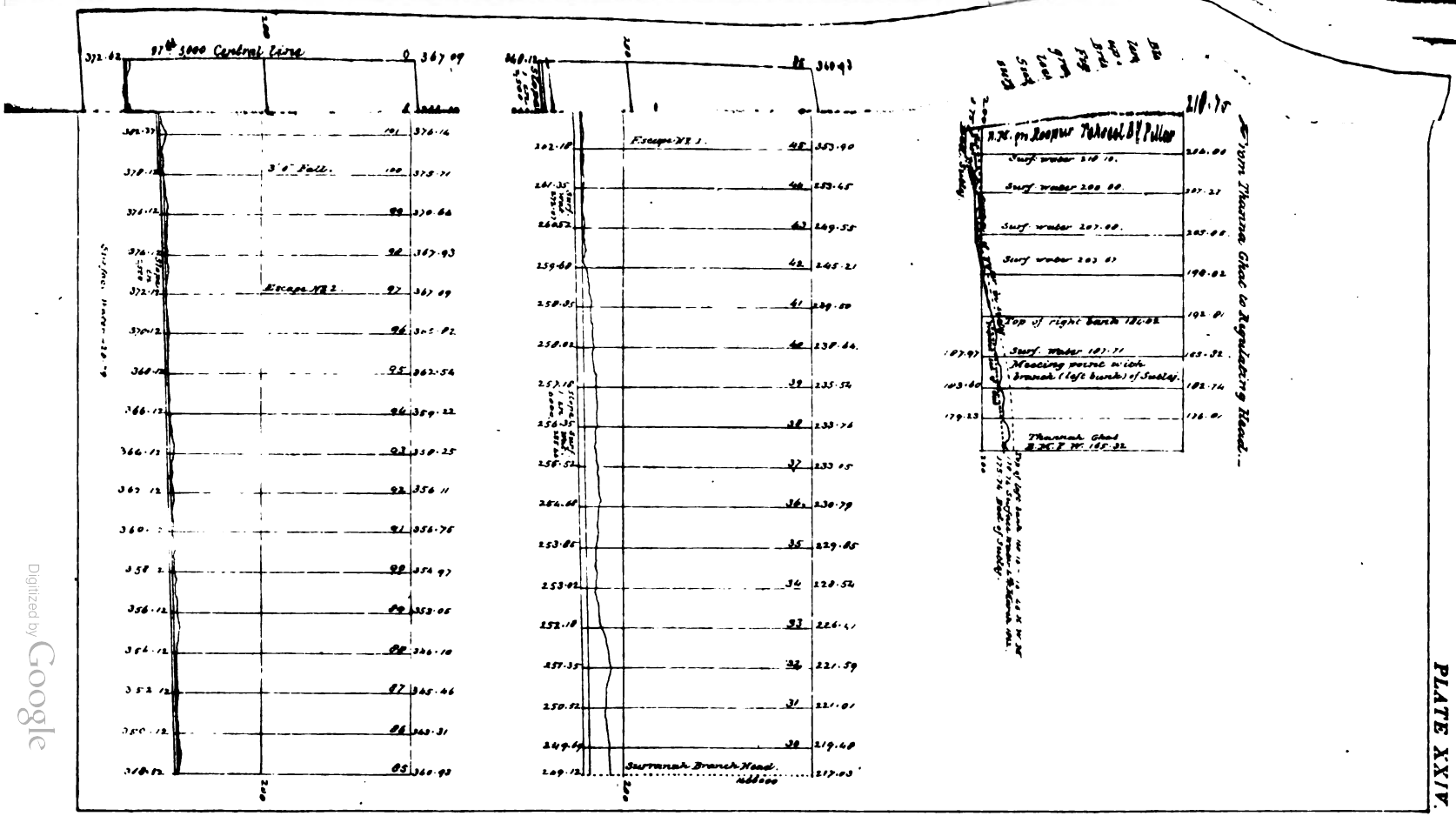


PLATE XXIV.

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crossing point of the Sursa, supposing the latter to be crossed on the *level*. At first sight, an aqueduct there seemed to be the most advantageous mode of effecting the passage, as it would have carried the Canal free from the silt of the Sursa floods, and at an elevation which would have diminished materially the depth of excavation at the entrance of the bangur; the cost of such a work however would have been very large, fully as expensive as that over the Solanee on the Ganges Canal, without the collateral advantage of high land on either side from which earth for the embankments might be procured; works for a level crossing were therefore decided on.

As the eastern branch carries only a small proportion of the cold weather supply of the Sutlej, it is necessary to divert the main stream into it above the permanent head works. For this purpose the Thanna Ghât is the most suitable site for either temporary or permanent bunds across the stream; the river there runs in one channel with the exception of a shallow film (not above a few inches deep when I saw it in February last) which runs over the shingly bed along the western edge; a low shingle bund would be sufficient to turn this also into the main channel. The bed is of good sized boulders and shingle, and the left bank well elevated above the reach of ordinary floods, though a little water is said to have topped it some twenty years ago (probably in the rainy season of 1842, when the works of the Eastern Jumna Canal suffered so much from the floods); no such event has occurred either before or since in the memory of the oldest inhabitants, the soil is as good as can be expected in such a position and is under cultivation all the year round, the width between the two branches is fully three-quarters of a mile. The stream when I saw it in February last was about 500 feet wide at the surface, with a maximum depth in the centre of 5 feet. The velocity seemed to be about the same as at the Suraee Ghât where I found the maximum at the surface to be $3\frac{1}{4}$ feet per second. An old channel, with a boulder bed, dry except during floods, leads from this point into the eastern branch, through which the whole supply may be turned by a cut 1,100 feet in length, 200 feet wide, with a longitudinal slope of bed of 1 in 916. It is proposed to divert the stream for the present into this cut by means of temporary bunds of shingle, boulders and brushwood, as on the Jumna and Ravee Canals, though it will hereafter, I believe, be found that a permanent masonry work of some kind will in all these cases effect the object more efficiently and economically. The eastern branch where the cut would join it, is about 300 feet

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wide, with well defined banks on either side sufficiently high to carry a larger body of water than the river is ever likely to supply, except in the rainy season; the declivity of its bed down to the site of the permanent head works is 1 in 801, over boulders and shingle.

No work will be necessary in the eastern branch to adapt it to our purpose down to the site of the permanent Canal head. The position of this was mainly determined, as I have mentioned before, by the level of the bed of the river there; the annexed sketch taken from actual survey, will I believe make the locality and proposed arrangement of works sufficiently intelligible. The works consist of a Dam bridge across the branch, connected by a masonry revetment with a Regulating bridge at the entrance to the Canal. The Lohund torrent joins the branch immediately above, about 2,500 feet from the foot of the low range of hills whence it makes its exit; the floods of this rao come down with great velocity, carrying with them quantities of sand, shingle and boulders, some of the latter of considerable size. The strip of low land between the foot of the hills and the bank of the Sutlej here is never topped, even in the highest floods, and is so narrow that there is little risk of the torrent ever encroaching on the Canal works; a small channel, shown in the plan on its left bank, dry except in flood, must however be closed by a bund, which, with the raising of the ground thereabout by the spoil from the Canal channel, will make all safe as far as it is concerned. The right flank of the Dam rests on the island on which the village of Koothoopoora is situated; the land here was topped by the floods of last year (the highest on record) but in ordinary floods it remains dry, and a small earthen embankment along the depressed portions at the edge of its banks would effectually prevent this in future. Below Koothoopoora the surface of the island descends rapidly till it is lost in the shingly bed of the river; the old channel, shown in the sketch, taking off on the right bank opposite Keerutpoor, will enable us to turn off the water in the branch, while the head works are under construction. The bed of the branch above, and for some distance below the Dam, is composed of shingle and good sized boulders to a considerable depth; the longitudinal slope of the bed decreases suddenly a short distance above at the foot of a steep rapid, the slope downwards for 2 or 3 miles averaging 1 in 1536, while that above is 1 in 801, a circumstance of no small advantage in constructing a permanent bar across the bed.

It will thus I think be clear that there is little choice of a position for a

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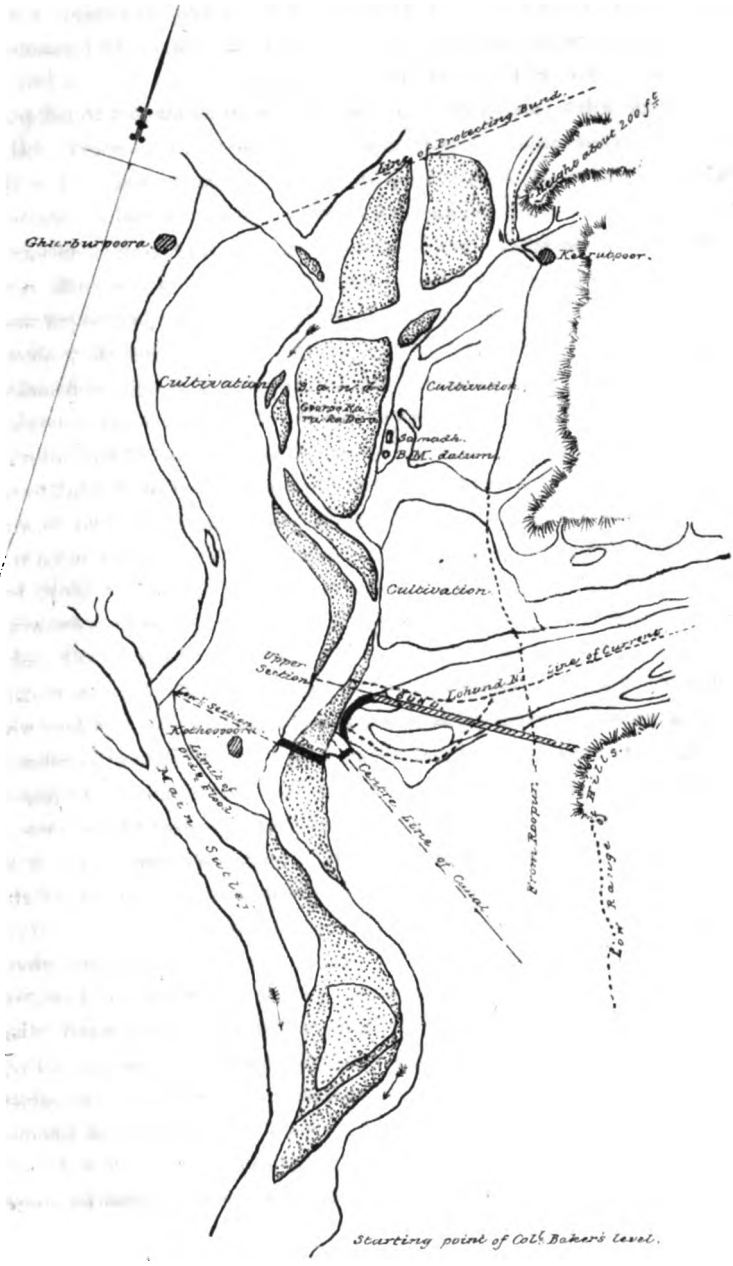
# SUTLEJ CANAL PROJECT.

## SITE OF HEAD WORKS.




Scale, 8 inches = 1 Mile.

LITHO: T.C. PRESS.

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permanent head; to have sought one higher up the river would have involved expensive works for the passage of the Lohund, a first class mountain torrent, and the spur of the low hills on which Keerutpoor is situated is about 200 feet high within 50 feet of the water's edge, while below Koothoopoora there is no suitable ground on the right bank down to the Suraee Ghât on which a permanent work might safely abut. By a curious coincidence it is the very spot pointed out by local tradition as the head of the old Mahommedan Canal, adding another instance to the many already existing, of the intelligence of these engineers of a comparatively barbarous age, whose mother wit seemed often to have directed them to the same conclusions as the light of modern science and experience have led their successors to.

The *Dam* consists of a continuous flooring of masonry across the bed of the branch, slightly depressed below its present level; piers 6 feet high and 3 feet thick, dividing the waterway in the centre into twenty-four bays of 10 feet each, three more being situated close to the left abutment to allow of a scour in front of the Regulating Bridge. The total width between the abutments is 700 feet, the remainder of the space being filled up by a masonry weir raised to the height of the piers; giving a waterway of 270 feet in width from the bed to the top of the piers, 700 feet in the clear above that level. The side revetments are carried up well above the level of the highest possible flood; the flooring at the tail of the Dam is depressed so as to form a kind of cistern which may afterwards be covered with a layer of large boulders, with the view of giving a rough hard surface on which the rush of water may partially expend its violence; sloping tail-walls, similar to those so successfully employed by Captain Dyas on the Baree Doab Canal, have been added below. The piers are adapted for the reception of sleepers and falling gates, to retain the water at the height necessary for the Canal supply; the chokies on either flank are intended as godowns for the regulating gear when not in use, and shelter for the working parties attached to the works in the rainy season.

The *Regulating Bridge* at the Canal mouth is designed with a waterway of 176 feet, the mean section of the Canal stream being 196 feet (as will be shown hereafter), divided into fourteen central bays of 10 feet each, and two at the sides of 18 feet each; I have designed the central bays at a less width than has been usually given in works of this nature, on account of the difficulty which has been experienced in working



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sluice gates of larger dimensions, the weight of which, here especially, must have been excessive to stand the pressure of floods rising 18 feet above the bed; the piers are grooved for the reception of gates, and windlasses will be fixed on the top of the piers. The two side openings will be each 18 feet wide to admit of the passage of boats and rafts, and lock chambers with gates of the usual description have been added, down-stream, to give the means of closing up the passages in floods. 10 feet clear headway above full supply is given under the crowns of the arches; a fall of half a foot is designed in the flooring of the bridge to give the stream a set inwards, the increased velocity due to which will I think fully compensate for the somewhat contracted waterway through the arches; the banks down-stream are protected by revetments, sloping tail-wails, and cross curtains. The revetment on the up-stream right flank will be connected with the bund mentioned above, which will be constructed in a continuous line up to the foot of the low hills to protect the works from any possible incursion of the Lohund. The roadway of the bridge is 22 feet wide between the parapets, as the main road up the valley, which at certain seasons is crowded by thousands of pilgrims to the Hindoo shrines of Nundpoor and Nainadavee, must cross here. The greater part of these works will be constructed of boulder masonry in lime cement, boulders being procurable in any quantity from the beds of the Sutlej and Lohund; in the arches, cutwaters and other work requiring close fitting, bricks must be used. The depth of 6 feet given to the curtain, tail-walls, &c., will I believe be ample in so good a soil; the spoil from the Canal excavation will be sufficient to fill up the old side channels of the Lohund behind the bund, and raise all that space well above the level of any possible flood.

The *dimensions of the Canal channel* from the heads to the Sursa have been calculated for a maximum discharge of 3,500 cubic feet per second, with a mean velocity of 3 feet per second on a longitudinal declivity of 1 in 4800, the bottom width being 190 feet, with a depth of water at full supply of 6 feet; the tow-paths, 15 feet wide on either side, will be kept at a constant level of 2 feet above the full supply; the road banks will in general be on the level of the natural surface, raised wherever necessary, so as to be nowhere less than 2 feet above the tow-paths. The soil is so sandy from a short distance below the head, that I do not think it advisable to exceed the limit of 3 feet per second

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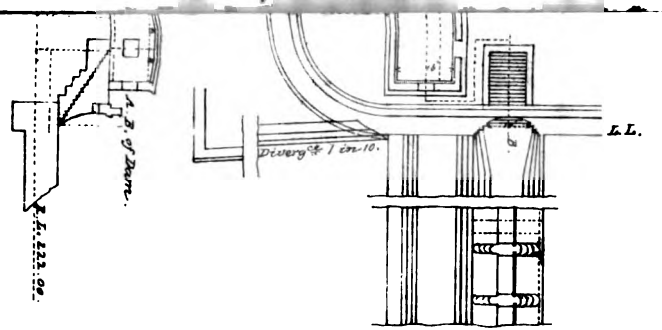
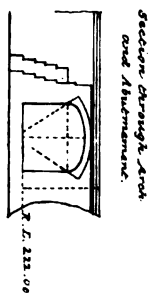
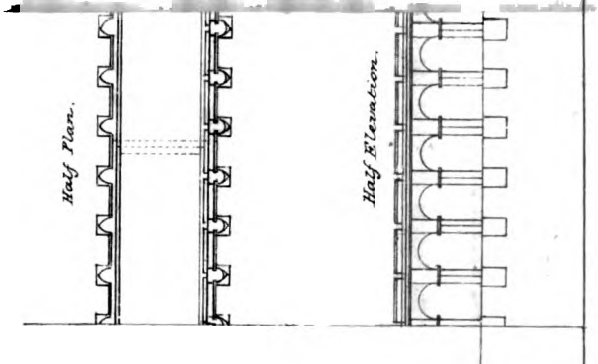
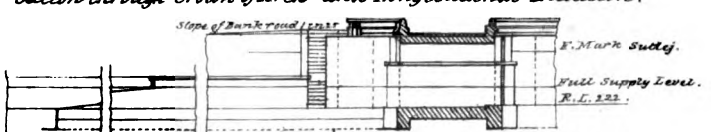
# SUTLEJ CANAL PROJECT.




Section through Crown of Arch and Longitudinal Elevation.



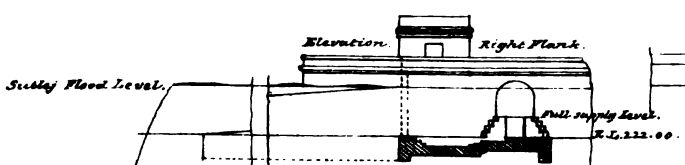




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PLATE XXVI

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in velocity of current, hence the great width given to the channel. The formulæ, on which this and all other similar calculations throughout the project have been based, will be found in Appendix A., and the detail and points of change of section will be found in the Tabular Statement at the end. The longitudinal slope of bed might have been diminished on this line by the construction of an overfall which would have rendered a less width of channel necessary; the present arrangement seems to me preferable. The distances marked off on the central lines of Canal on the map, show lengths of 5,000 feet, which I have adopted as on the Baree Doab Canal, instead of the mile, for greater convenience in calculation. The sheets of longitudinal sections of Canal channels give full information as to depth of excavation, levels of bed of nullas, flooring of dams, springs, &c.

Between the 1st and 2nd five thousand an *Inlet* will be required, to admit drainage water from the low hills on the left bank which there is no other mode of getting rid of. It is designed with a waterway of 50 feet in the clear, and a perpendicular drop into the Canal, the crest of which is raised above the full supply level; nearly the whole of this may be built of boulders.

A *Wooden Bridge* with a roadway 12 feet wide will be necessary at the 2nd five thousand, for the country traffic and to give a passage to the Suraee Ghât immediately opposite; the spans for this and similar bridges elsewhere have been designed with reference to the length of the timbers usually procurable, about 15 or 16 feet; two of these scarfed in the centre, strengthened by a straining beam and side struts, will be sufficient to span a 30 feet bay, the number varying according to the width of the roadway; over these may be laid kurries and boarding, or any material which may be found most economical according to locality; the uprights supporting the roadway beams will rest on narrow piers of masonry built in the channel up to the level of the tow-path; the passage along the tow-paths will be left free on either side. This form of bridge will, I think be found the simplest and most economical which could be devised; it can be put up by common workmen without difficulty, and though not regularly trussed, is strong enough for all the purposes of the country traffic. Other than temporary structures they do not pretend to be. I have only adopted them in accordance with my instructions, which were, if I understood them aright, to design

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every thing connected with the Canal on as economical a scale as possible, except those works on which the efficiency and security of the water supply depended. These latter it would of course be false economy to construct other than of the best and most lasting description.

Below this bridge the line crosses the Uttaree Nullah, a mountain torrent draining the uplands near Hindour, about 200 feet wide, with an average depth of 4 feet; the declivity of its bed, nearly 1 in 602; the soil is of shingle, earth, and small boulders; a very small stream of water was running down it when I crossed. As this is so close to another torrent, the Kalee Koondwalee (or Koklee of Colonel Baker) a *Cut* 100 feet wide, is designed to turn it into the latter; the length would be 5,800 feet, with a declivity of 1 in 661, in good firm soil; the banks at the head of the cut are high, far above the reach of any flood, so that although the diversion of the stream must necessarily be very abrupt, I think it may be done without much risk, if the bund across the channel be carefully looked to for the first few rainy seasons.

At the 4th five thousand we come to the Kalee Koondwalee Nullah, which must be crossed by a *Dam*, the Sutlej here approaching so close to the low hills that the back-water from its floods extends up the bed of the torrent almost to their foot; the position will be best explained by the annexed sketch, which shows the limit of the Sutlej floods on the banks below the village of Beylee. There is no record of any flood having risen beyond this limit and the ground on the line of Canal is several feet above that level; the longitudinal slope of the bed is nearly 1 in 390 where the line crosses, yet such is the influence of the back-water from the floods of the Sutlej, that little but sand is to be found in the bed, although not very far up within the hills, boulders and shingle are brought down in large quantities. The bed of the Canal here passes about 4 feet below the present bed of the torrent; this, awkward as it confessedly is, could not be avoided; to cross anywhere lower down the torrent would bring the line into too close proximity to the current of the Sutlej floods; the only disadvantage attending it, however, is the chance of silting up after a flood has subsided, which the rush of water through the Dam will in a great measure obviate.

The works projected here consist of a *Dam* and *Regulating Bridge* as at the heads, with bunds and spurs on either bank of the torrent above the Canal line, to keep the direction of floods as nearly as possible perpendi-

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cular to the Dam. Now as to the *waterway* necessary here for the passage of the floods of both torrents, if the discharge of the Kalee Koondwalee alone be calculated from the area of its flood-water section, with the velocity due to the declivity of its bed, the result is nearly 11,500 cubic feet per second, a quantity manifestly much in excess of what could possibly be brought down by such a drainage line: I have therefore taken Sir Proby Cautley's datum of the discharge due to a maximum rain-fall of half an inch per hour, over the whole area of catchment basin, or 323 cubic feet per second, per square mile of area. On this the calculations for the waterway of all the Canal works in the Ganges Khadir were based, (*vide* his last Report on the Ganges Canal,) and as those works have stood the test of 10 years successive floods uninjured, I think we may now assume it to be a safe limit. The aggregate area of the catchment basins of the Uttaree and Kalee Koondwalee Nullahs being then (as taken from the Revenue Survey maps) about 31½ square miles, the maximum discharge would be 10,237 cubic feet per second. To pass this off, a waterway has been given to the Dam of 200 feet divided into twenty bays of 10 feet each, by piers 3 feet thick and 6 feet in height; over the top of the piers there is a clear passage of 350 feet in width between the abutments.

The *Regulating Bridge*, to prevent the passage of floods from the torrents down the Canal, will have a total waterway of 206 feet (the mean waterway of channel being 196 feet) divided into seventeen central spans of 10 feet each, and two of 18 feet at the sides for the passage of boats, &c.; a greater waterway has been given here than at the heads, where the velocity through the bridge will be accelerated by the overfall in the flooring, which it is not considered advisable to adopt here, on account of the very sandy nature of the soil; with an increased velocity below this bridge the banks on either side would undubitably be cut away for some distance, unless protected by masonry or piling. All deep foundations in both Dam and Regulator must be based on under-sunk wells, water being found close to the surface; they have been projected 15 feet below the level of the Dam flooring, a depth sufficient I think to secure them from any possible disturbance in this locality. The actual height of the wells will be only about 9 feet, as it is possible to lower the surface level of the springs 6 feet below the Dam flooring. The foundation above will be formed by a casing of masonry filled in with dry boulders, the flooring 2·5 feet thick over all.

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I have adopted the old round form of well in place of the "block" in all foundations of this nature, as the most economical, from its now well known superiority in facility of under-sinking.

Between the Kalee Koondwalee and the Sursa, provision must be made for the disposal of a small amount of drainage from the low hills in the vicinity of the fort of Bhurtpoor; *two Inlets* similar to that near Boonga of 50 feet waterway each, will I think be sufficient. It is possible to pass this drainage under the Canal and so get rid of some silt, but the cost of syphons with so great a width of channel would be considerable, an expense which we should be hardly justified in incurring considering that the reservoir formed in the Sursa will intercept a large proportion of the deposit which may be thus brought down in floods.

A *Timber Bridge* for cross country traffic will be required somewhere near the village of Kot; it will be similar in all respects to that near Boonga.

At the 9th five thousand we reach the Sursa, by far the most formidable of the obstacles in the Sutlej valley; the width of its flood waters is here upwards of a mile, the central current running with a velocity due to a declivity of 1 in 638; the bed generally sand with a sprinkling of shingle and boulders; patches of boulders at varying depths are met with, but they are few and far between; quick-sands are numerous, so that it is dangerous crossing after even a small flood except at the spots used for the purpose by the villagers; the annexed sketch with the longitudinal and cross sections in the sheets of sections will give a very fair idea of its size and capacity. Four torrents combine to form the stream as we find it in the valley; the junction of three of these is effected in the low hills about 3 miles above the Canal crossing; two are comparatively insignificant, draining a length of about 6 miles of the hills on either side; the central channel, which retains its name after the junction, drains a valley some 20 miles long behind the outer range of hills, from the watershed of Pinjor; the fourth affluent joins it just above its exit from the hills, carrying into it the drainage from some 10 miles of the hills towards Hindour. The declivity of its bed diminishes very rapidly from the village of Indurpoor to a little below the crossing of the Canal, whence to the Sutlej the slope is tolerably uniform. Our levels show that the level of the bed here has not altered since Colonel Baker observed it twenty years ago; shingle and

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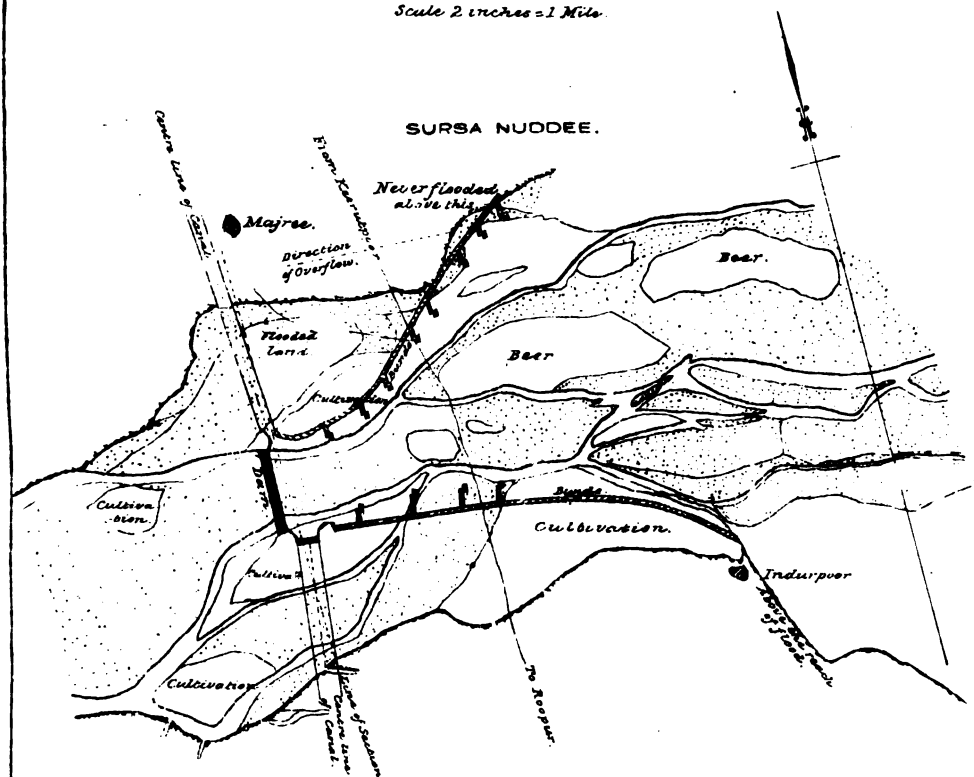
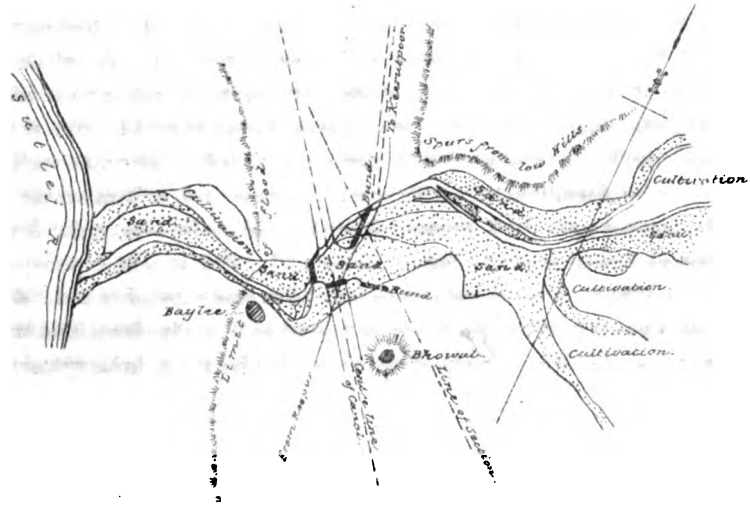
# SUTLEJ CANAL PROJECT

Scale 2 inches = 1 Mile

## SURSA NUDDEE.




## KALEE KOONDWALEE NUDDEE

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boulders are visible in the bed about half a mile above the Canal line, rapidly increasing in size as we ascend the course of the stream, clearly pointing out, I think, the safest site for any permanent works in its bed; nearer the hills indeed it would be hardly possible to carry the line, as a reference to the large map will show, and every foot lower down adds to the depth of excavation in the bangur; the bunds in the sketch, show the extent to which it will be necessary to provide protective works; above their upper extremities the land on either side is high, out of all risk from floods. It is evident from the section that a large proportion of the present wide channel cannot be occupied in floods by a stream running with any great velocity; the existence of sand beds and sandy islands to such an extent in a torrent with so great a declivity puts it out of the question; in fact calculating the discharge by the area of this flood section, and the velocity due to the observed declivity of the central channel, we obtain the enormous amount of 129,548 cubic feet per second, a discharge equal to that of some of the first class rivers in Europe. Here, therefore, I have assumed, as in the case of the Kalee Koondwalee, the maximum discharge to be provided for, as that due to a rain-fall of half an inch in depth over the whole area of catchment basin.

The works projected for the passage here are similar to those at the head and Kalee Koondwalee—a *Dam* provided with sluices for the passage of the floods of the torrent, with piers sufficiently high to retain the Canal supply—and a *Regulating Bridge* to prevent more than the required supply passing down the Canal. The bed of the torrent having apparently remained at the same level for the last twenty years the floorings of the Dam and Regulating Bridge, as well as the plinths of revetments, &c., up-stream, have been projected on the present level of the bed at the crossing. The discharge to be provided for being that due to the half inch rain-fall over a catchment basin about 26 miles long by 9½ miles wide (= 247 square miles) or 79,781 cubic feet per second, a waterway of 920 × 7 is given through the piers of the Dam, and a clear width over the top of 1,218 feet between the abutments; which it will be observed corresponds very nearly with the width of the central channel of the torrent at the point of crossing. With this waterway, the calculated afflux in the highest known flood (6½ feet above the level of the Dam flooring) would not raise the

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water level higher than 2 feet above the top of the Dam at most. The bunds and spurs on either side, up-stream, will be so arranged as to direct the flood current perpendicularly on the line of Dam, the present side channels being closed by the same means. The island on which the Regulating Bridge will be situated, is submerged in high floods to a depth of about 1¼ feet; that on the left flank from 2 to 3½ feet.

The foundations of the Dam and its revetments will be sunk to a level of 15 feet below the sill, the surface of the springs, which here is kept at the level of the bed by the small perennial stream from the hills, can be lowered about 6 feet by a drainage cut, so that it will only be necessary to undersink for a depth of 9 feet; the foundations above this being completed to the level of the sill by masonry walls under the front and rear of the line of piers, connected at intervals by cross walls, the intervening spaces being filled up with boulders laid dry, covered at the top by a layer of masonry sufficiently thick to withstand the erosive action of the current, and filled with incompressible material. A like construction has been adopted in all full foundations where the width is considerable; the expense of these undersunk foundations, it will be seen from the estimate, forms a large proportion of the total cost of the works—they cannot, however, be dispensed with in such a soil. The circles on the plans show the position and number of the wells. The width of the Dam (1,213 feet) is divided into ninety-two bays of 10 feet each, divided by piers 3 feet thick—a platform 10 feet in width adjoining each flank revetment. The top is on one uniform level of 7 feet above the flooring; the length of the piers 18½ feet; grooves, &c., are provided for the reception of sluice planks and falling gates; the chokies on either flank are intended for the reception of the sluice gear when not in use, and as shelter for the working parties; a curtain is sunk to the full depth the whole way across, 40 feet below the line of piers, connected with the foundations of the side revetments; sloping tail-walls are added for further security. The form of raised weir, instead of additional sluice openings at the flanks of the Dam, designed in the Dam at the head works, I do not think it advisable to adopt here in consideration of the violent action of a fall of water on so sandy a bed. The space between the Dam and curtain wall, down-stream, will be covered with a layer of boulders, the lowest course, laid in mortar, to protect the foundations from the risk of being undermined; a

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thin water-proof flooring, well protected from the impact of the current, would be sufficient I believe in most cases to preserve the under soil from all erosive action.

The *Regulating Bridge* is designed with a waterway of 186 feet (the mean waterway of the Canal channel below being 177 feet) divided into fifteen central bays of 10 feet each, and two at the sides of 18 feet each, for navigation purposes. The initial velocity of the current being here very much diminished by its passage through the large reservoir which will be formed in the Sursa, a fall of half a foot is given in the flooring of the bridge to increase the velocity of entry; with this aid, the waterway will I think be found ample. The bridge will be all of masonry, arched across, a clear headway of 10 feet being left from the soffits of the arches to the surface of full supply; the 10 feet bays will be closed in floods, with gates worked by windlasses fixed on the top of the piers; two gates each 3½ feet high for each bay, with sleepers to be laid on top in case of an extraordinary flood; the regulation at the side openings will be effected by lock gates in chambers, down-stream, as at the heads; the width of roadway above will be 20 feet between the parapets. Revetments, sloping tail-walls, and cross curtain, with dry boulder flooring, are designed for the protection of the banks and bed down-stream. The foundations will be laid at the same level, and in the form described for the Dam, excepting the revetment and tail-walls in the Canal channel down-stream, where it appears sufficient to give them a maximum depth of 8 feet, which can be effected without having recourse to undersinking, the deep foundations of the bridge and its up-stream revetment affording ample protection to this part of the works from the floods of the torrent. The revetments, up-stream, will be built up 10 feet above the level of the Dam flooring with a parapet 2 feet in height, making the total height 12 feet, sufficient I think to secure the works from being topped by any possible flood. The bunds to confine the torrent will be connected on the left bank with the bridge revetment; on the right, with a paved slope protecting the left bank of the Canal channel at its entry. The mass of these bunds will be formed of shingle, clay and sand, with a paved slope in front, further protected at intervals by spurs of crib-work filled with boulders. A small quantity of drainage from the land on the left bank of the torrent will have to be passed off either over or through the bund —where and how can best be determined at the time of its construction.



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### From the Sursa to the Branch Head at Subranah.

The longitudinal slope of the bed below the Sursa having been fixed at 1 in 6000, with reference to the relative levels of the beds of the drainage lines and surface of the high land lower down, the consequent dimensions of channel for a discharge of 3,500 cubic feet per second, with a mean velocity of about 3 feet per second are —

| | | |
|---|---|---|
| Bottom width, | .. .. .. .. .. | 170 feet. |
| Depth of water at full supply, | .. .. .. | 7 „ |

with side slopes of 1 in 1, tow-paths on each side 15 feet wide, the top surface being kept at a uniform level of 2 feet above the full supply, by excavating or raising according to circumstances.

A reference to the map will show that the spur of the low hills on which Roopur is situated, running out to the edge of the Sutlej, divides the drainage of this portion of the valley into two distinct sections. The upper portion, between the Sursa and Roopur is carried off by five torrents, whose sources lie some 2 or 3 miles within the range of low hills, of no great size individually, though their aggregate capacity is considerable. They all run in sandy beds on very steep declivities; the one nearest the Sursa, locally named the Gunowlie Khud, brings down immense quantities of sand, or rather spreads its silt over a very large surface, immediately below the crossing point of the Canal; the sand lies there in huge mounds, and the villagers of Nooho complain bitterly of its inroads on their land within the last few years. The largest of the five and that which carries the greatest volume of water, is that near Chundpoor, about a mile and a half further on. The declivities of their beds are as follows:—

| | | |
|---|---|---|
| Gunowlie Khud, | .. .. .. | 1 in 320 to 1 in 446 |
| Chundpoor, .. | .. .. .. | 1 in 209 |
| Mullikpoor, .. | .. .. .. | 1 in 223 |
| Ladoal, .. | .. .. .. | 1 in 226 |
| Hooseinpoor, | .. .. .. | 1 in 324 |

The valley of the Hooseinpoor Khud is depressed considerably below the others; the depression continuing close into the foot of the low hills. Now, to construct superpassages or aqueducts for the separate passage of each of these torrents, would involve a very heavy expenditure; and level crossings, even were they practicable, are out of the question with flood water so heavily laden with silt; the foundations of any works besides, con-

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structed across beds on such steep declivities would be constantly exposed to the risk of being undermined by floods. The safest and most economical course appeared to me therefore to be, to collect all the separate drainages into one channel if it were practicable, and pass the Canal over the combined stream by an aqueduct. This the levels showed the possibility of; the Hooseinpoor Khud affording the necessary outfall, secured by the depression of its valley from any risk of flooding the lands on either side. A cut or catch-water drain 22,700 feet in length, is accordingly projected from the Gunowlie Khud into the Hooseinpoor Nullah, which will intercept all drainage crossing it from the low hills; the declivity of bed would be 1 in 466 from the Gunowlie to the Chundpoor Khud, thence onward to the end 1 in 497. A short junction from the Ladoal Khud, will I think be necessary in addition, the present channel meeting the Gunowlie cut, at an awkward angle. The discharge of the outfall channel has been calculated as in the case of the Sursa, from a half-inch rain-fall over the whole catchment basin, as taken from the Revenue Survey map, about 4 miles × 3 = 12 square miles; this amounts to 3,876 cubic feet per second, for which a channel, 100 feet wide with 5 feet depth of water and side slopes of ½ in 1 on the given declivity of 1 in 497, will suffice, the widths of the cut will vary as follows:—

| | | |
|---|---|---|
| From Gunowlie to Chundpoor Khud, .. .. .. | 60 | feet. |
| Chundpoor to junction of Ladoal, .. .. .. | 80 | „ |
| Below Ladoal cut, .. .. .. .. | 100 | „ |
| Width of Ladoal cut, .. .. .. .. | 30 | „ |

the present channels of the several Khuds will be bunded across by embankments formed of the spoil from the cuts, protected by spurs at each crossing. If these points be carefully looked after for the first few rainy seasons, no fears need be entertained for the safety of the embankments; silt will doubtless be deposited in considerable quantities at first along the cut, but in course of time the floods will regulate the level of the bed to the slope best suited to the varying discharge and velocity. The several cuts have been made sufficiently large to lead the streams in the proper direction, leaving the floods to widen them to the requisite dimensions.

The *Aqueduct* to carry the Canal over the outfall, will be situated a little in advance of the 15th five thousand; the aggregate water-way below is 105 feet, divided into three spans of 35 feet each, by piers 6 feet thick; the passage for the Canal above is 180 feet in total width, divided into two channels, each 90 feet wide by a central pier 4 feet in thickness, which

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will allow of repairs being made without shutting off the whole Canal supply; passages are arranged for on either side, on the level of the tow-path (9 feet above the Canal bed), 4 feet in width on the left, 10 feet on the right bank; the greater width on the right bank being given to admit of the passage of wheeled vehicles; corbels, 2 feet wide on the Canal side will somewhat increase these widths and afford space for a railing, which may hereafter be found necessary, without encroaching on the width of the passage; the parapets, 2 feet high, will be projected clear of the head walls of the aqueduct. The difference of level between the beds of the Canal and outfall channel is 14·79 feet, which is thus disposed of:—

| | |
|---|---|
| Height to springing of arches, .. .. .. .. | 6·00 |
| Rise of arches (segment of 60°), .. .. .. .. | 4·69 |
| Thickness of arch, .. .. .. .. .. | 3·00 |
| Brick-on-edge and flooring, .. .. .. .. | 1·10 |
| Total, .. ... | 14·79 |

The flooring will be composed of asphalte or some substance impervious to water; the velocity of the current being so small, there will be little danger of even puddle being washed away; passages in the masonry above the piers will be arranged for in the course of construction to carry off any leakage from the backing of the arches; the puddle backing to the abutments will be continued under the Canal bed for a length of 60 feet from the masonry, up and down-stream, covered over with a layer of boulders or kunkur; no flooring under the arches has been deemed necessary as the tendency will, I think, be rather to silt up than excavate. The foundations will be wide shells of masonry filled with boulders or kunkur, resting on a stratum of shingle or boulders, which a trial well sunk on the spot showed the existence of; water-wings, 30 feet long, sunk to the same depth, are added, up and down-stream, to secure the wing-walls of the work from injury; their foundations being only carried down to the level of the bed of the outfall channel. The mass of the work can be built of boulders or blocks of kunkur and hard conglomerate, procurable from the ravines in the neighbouring low hills. The longitudinal section of the Canal channel shows, that the bed meets the ground surface about 1,000 feet above, and 2,000 feet below, the aqueduct, the maximum difference of level being about 8 feet. To secure the embankments from the ravages of rats and other vermin, a wall or core of sand, 4 feet in thickness, extending from the ground surface up to the level of full supply in the

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Canal, will be carried through the centre of the embankments right and left, from the wing-walls of the aqueduct to the points up and down-stream, where the Canal is again under soil. This expedient I believe has not yet been tried in Irrigation Works in these provinces, but in both America and Holland it appears to have been long known and practised successfully. The embankments being sufficiently thick to prevent all risk of percolation, the only danger to be apprehended is from holes burrowed by rats, moles, and other vermin. If a masonry wall be substituted for the sand, as was done by Captain Dyas in an embankment a mile long on the Baree Doab Canal, the cost would be, supposing it to be only 1½ feet thick, and built at the lowest possible rate, fully eight times greater. It will not be necessary to fill the space between the embankments right and left up to the level of the bed except a length of about 250 feet, up and down-stream, from the aqueduct; bars 15 feet wide will be formed at intervals up to that level to stop any current below, the remaining space may be left to be filled up by silt deposits from the Canal stream.

About a mile below this aqueduct we come to the watershed of the Roopur spur, between which and the point of the bangur near the village of Sulowra, three sandy torrents, two, the Soogh and Boodkee, of considerable size, cross the valley. The average declivities of their beds are as follows:—

| | |
|---|---|
| Roopur Nullah, ... ... ... | 1 in 818 |
| Soogh, ... ... ... ... | 1 in 311 and 1 in 429 |
| Boodkee, ... ... ... ... | 1 in 526 |

These it is proposed to deal with similarly to the drainages above Roopur; as level crossings, though practicable, could not be recommended where sand is brought down in such quantities, as is apparent from the huge ridges lining the banks of these torrents; it would besides involve a very awkward lining out of the Canal channel in a soil for the most part of pure sand. The Roopur Nullah being on the most depressed level of the three and lying close to high land, by which the length of embankment for the Canal is reduced to a minimum, its channel has been chosen for the outfall cut, into which the Soogh can be diverted by a cut above the high land on which the town of Kotluh stands; and the Boodkee by another, commencing from the village of Rungheelpoor, which would join the outfall close above the town

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of Roopur; the lines for these cuts were selected after a careful examination of the localities and levels. I do not think they could be altered with advantage; a reference to the map will explain their positions more clearly. The cut from the Soogh would be beyond all risk at a distance of about 1,000 feet below its head, as it there enters a valley bounded by high hills on either side; its channel for this 1,000 feet is projected at 200 feet in width, the remainder down to the junction with the Boodkee cut, 100 feet wide, with a declivity of bed of 1 in 373. The Boodkee cut takes off from a point where the current of the torrent sets directly into it; the channel is estimated at 200 feet in width for the first 1,000 feet, the remainder contracted to 100 feet, on a uniform declivity of 1 in 661. The present channels of the torrents will be blocked below the cuts by earthen embankments protected by spurs of open piling similar to those employed so successfully in the Sombe torrent above the Western Jumna Canal works at Dadoopoor; the effect of a silt bearing stream with such a construction being to deposit sand at the foot of the embankments in rear of the spurs. For the calculation of the combined discharge of the outfall channel we have a catchment basin about 10 miles long by 7 miles wide, or 70 square miles, which, with the rain-fall we have hitherto assumed, would give a maximum discharge of 22,610 cubic feet per second; for this a channel 350 feet wide, with a depth of water of 6 feet, and a declivity of bed of 1 in 425, will suffice, (the declivity is the mean of the slope of bed, above and below the Canal crossing, the former being 1 in 373, the latter 1 in 478); the cut will only be excavated to a width of 250 feet.

The *Aqueduct* to cross this outfall will be situated between the 16th and 17th five thousands, about ¼ mile below the town of Roopur. The required waterway under the aqueduct being 350 feet, the work is projected in 10 spans of 35 feet each, divided by piers 6 feet in thickness. The depth from the Canal bed to the bed of the outfall channel, is thus divided :—

| | | | | | |
|---|---|---|---|---|---|
| Height to springings of arches, | .. | .. | .. | .. | 6·00 |
| Rise of arches, .. .. | .. | .. | .. | .. | 4·69 |
| Thickness of arch at crown, | .. | .. | .. | .. | 3·00 |
| Brick-on-edge and flooring, | .. | .. | .. | .. | 1·00 |
| | | Total, | .. | .. | 14·69 |

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The trial-well sunk here, showed nothing but tolerably firm clay below a depth of 3 feet from the present bed of the Nullah; it has been therefore considered sufficient to give the foundations the same depth as at the aqueduct above Roopur; all other details are the same as described for that work.

The drainage of the strip of land lying between the Boodkee cut and the Canal line must be provided for before reaching the Sulowra point; the quantity draining off so sandy a soil with a very small declivity of surface cannot be very great; an inlet of 50 feet waterway, similar to that at Boonga, on the left bank, where the channel of the Boodkee now crosses, will, I think, be sufficient. An outlet of the same waterway is estimated for on the opposite bank, to give egress to any extraordinary amount of flood water.

From the Sulowra point the line would keep close to the foot of the high land so as to retain the surface level of the water within soil; another inlet will I think be necessary here, unless it be found practicable by means of catch-water drains, to divert the drainage from the ravines off the Canal line; the estimate will, I believe, cover any expense on works of the kind which may be found necessary.

At the 23rd five thousand, we come to the Seesooan torrent, where a *Superpassage* is projected; the Canal bed being at a sufficient depth below the bed of the torrent. Just before meeting it, the line passes through a spur of the high land with a maximum depth of excavation of 43½ feet; this, I would have avoided, had the levels of the bed of the Seesooan admitted of it, and so saved a length of half a mile of deep excavation; but the rapid fall in the bed of the torrent precludes the possibility of carrying the line further to the westward. The declivity through the contracted channel above Dolchee Majra (at one place it is only 100 feet wide) is 1 in 549, below which it continues tolerably uniform at 1 in 794; westward of the Canal crossing, it again increases where the channel emerges into the low land of the Sutlej valley. At the point where Captain Dyas's levels crossed, the bed is raised above the level of the adjoining land by the quantity of silt annually brought down in floods; the sand heaps at the site of the superpassage are of no great depth, but from Balsinda downwards, the banks are lined by enormous ridges, some 20 and even 30 feet in height. The torrent takes an abrupt turn just in advance of the contracted channel which brings the flood current in contact with

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the Canal line at an awkward angle. To remedy this a cut will be necessary, about 4,000 feet in length, commencing in the high land on the left bank opposite the village of Dolchee Majra, 150 feet wide for the first 500 feet, 100 feet for the remainder; the present channel will be closed by an embankment (formed of the spoil) just below the mouth of the cut; this must be so situated as to intercept the drainage water which comes down a deep ravine on the right bank, from the high land near the village of Sólkeean; a reference to the map will show the position of this cut terminating on the superpassage. The Seescoan receives very little surface drainage below the point where it takes a westerly course, the fall of the country on the left bank being all to the south-west, while the edge of the Boodkee valley approaches close to the right bank of its northerly feeder, a small torrent passing by the village of Seealbah; taking then the catchment basin to be 8 miles in length by 3 miles in width, we obtain an area of 24 square miles, which would give a maximum rain-fall to be carried off of 7,752 cubic feet per second, agreeing very closely with the discharge calculated from the area of the section at the Canal crossing, with the velocity due to a declivity of 1 in 794; to pass off this discharge, a waterway of 150 feet wide by 6½ feet in depth, on the given declivity of 1 in 794, will be required.

The difference of level between the beds of the Canal and the torrent is 21·93 feet, which is thus disposed of:—

| | | | | | |
|---|---|---|---|---|---|
| Depth of water in Canal, | ... | ... | ... | ... | 7·00 |
| Headway up to soffit of arch, | ... | ... | ... | ... | 10·00 |
| Thickness of arch, ... | ... | ... | ... | ... | 3·00 |
| Brick-on-edge and flooring, | ... | ... | ... | ... | 1·93 |
| | | | Total, | ... | 21·93 |

The Canal channel will be spanned by three central arches of 45 feet span each, and two at the sides of 32 feet each; tow-paths 7½ feet wide in the clear will be carried under each side arch, leaving an aggregate waterway of 184 feet. The mean waterway of the Canal channel is only 177 feet; the addition is made in this work, in consideration of the impossibility of increasing its dimensions should the Canal be required to carry a larger supply hereafter. The waterway for the torrent above, is projected in one channel 150 feet wide at bottom, with side walls (head walls of the work) 10 feet in height, 5 feet thick at the base, 4 feet at top; the flooring over the arches will be

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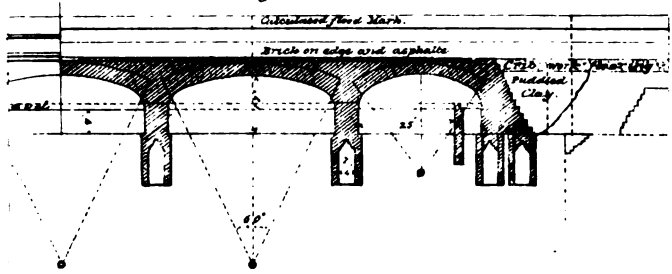
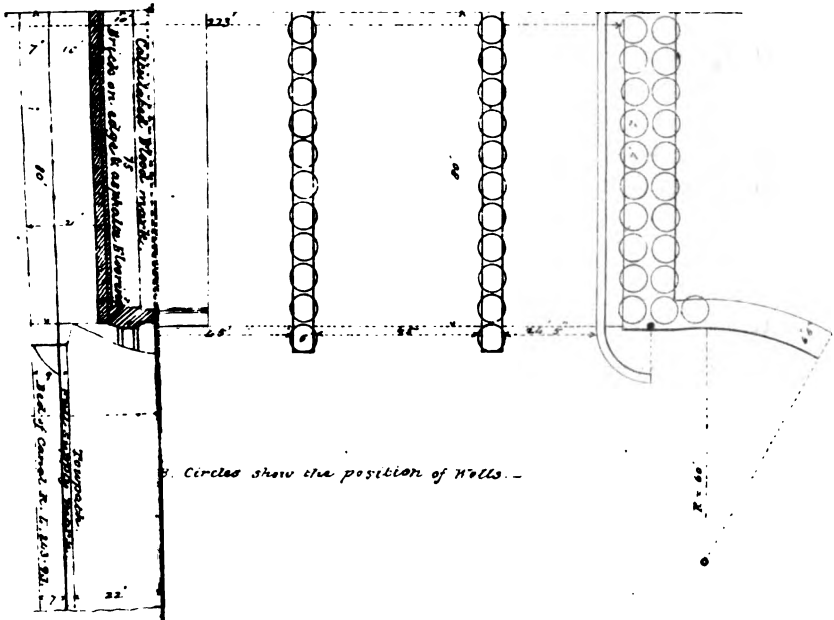
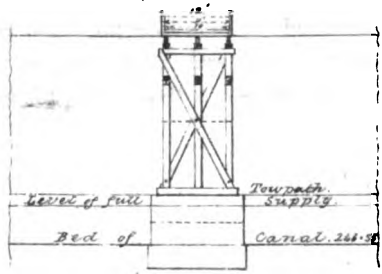
## Half Longitudinal Section.




## Cross Section and Elevation.

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formed as in the Roopur aqueducts, except that the upper surface, being exposed to the action of a more rapid current, must be made of some hard material, probably a layer of kunkur slabs; the backing of the abutments will be of puddled clay covered with a flooring of kunkur, slag or boulders, packed in cribs. The foundations of piers and abutments must here be undersunk, the surface of the springs lying some 5 feet above the level of the Canal bed, below which it will not be possible to drain. I was not able to get a trial-well sunk, owing to the lateness of the season, (the middle of last June,) when those higher up the line had been completed; there is little doubt, however, that nothing except sand will be found at that depth in such a locality. The foundations of the wing-walls need not be carried lower than the bed of the Canal at their junction with the abutment, thence diminishing upwards by steps, as shown in the plan; the tow-path retaining walls being quite separate from the body of the work, and having no weight to support, will not require foundations deeper than 4 or 5 feet, which may be laid in with the aid of pumping; the wing-walls will be carried out sufficiently far, up and down-stream, to keep floods well away from the edge of the Canal excavation; crib-work revetments, 130 feet in length, with spurs, will be added at their extremities to preserve the banks from cutting and keep the current in the proper channel.

On the left bank of the Seesooan valley, at the 24th five thousand, the line enters the *Bangar* with a maximum depth of excavation of 44 feet, diminishing to 32 feet at the point fixed on for the site of the first branch head, 1,600 feet in advance of the 29th five thousand. This deep excavation has, from the first, been one of the main difficulties of the project, not only on account of the heavy expenditure involved, but also the numerous disadvantages attending deep cuttings in sandy soil. The depth on the present line, I do not believe it possible to reduce, considering the levels of the Canal bed with reference to those of the drainage of the Khadir. The channel is carried down to the Surranah branch head with a uniform bottom width of 170 feet, side slopes of 1 in 1, with berms 15 feet wide on either bank, excavated to a uniform level of 2 feet above the calculated full supply; the slope of the cutting, up to the ground surface being 1 in 1½. I had at first projected the width of berm at 20 feet, to give room for any slipping which might take place in the sandy slopes, but



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have diminished it in the estimate, solely on the score of expense, to a limit, below which I do not think it can be safely reduced.

Five *Bridges* will be required to keep up cross communication on this section of the line, two with a roadway 20 feet in width, for the roads from the Roopur Ghât to Buddee and the town of Roopur; for the rest, a roadway 12 feet wide will suffice; all will be of timber resting on low masonry piers as before described.

The *widths of land* for the line have been calculated with reference to the space required for the disposal of the spoil from the channel excavation, giving a clear width of 30 feet from the edge of the cuttings to the foot of the spoil bank, part of which will be occupied by the Canal patrolling road; and a road 20 feet wide, outside the spoil bank along the boundary ditch, to give a passage for the country traffic. These widths will be:—

| | |
|---|---|
| From the heads to the commencement of the deep excavation at the 22nd five thousand,... ... ... ... | 600 feet |
| Below that, .. ... ... ... ... ... | 1,300 „ |
| Diminishing gradually to, ... ... ... ... at the Surranah branch head. | 900 „ |

From the heads to Roopur, the right bank boundary road must be widened to 30 feet, as it will take the place of the present main road along the valley which the Canal will cross at several points. These roads are entered in the estimate as a separate item; the experience on other similar works has fully proved that they are absolutely necessary.

An Escape would have been projected from the central channel above the Surranah branch head, had it been practicable; the Sursa, however, will afford the means of regulating the supply entering the channel, and with the aid of the small outlet at the Boodkee, in carrying off the small amount of drainage let in there, I think the works may be considered quite secure.

Four 1*st class* and three *2nd class Chokies* will be required on this section of the line. A 1st class at the head works, another at the Sursa, and a third near Roopur, the fourth at the Surranah branch head. One 2nd class near the bunds at the Thannah Ghât, a second at the Kalee Koondwalee crossing, and a third at the Seesooan superpassage. The cost of temporary shelter for the native Establishment and workmen will be covered by the per centage on the works.

*Workshops* on an extensive scale will not, I believe, be necessary, as

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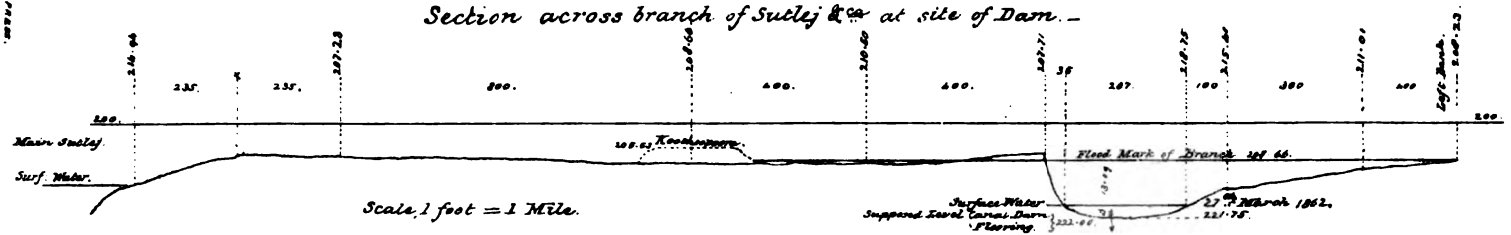
# SUTLEJ CANAL PROJECT

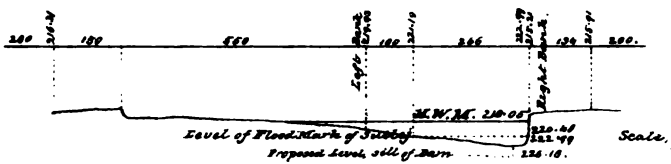
## CROSS SECTIONS.

### Section across branch of Sutlej & Co at site of Dam.—



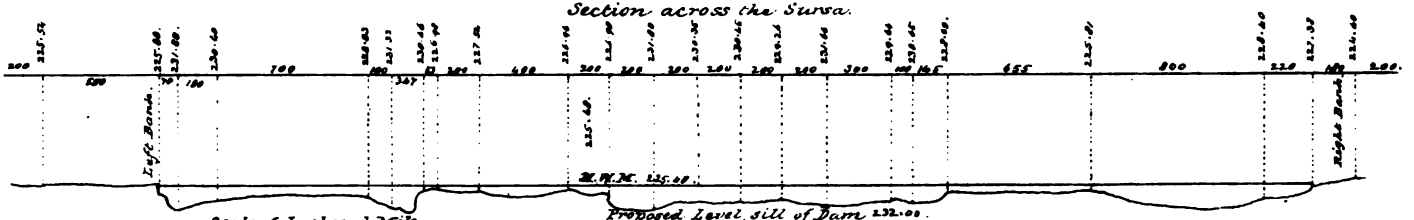

Scale, 1 foot = 1 Mile.

### Section across Kalee Koondwalee Nuddee.




Scale, Hor.l 1 foot = 1 Mile.
Vert.l 10 times Hor.l

### Section across the Sursa.




Scale, 6 Inches = 1 Mile.

### Section of Canal Channel from heads to Sursa.

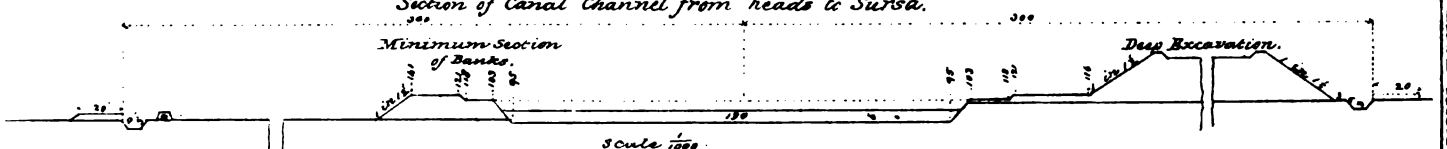



PLATE XXX.

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any heavy wood or iron-work required, can be made up in the Baree Doab or Ganges Canal Workshops; all *ordinary* work of this description, however, can be executed more cheaply on the spot, as the expense of carriage will be thereby saved, and a range of workshops has therefore been estimated for.

The land required about these buildings has been estimated at 5 acres for each 1st class chokie, 2 acres for each 2nd class; for workshops, the same as for a 1st class chokie.

*Plantations* have not been estimated for, on the score of economy, not being an absolutely necessity; a small monthly expenditure would, however, afford the means of maintaining nurseries of young forest trees, which might be planted out during the construction of the works wherever water was near at hand, and along the banks generally after the admission of the Canal supply.

At the Surranah branch head, this portion of the project properly speaking ends. Though included in the estimate for the passage of the Khadir, the details of the regulating bridge and the reasons for fixing it at Surranah will be more appropriately considered along with the detail of distribution over the several branch lines; the channel up to this point will carry the full supply of 3,500 cubic feet, as it does not seem advisable to expend any in irrigation in the Sutlej valley where rain is plentiful and the springs near the surface, while every available drop would be of untold value to the thirsty districts below. The level of the surface of the water in wells lying near the Canal line is shown in the longitudinal section. It is everywhere either very near, or above the Canal bed up to the entrance of the high land; this is a favorable circumstance insomuch that it will diminish to a great degree the loss by absorption, which otherwise, in so sandy a soil, would have been considerable.

*(To be continued.)*

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## No. LXVI.

## VENTILATION OF BARRACKS AND JAILS.

*On the Possibility of Ventilating and Cooling Barracks and Jails, by means easily available in India and at small expense.* By Major F. De Bude, R.A.

Air exhaled from the lungs and given off from the surface of the bodies of animals is hotter, and consequently lighter than the surrounding air, and therefore rises.

The air therefore in a room occupied by human beings is coolest and purest near the floor, hottest and most vitiated, near the roof.

While this rule holds good for all rooms in both cold and hot countries, (England and India for example,) there is this difference, that in a cold country the air inside a room is almost always warmer than the external air; consequently ventilation can be secured by means of the chimney, or better still by some outlet near the roof.

In India the outer air is through a great part of the year hotter than even the vitiated or hottest air inside a room; which, consequently, being heavier, would not rise and escape even if outlets were left for it in or near the roof.

But even in England it has been found necessary to adopt some plan for drawing off the vitiated air, other than merely leaving holes for its escape.

Dr. Reid's plan of ventilation in England as applied to the Houses of Parliament and other buildings, is this—

Let AB be the roof, and CD the floor of a room.

A pipe, *ab*, with holes *x*, runs along the roof AB down one side BD, and communicates with a furnace E and chimney EH.

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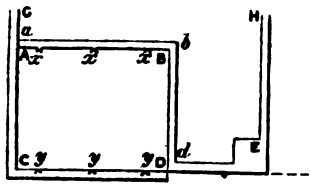
Another pipe runs along the floor CD, with holes *y*, opening into the room, up the side AC and above the roof to G.

The air in the chimney EH, being heated by the furnace, rises, and its place is occupied by the vitiated air in the room, rushing through the holes *x* into the pipe *abd*, and bottom of furnace.




The doors and windows of the room being closed, the air drawn off by the furnace is replaced by that flowing down the tube GCD, and into the room by the holes *y*.

Thus a constant stream of fresh air is kept up which pervades every part of the room. The bad air rises naturally to the top and is as constantly drawn off. No portion of the vitiated air is breathed a second time.

The only plan of ventilation adopted in India is this, (stirring the air by means of punkahs does not constitute ventilation)—

The mouth of a thermantidote (or revolving wheel with fans) is introduced into the room through a hole in a wall or door. The outer air is sucked in at the axles by the revolution of the wheel and blown into the room through the mouth, and this air is cooled by passing through wet tatties into the thermantidote. All doors and windows are kept shut to exclude heat, dust, and flies. Now it is evident that if air be constantly blown into a room, a corresponding proportion must find its way out somehow, and thus a sort of ventilation ensues.

But it must be remembered that the windows are tightly shut; that the doors, through the chinks of which, the greater part of the air must escape, are near the bottom of the room, and that the cold air which comes in at the mouth of the thermandidote naturally remains near the bottom. It therefore follows that the greater portion of the air which finds its way out, is the recently introduced fresh air, while the worst and highest is scarcely touched, and that part of it being acted on by the eddy produced by the thermantidote, is drawn down as it gradually cools and is re-inhaled again and again before it gets out.

If this be true, the English plan is far better than the Indian

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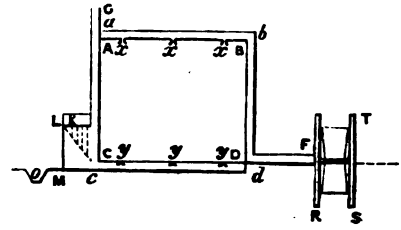
one, and there appears no difficulty in the way of its adoption in India.

First, to cool the air in its passage to the holes *y* in the floor, let it pass through a tattie CL, in a small chamber CLM.

A trough at K with holes for the water to drip through on to the tattie, and a cistern O to drain the chamber, and from which the trough K could be constantly refilled would complete the apparatus. At the other end of the building would be either a furnace and chimney, as shown in the previous figure, or a thermandidote, as here shown; but which, instead of driving air *into* the room, would be used to exhaust air *from* the room. Unless, however, fuel is very dear, the furnace plan is decidedly to be preferred, and there is no reason why the furnaces for ventilation should not be applied to the purposes of cooking as well.




That a thermantidote has great power in exhausting a tube, is shown by the fact that it is used in England for that purpose.

In a railway described in a recent number of the St. James' Magazine, the carriages are driven by means of a pipe exhausted in this very way. The space round the axle at one side opens into the pipe; the other side is closed. The wheel a very large one, worked by steam, is open at the circumference. By the revolution of this wheel an immense length of pipe is exhausted in a very short time.

Perhaps a Persian wheel worked by a couple of bullocks would be found to work a thermantidote wheel with sufficient rapidity to exhaust the air from a large barrack; this, however, can only be decided by experiment.

In speaking of a thermantidote wheel, of course an ordinary thermantidote wheel is not intended, but one of proportions scientifically arranged to produce the required effect in the most complete way.

If metal pipes at the roof be objectionable, bundles of hollow bamboo or a light tin pipe suspended from the roof and communicating with the pipe *bd* at B would answer equally well. The Messrs. Chambers (as described in Chambers's Journal) have used tin pipes suspend-

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ed from the roof for warming their very extensive printing rooms *with steam*, with great success. Here tin pipes have no steam pressure to bear, and a hole in the soldering here and there would be no great disadvantage.

In buildings to be constructed hereafter, instead of metal or bamboo tubes, let a pipe of masonry run along the top of the walls with openings into the rooms; the pipe being the width of the wall and strengthened by arches where it would have to bear the weight of the beams, the section across the pipe having an area of 6 × 6 inches.

The expense after the first start would be that of working the thermantidote, or of keeping the furnace alight at one end, and of filling the trough K at the other.

The trial of this plan would cost little, and if successful, it would add much to the health of large bodies of men inhabiting one building, as it ensures a constant supply of fresh and cool air without the disadvantages attending our present method of cooling rooms, viz., darkness and the necessity of re-inhaling vitiated air.

The success of the experiment depends, as far as the thermandidote part is concerned, on the quantity of air which can be exhausted by a wheel worked by bullocks—for the rest, *nothing else has been recommended which has not been tried already and found to succeed.*

F. R. De Bude.

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Note by Editor.

The plan of ventilation above proposed would no doubt answer for a large room, or even for a moderately sized barrack. In a large barrack, however, and especially if the external temperature were very high, I should feel inclined to supplement the furnace arrangement by thermandidotes, blowing in fresh air as proposed in page 109, which would greatly increase the activity of the draught. It would of course be necessary to keep all the doors and windows closed, except such as were not absolutely required for ingress and egress, but this could be done without inconvenience. In the 2nd Volume of the "Aide Memoire," page 406, will be found a drawing and description of Haig's Pneumatic Engine, which is an exhaust thermantidote capable of discharging 6,000 cubic feet of air per hour, and used to ventilate mines or the holds of vessels; but a much more powerful machine would be required for a barrack, where the quantity of foul air to be withdrawn is 2,000 feet per minute.

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# No. LXVII.

## TABLE OF RATES OF WORK PREVAILING IN THE PRINCIPAL EXECUTIVE DIVISIONS OF THE HYDERABAD CIRCLE, PUBLIC WORKS DEPARTMENT, IN OR ABOUT THE MONTH OF MAY, 1864.

| Details. | Period or quantity. | Names of Stations. Secunderabad. | Aurungabad. | Oomrawutty. | Aukolah. | Remarks. |
|---|---|---|---|---|---|---|
| **RATES OF LABOR.*** | | | | | | * The rates of labor of every description are rising at a very great rate, but more especially able-bodied coolies. Agents from several distant quarters are in the market; it is said that coolies have been offered as much as Rs. 7 per month, but as a rule they are loath to leave their homes. |
| *Stone masons.* | | | | | | |
| Skilled workman, .. .. .. | per day, | .. | 0 12 0 | 9 & 10 | | |
| Ordinary do., .. .. .. | „ | .. | .. | 5 to 8 | | |
| *Bricklayers.* | | | | | | |
| Mistrie bricklayer, .. .. .. | per month, | .. | 15 0 0 | .. | .. | |
| Skilled workman, .. .. .. | „ day, | 0 6 0 | 0 8 0 | 8 & 9 | 11 & 12 | |
| Ordinary do., .. .. .. | „ | 4 to 6 | 0 7 0 | 5 to 7 | 0 10 0 | |
| *Carpenters.* | | | | | | |
| Skilled workman, .. .. .. | per day, | 0 6 0 | 1 0 0 | 0 9 0 | 1 0 0 | |
| Ordinary do., .. .. .. | „ | 4 to 5 | 0 12 0 | 0 8 0 | 8 to 14 | |
| *Smiths.* | | | | | | |
| Mistrie smith, .. .. .. | per month, | .. | 15 0 0 | .. | .. | |

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| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Skilled workman, .. .. .. | per day, | 0 | 6 | 0 | | .. | | 1 | 0 | 0 | 0 | 15 | 0 |
| Ordinary do., .. .. .. | „ | 0 | 5 | 0 | | .. | | 0 | 12 | 0 | | .. | |
| *Painter*, .. .. | „ | 0 | 6 | 6 | 0 | 8 | 0 | | .. | | | .. | |
| *Bheestie*, .. .. | „ | | .. | | 0 | 5 | 6 | 0 | 10 | 0 | 0 | 8 | 0 |
| *Laborers.* | | | | | | | | | | | | | |
| Beldar, .. .. .. .. | „ | | .. | | 0 | 3 | 3 | 0 | 4 | 6 | 0 | 4 | 0 |
| Mate coolie, .. .. .. .. | „ | 0 | 2 | 9 | 0 | 2 | 0 | 0 | 4 | 0 | 0 | 3 | 0 |
| Coolie,* .. .. .. .. | „ | 1½ | to | 2½ | 0 | 1 | 6 | 0 | 1 | 9 | 1½ | & | 2 |
| RATES OF MATERIALS. | | | | | | | | | | | | | |
| Ashlar or cut stone, best quality, at the quarry, .. .. .. | per cub. ft. | | .. | | 0 | 11 | 0 | 0 | 4 | 9 | | .. | |
| Stone, best quality, hammer dressed, at the quarry, .. .. .. | „ | | .. | | | .. | | 0 | 6 | 6 | | .. | |
| Boulders or undressed stone, at quarry, .. .. .. .. .. | „ | | .. | | | .. | | 0 | 2 | 6 | | .. | |
| Bricks (best) $9'' \times 4\frac{1}{2}'' \times 2''$ at kiln, | per 1000 | 6 | 0 | 0 | | .. | | | .. | | 5 | 0 | 0 |
| Tiles, common, native, at kiln, .. | „ | 2 | 8 | 0 | 3 | 0 | 0 | | .. | | 3 | 8 | 0 |
| Lime, best kunkur, at kiln, .. | per 100 mds. | 39 | 0 | 0 | 50 | 0 | 0 | 49 | 0 | 0 | 45 | 0 | 0 |
| „ stone, „ .. .. | „ | 54 | 0 | 0 | | not | | used. | | | | | |
| Sand, clean sharp river, on work, carried—miles, .. .. .. | per 100 mds. | 6 | 8 | 0 | | .. | | | .. | | 6 | 4 | 0 |
| *Timber.*† | | | | | | | | | | | | | |
| Teak, rough, in the log, on work, carried—miles, .. .. .. | per cub. ft. | 3 | 0 | 0 | 2 | 0 | 0 | 1 | 8 | 0 | 4 | 0 | 0 |
| *Cartage.*‡ | | | | | | | | | | | | | |
| 2-bullock cart, to carry 10 maunds, | per day. | 0 | 12 | 0 | 0 | 12 | 0 | 1 | 0 | 0 | 0 | 12 | 0 |

* The coolies in this part of the country are chiefly women and children.

† The timber chiefly used in the Secunderabad division is Burmah or Rangoon teak its price is much enhanced from cost of carriage; the other timber is somewhat similar to that at Agra, called Masts, and are bought by the piece, and in consequence of waste, are scarcely deducible to cubic feet. The timber at Aukolah comes from Canara, *vid* Bombay; the high price is owing also to carriage—it was procured for a new jail.

‡ The carts and cattle are very small in this Province, and it is doubtful whether as a rule the load is not considerable less than 10 imperial maunds, but the measures and weights being local, it is difficult to get at a correct result.



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| Details. | Period or quantity. | Names of Stations. Secunderabad. | Aurungabad. | Oomrawutty. | Ankolah. | Remarks. |
|---|---|---|---|---|---|---|
| **Rates of Work.** | | | | | | * There are no metalled roads properly so called in this Province, the usual covering being sand and moorum, generally collected from the beds of rivers and nullahs, the cost is chiefly on cartage, the spreading and rolling being a comparatively small per centage. |
| *Roads.* * | | | | | | |
| *Earthwork.* † | | | | | | † Complaints are being made that even these high rates are not sufficient to induce contractors to undertake the work in portions of the road division, owing to scarcity of labor. |
| Earthwork excavated in light clay or sandy soil, carried if necessary up to 75 feet and deposited in bank, .. .. .. .. | per 1,000 c. ft. | 3 8 0 | 5 0 0 | 8 0 0 | 6 0 0 | |
| *Foundations.* | | | | | | |
| Excavation of foundations in rock, where no pumping or baling is required, .. .. .. .. | per 100 c. ft. | .. | .. | 14 0 0 | .. | |
| Ditto, ditto, in soil, clay, gravel or sand, where no pumping or baling is required, including all planks, shores, struts, &c., .. .. | „ | 0 10 0 | 1 0 0 | 0 8 0 | 1 14 0 | |
| Concrete or beton, .. .. .. | „ | 4 12 0 | 15 0 0 | 15 0 0 | 15 0 0 | |
| *Stone-work.* | | | | | | |
| *(All set in best mortar.)* | | | | | | |
| Ashlar, plain, .. .. .. | per cub. ft. | .. | 20 0 0 | .. | .. | |
| Ditto, voussoirs for arches, .. .. | „ | .. | .. | 51 4 0 | .. | |

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coursed rubble, .. .. .. | per 100 c. ft. | | | .. | | 18 | 4 | 0 | 32 | 0 | 0 | 35 | 0 | 0 |
| Rubble, .. .. .. .. | „ | | | .. | | 25 | 0 | 0 | 42 | 0 | 0 | | .. | |
| ***Brick-work.*** | | | | | | | | | | | | | | |
| Second class brick-work in walls with best bricks, (not dressed) set in best mortar, ditto, .. .. | „ | 17 | 8 | 0 | | .. | | | .. | | | 25 | 0 | 0 |
| Third-class brick-work in walls, with good bricks, set in mud, ditto, .. | „ | 6 | 0 | 0 | | .. | | | .. | | | | .. | |
| First-class brick-work in arches, with dressed faces, including centering up to 16 feet span, .. .. | „ | | | .. | | .. | | | .. | | | 30 | 0 | 0 |
| ***Plastering.*** | | | | | | | | | | | | | | |
| Best lime plastering for exterior walls ½", .. .. .. .. | per 100 sup. f. | 2 | 0 | 0 | | 3 | 0 | 0 | | .. | | | .. | |
| White washing, 2 coats, .. .. | „ | 0 | 6 | 5 | | 0 | 4 | 0 | | .. | | | .. | |
| ***Roofing.*** | | | | | | | | | | | | | | |
| ***(Exclusive of timber framing).*** | | | | | | | | | | | | | | |
| Flat pucka terrace roofing, on one course of flat bricks or tiles, .. | per 100 sup. ft. | 20 | 0 | 0 | | .. | | | .. | | | | .. | |
| Tile roofing set in mortar on one layer of flat brick, .. .. | „ | 16 | 0 | 0 | | 25 | 0 | 0 | | .. | | | .. | |
| ***Flooring.*** ‡ | | | | | | | | | | | | | | |
| Slate floor, laminated, .. .. | „ | 18 | 5 | 6 | | | .. | | | .. | | | .. | |

‡ The buildings in the Secunderabad division are all being floored with granite, on which the Executive Engineer remarks, "the only class of men who undertake this work are few in number, and although there is no want of granite rock, it is not safe to enter into any contract with them; and a great deal of management is required to get any work at all out of such an intractable set of people as they are known to be."

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| Details. | Period or quantity. | Names of Stations. Secunderabad. | Aurungabad. | Oomrawuty. | Aukolah. | Remarks. |
|---|---|---|---|---|---|---|
| *Timber-work.* | | | | | | |
| Teak timber, wrought and put up in roofs, bridges or centerings, including nails and screws, but exclusive of bolts and straps, .. | per cub. ft. | 3 5 0 | .. | .. | .. | |
| Pannelled doors of Saul, Deodar, Teak or Sissoo, .. .. .. | per sup. ft. | 0 14 0 | 0 15 0 | .. | .. | |
| *Painting.* | | | | | | |
| Painting wood, with 3 coats, Green, Red or White, .. .. .. | per 100 sup. ft. | 10 0 0 | 8 0 0 | .. | .. | |

Memo.—The only station in this Province at which masonry works are being carried on is Secunderabad, the other stations given are sub-divisions of roads; the rates therefore except for the station of Secunderabad are not trustworthy as guides, the roads in the province are so extensive and pass through districts so varying in population and from other causes, the Executive Engineers have not yet been able to prepare trustworthy estimates. In many places laborers are very difficult to procure, but carts almost entirely so. In some instances, common hammer-dressed masonry for culverts has cost the enormous sum of Rs. 100 per 100 cubic feet, owing to the distance material had to be carried.

Bolarum,
23rd *August*, 1864.

Chas. Nuttall,
*Deputy Controller and Examiner,*
*P. Works Accounts, Hyderabad.*

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## No. LXVIII.

# RAILWAY SUSPENSION BRIDGES.

*On the effect of an Unattached Suspended Iron Girder in checking the undulation of the road, as a heavy Train passes over a Railway Suspension Bridge.* By Archdeacon Pratt.

*To the Editor of Professional Papers on Indian Engineering.*

Sir,—Three years ago Mr. Turnbull, the Chief Engineer of the East India Railway Company, requested me to give an opinion, on theoretical grounds, regarding the effect of a Suspended Iron Girder in checking the undulation as a heavy train passes over a Railway Suspension Bridge. He gave me the data of the bridge he had projected for the Hooghly. A calculation was made and published in London, in the "Philosophical Magazine," for June 1862, and a report of the results was given to Mr. Turnbull.

As the subject of a Railway Suspension Bridge across the Hooghly is being revived, it occurs to me that it may not be unacceptable to you if I enter a little more into detail, than I did in the "Philosophical Magazine," in explanation of the process I followed in making the calculation there published. It affords a good illustration of the kind of help that theory can lend to practice.

2. The data of the bridge which Mr. Turnbull proposes to construct are as follows:—

The bridge consists of five spans and two half spans. Each span is 400 feet; the versed sine of the chains at the middle point is 38 feet 4 inches; the weight of the chains, including suspending rods, 200

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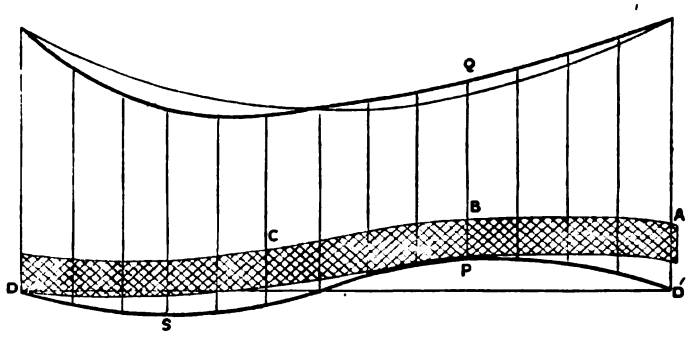
tons; the weight of the girder and roadway 350 tons: the maximum moving load, when occupying the whole span, 400 tons; the depression of the girder at its middle point, when supported at its two ends, from its own weight alone, 0·7 foot, from the weight of the train 0·9 foot in addition, making 1·6 foot in all.

3. Suppose that on the train coming upon the bridge the roadway is thrown into undulation. The iron-girder will partake of the effect. The undulation, however, can never become so great as is represented in the following diagram, in which the girder is actually separated for




a time from the roadway, except at two points of support D and P. For the enormous weight which would in that case be brought upon the point P would prevent such a rise. More than half the weight of the girder would be thrown upon the suspending rod QP; and the weight of the train could never communicate through the chains an upward tension in the direction PQ capable of sustaining this load. It is clear from this, that the weight of the girder will keep down the undulation, and that in this arrangement of a Suspended Girder, the undulation of the roadway can never exceed the curvature of which the girder alone is susceptible when left free to itself. The girder and roadway (or rather, the loops of the suspending rods in which the girder lies, and which are always in the same level as the roadway) will always remain in contact. It is in this that the great advantage is seen of having the girder *freely* suspended, that is, lying in the loops of the suspending rods *unattached* to them. If the girder were attached all along to the loops and so to the roadway, the effect would be, that when the road is thrown into undulation, a force would be

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produced all along the girder, through the points of attachment, which would assist in bending the girder more than the natural flexure into which its own weight alone would bring it. Thus, to refer to the diagram; as the natural flexure of the girder when left to itself is only DP, and of the roadway caused by the train (if there were no girder to keep the undulation down) is DSP, then the curvature of both of them, if they were attached to each other, would lie somewhere between these curves, and would therefore be greater than that of the free girder. But the undulation of the roadway can never, for the reason I have assigned, be greater than that of the girder. Hence the undulation of the roadway is least when the girder is suspended free and unattached. In order, then, to find the degree of undulation of which the roadway is susceptible in this arrangement, we must find the degree of flexure which the girder can undergo.

4. I will take the extreme case of the girder and roadway being thrown into their greatest possible degree of flexure, that is, the girder on the verge of separating from the roadway except at the two points D and P. Take B, immediately over P, make BC = BA. Then the flexure of the girder cannot be greater than that of a free girder of length AC, suspended at its middle point P. It may be less than this, because the undulation may be so far checked as not to give the girder the whole flexure of which it is naturally susceptible. But it cannot be more. Now the flexure of a lattice girder suspended at its two ends, or at its middle point, varies as the square of its length, all other things being the same. If the girder were a solid beam its flexure would vary as the cube of its length: but being a lattice, in which the upper and lower bars sustain the weight by compression and extension, the flexure varies only as the square. Hence the greatest possible flexure of AC is to that of the whole AD (= 0·7 foot) as $AC^2 : AD^2$. And the flexure of CD is to that of the whole as $CD^2 : AC^2$. If then, we can find the position of the point P, where the upward pressure produced by the undulation is the greatest, for every position of the train upon the bridge, we can at once find the greatest flexure of which the girder is susceptible, and therefore the greatest undulation to which the roadway is liable. It is to the solution of this problem that the calculation in the "Philosophical Magazine" is devoted. The line of reasoning I will now explain.

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5. I suppose the train to be at rest on the bridge. We have first to find the form into which each chain is forced by the weight of the train. The roadway, train, and chains, are in this calculation considered to be perfectly flexible and devoid of all stiffness. This is taking the most unfavorable case which could possibly occur, as the natural stiffness must produce resistence and friction enough to check a part of the undulation which would arise in a perfectly flexible body. I shall suppose the weight of the roadway and suspending rods to be thrown into the chains so as virtually to increase their uniform thickness; and the same with the train, the weight of which I suppose to be added to the part of the chains immediately over the train, virtually increasing its uniform thickness. Suppose that the virtual thickness of the chains loaded by the train, is $\beta$ times the virtual thickness of the chains without the train but with only the roadway and rods. Then in the Hooghly bridge $\beta = 200 + 350 + 400$ tons $\div 200 + 350$ tons $= \frac{19}{11}$. When the whole bridge is covered by the train the curve of the chains will be the common catenary. When the train is only partly on the bridge each chain will virtually consist of two parts, one $\beta$ times as thick as the other. The first part of the problem solved in the "Philosophical Magazine," is to find the form in which this compound chain will hang. Each of the two parts of the chain will be uniform and hang in a common catenary; but the two catenaries to which the two parts belong will be different to each other. They will have a common tangent at the point where they meet. The following

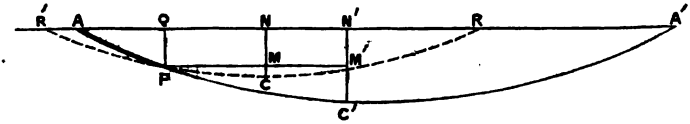


diagram represents the curves. APA′ is the whole chain; AP is the thick part and belongs to the catenary APR: the other part PA′ hangs in the catenary A′PR′; the two catenaries have a common tangent at P; C and C′ are the lowest points of the catenaries.

6. The calculation brings out the following results:—Let C be the length of chain, the weight of which measures the tension at the lowest point of the common catenary in which the chain hangs when the whole bridge is covered by the train or has none on it; $c$ and $c'$ the

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lengths of chain which measure the tensions at the lowest points of the catenaries AP, and PA′.

Let CN $= k$, C′N′ $= k'$, AA′ $= 2b$, NA $= h$, N′A $= h'$, APA′ $= 2m$, AP $= t$, the distance the train is on the bridge.

Then

$$\frac{c^2}{C^2} = \tfrac{1}{2}\left(1 - \frac{\beta-1}{\beta}(1-\tfrac{t}{2m})^2\right)^2$$

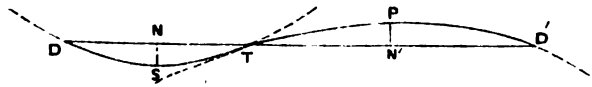
$$+ \frac{\beta-1}{2}\left(1 - \frac{t}{m} - \frac{\beta-1}{\beta}(1-\tfrac{t}{2m})^2\right)^2 + \frac{\beta}{2}\left(1 - \frac{\beta-1}{\beta}(1-\tfrac{t^2}{4m^2})\right)^2$$

$$c' = \beta c, \text{ and}$$

$$h = \frac{m^2}{2c}\left(1 - \frac{\beta-1}{\beta}(1-\tfrac{t}{2m})^2\right)^2, k = b\left(1 - \frac{\beta-1}{\beta}(1-\tfrac{t}{2m})^2\right)$$

$$h' = \frac{\beta m^2}{2c}\left(1 - \frac{\beta-1}{\beta}(1-\tfrac{t^2}{4m^2})\right)^2, k' = \beta b\left(1 - \frac{\beta-1}{\beta}(1-\tfrac{t^2}{4m^2})\right)$$

7. Having thus found the form into which the chain is distorted for any position of the train on the bridge, the curve into which the roadway is thrown by this distortion has next be calculated. This is done in the "Philosophical Magazine," by comparing the compound catenary into which the chain is now drawn, with the catenary in which it hangs when the train covers the whole road. The vertical spaces between these two curves, at successive points across the bridge, by which the first curve is below or above the second, exactly equal the spaces through which the roadway is depressed or lifted up. The result of the calculation is, that the roadway is drawn into an undulation consisting of a parabolic depression and a parabolic elevation, the two portions of parabolas uniting at a common point of the roadway which is not raised or depressed; and at that point the parabolas touch each other, as in the following diagram—




The calculation makes—

Greatest depression, or NS $= \dfrac{\left(\frac{k}{b}\frac{C}{c}-1\right)^2}{\frac{C}{c}-1}$ H.

Horizontal distance of ditto, or DN $= \dfrac{\frac{k}{b}\frac{C}{c}-1}{\frac{C}{c}-1}$ $b$.



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$$\text{Greatest elevation, or PN}' = \frac{\left(1-\frac{k}{b}\frac{C}{c'}\right)^2}{1-\frac{C}{c'}}\,H.$$

$$\text{Horizontal distance of ditto, or D'N}' = \frac{1-\frac{k}{b}\frac{C}{c'}}{1-\frac{C}{c'}}\,b.$$

H is the value of $k$ when the whole chain hangs in one catenary, or when $\beta = 1$. If these formulæ be reduced to numbers they lead to the following Table :—

| | Distance the train has passed along on the roadway, or $t$. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 40 feet. | 80 feet. | 120 feet. | 160 feet. | 200 feet. | 240 feet. | 280 feet. | 320 feet. | 360 feet. | 400 feet. |
| Greatest depression of roadway under the train, *in feet*, | 0·64 | 1·57 | 2·15 | 2·24 | 1·99 | 1·54 | 1·01 | 0·53 | 0·16 | 0 |
| Horizontal distance of this *depression*, ... ... ... | 33 | 56 | 73 | 86 | 97 | 105 | 113 | 120 | 127 | |
| Greatest elevation of roadway beyond the train, ... | 0·28 | 0·97 | 1·73 | 2·24 | 2·42 | 2·25 | 1·78 | 1·11 | 0·39 | 0 |
| Horizontal distance of this elevation from the left pier, | 271 | 275 | 279 | 287 | 297 | 309 | 324 | 342 | 367 | |

8. This Table shows us whereabouts the point P of greatest upward pressure on the girder will be, for different positions of the train on the bridge. We can, therefore, now bring the principle of para. 4 to bear, in order to find the greatest possible amount of flexure that the girder can undergo, and therefore the greatest possible undulation which the roadway can receive. The application of that principle leads to the two following Tables :—

| | Distance the train has passed along the roadway. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 40 feet. | 80 feet. | 120 feet. | 160 feet. | 200 feet. | 240 feet. | 280 feet. | 320 feet. | 360 feet. | 400 feet. |
| Distance of the greatest elevation of the roadway from the right-hand pier, *in feet*, | 129 | 125 | 121 | 112 | 103 | 91 | 74 | 58 | 33 | 0 |
| Ratio of this to half-length of the roadway, ... ... | 0·64 | 0·62 | 0·60 | 0·56 | 0·51 | 0·45 | 0·37 | 0·29 | 0·16 | 0 |
| Deflection of the girder AC, | 0·28 | 0·27 | 0·25 | 0·22 | 0·18 | 0·14 | 0·10 | 0·06 | 0·02 | 0 |

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As the train, therefore, occupies these successive positions, the deflection of the girder at P, upheaved and subjected to its own weight, would be continually diminishing,—beginning at the first position with only 0·28 foot or 3·4 inches, lessening to 0·18 foot or 2·2 inches when the train is half-way across, and becoming 0 when the whole train is on the roadway.

The greatest depression of the roadway and girder will be that corresponding to the deflection of a girder of the length DC. The following Table is constructed as the last was:—

| | Distance the train has passed along the roadway. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 40 feet. | 80 feet. | 120 feet. | 160 feet. | 200 feet. | 240 feet. | 280 feet. | 320 feet. | 360 feet. | 400 feet. |
| Distance of greatest depression from the left-hand pier, *in feet*, ... ... ... | 33 | 56 | 73 | 86 | 97 | 105 | 113 | 120 | 127 | |
| Ratio of this to half-length to the roadway, ... ... | 0·16 | 0·28 | 0·36 | 0·43 | 0·48 | 0·52 | 0·56 | 0·60 | 0·63 | |
| Deflection of the girder DC, | 0·02 | 0·05 | 0·09 | 0·13 | 0·16 | 0·19 | 0·22 | 0·25 | 0·28 | 0·70 |

9. A few words will be of use to explain these Tables. The chains and rods are supposed to be so adjusted that when no train is on the bridge, or when the whole bridge is covered by the train, the girder lying in the loops of the rods is perfectly horizontal, being sustained all along its length by the loops and having no deflection. When a small portion of the train is on the bridge on the left side, a slight depression underneath the middle of that portion will occur, and P the point of greatest elevation of the roadway will at the same time be slightly to the right of the middle of the bridge. The tendency of this will be to upheave the girder near its middle point and to draw upon, so to speak, its liability to deflection. This amount under no circumstances can exceed 0·7 foot; but in the actual case, as a small portion only of the train will be on the bridge, the force it produces will be small for overcoming friction and stiffness, and the deflection will no doubt be much less than this possible maximum.

The first of these two Tables shows that when the train is 40 feet on the bridge, the greatest deflection of the girder would be only 0·28 foot

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or 3·4 inches, on the double hypothesis of perfect flexibility and the girder being just on the verge of separating from the loops. Hence, in the actual case, the deflection will be much less than this. The second Table shows, that when the train has reached the right hand pier within 40 feet, the greatest possible deflection of the depressed portion of the girder is also 0·28 foot or 3·4 inches, which, for the reasons before stated, will be actually much reduced by the resistance of friction and stiffness. As the head of the train has different positions nearer and nearer to the right hand pier, the greatest possible deflection would vary rapidly from 0·28 foot to 0·7 foot, if the depressed portion of the girder were left perfectly free to itself to undergo its natural bending. But this will not be the case. The girder will not be separated from the loops, but will always lie in contact with them, and be partially supported so as not to be left to itself resting at only two points; so much so that when the head of the train is at the right hand pier the whole girder will be perfectly horizontal again, owing to the arrangement of the chains and rods, which I have already mentioned.

10. The result then, is this. The theory shows that the girder and roadway will be most deflected when either a small portion or nearly the whole of the bridge is covered by the train, and then it never could exceed 0·7 foot. But in these two cases the force of derangement brought to play by the weight of the train will be comparatively so small, that practically it will be very much counteracted by the resistance from friction and stiffness in the roadway and joints of the rods and chains, all of which are in the theory supposed to be perfectly flexible, and the actual deflection will be much less than 0·7 foot. Again: the force to overcome friction and stiffness is greatest when the train is half way over the bridge. But the theory shows, that then the deflection of the girder will be least, and will not, even if friction and stiffness be absent, be more than 0·16 or 0·18 foot, that is, about 2 inches, and therefore less than that in the actual case. This result is very satisfactory, and shows the advantage of the arrangement of a suspended and unattached girder.

11. The previous calculations have been made on the hypothesis of the train being at rest in different positions on the bridge.

There are two cases which I will now consider when the train is in

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motion: (1) when the curvature of the roadway is continuous, without any sudden change; (2) when there is a slight break in the curvature.

(1). When the train is moving with a velocity $v$, the curved roadway is subject to additional pressure from centrifugal force: the pressure is increased by this effect beyond the simple weight of the train in the ratio of

$$g + \frac{v^2}{\text{radius of curvature}} : g \text{ (or gravity)}.$$

If $h$ be the depression of the roadway when the train is in motion, $k$ the depression when it is at rest, and $2n$ the length of DC the part depressed, then, taking the curve to be part of a circle,

$$\text{radius of curvature} = \frac{2n^2}{h}; \text{ and } \frac{h}{k} = 1 + \frac{v^2}{2n^2 g} h;$$

$$\therefore h = \frac{k}{1 - \frac{v^2 k}{2gn^2}}.$$

The value of $k$ varies as $n^2$, as already stated, and equals 0·7 foot when $n = 200$ feet: also $g = 32$ feet, and $v = 88$ feet for a velocity of 60 miles an hour; hence the denominator of $h$.

$$= 1 - 0{\cdot}0021 \left(\frac{v}{88}\right)^2,$$

and the increase of $h$ above $k$ is therefore evanescent even for a velocity of 60 miles an hour.

If any part of the rail, from accident or bad structure, is more curved than I have supposed it to be, the radius of curvature of that part will be smaller, and the effect of centrifugal force proportionately greater.

(2). Next suppose that there is at some point of the rail a sudden change in the curvature, and that the tangents to the two parts of the curves at that point make a small angle $\theta$ with each other. The effect of this will be, that every time the wheels of the train come to that point an impulse or blow will be given to the roadway. The tendency of this blow will be suddenly to separate the roadway curve (which is the same as the curve in which the lowest points of the suspending rods lie) from the suspended girder, since the girder is not attached to the suspending rods. Thus the blow will bring into sudden action the downward pressure of the girder, which will consequently stifle the

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effect of the blow, and not suffer the roadway to be thrown into a greater undulation than the girder itself can assume under its own weight, as already described. No doubt a molecular tremor will run along the roadway, girder, and chain occasioned by the blow, but nothing more.

12. But as it is possible that by friction or accident the girder might get attached, at any rate in some places, to the loops and roadway, I will consider what the effect would be if the girder, instead of lying unattached in the loops of the suspending rods, were attached to the roadway.

I must premise that if M be the mass of the girder, and a vertical blow be given to it at any point between its two ends on which it is supported, so as to cause that point to descend with a velocity $u$, then $\frac{2}{3}$ M$u$ is the whole momentum communicated to the beam. For let $b'$ and $b''$ be the distances of the point of impulse from the left-hand and right-hand piers, $b' + b'' = 2b$; than the velocity communicated to a point at a horizontal distance $y$ to the left or right of the point of impulse will be

$$u\left(1 - \frac{y^2}{b'^2}\right) \text{ or } u\left(1 - \frac{y^2}{b''^2}\right),$$

and therefore the momentum of an elementary section of the girder of width $dy$, being integrated, will give the momentum of the whole girder

$$= \frac{Mu}{2b}\left\{\int\left(1 - \frac{y^2}{b'^2}\right)dy + \int\left(1 - \frac{y^2}{b''^2}\right)dy\right\}$$

$$= \frac{2}{3}Mu, \text{ the limits being } 0, b', \text{ and } 0, b''.$$

If the train reaches the point of interruption with a velocity $v$, it moves on beyond that point with the diminished velocity $v \cos \theta$, and it impinges on the roadway with a velocity $v \sin \theta$. The momentum thus communicated to the girder will be T$v \sin \theta$, T being the mass of the train;

$$\therefore \frac{2}{3}Mu = Tv \sin \theta, \therefore u = \frac{12}{7}v \sin \theta.$$

since M : T = 350 : 400 tons.

I will now find the depression which a blow communicating a velocity $u$ at the point of interruption will cause: I will take the worst position for the interruption, viz., the middle point. The girder unsupported by a chain will bend, as experiment shows, through 1·6 feet

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under its own weight, together with the weight of the maximum load, 400 tons. Let $z$ be the additional depression which would be caused by a pressure P; then

$$P = 750 \frac{z}{1{\cdot}6} = 470z \text{ tons, nearly,}$$

and the mass of the girder set in motion is equivalent to

$$\tfrac{3}{8} \times 350 \text{ tons} \div g,$$

$$\therefore \frac{d^2z}{dt^2} = -\frac{3g \times 470z}{2 \times 350} = -64z;$$

$$\therefore \left(\frac{dz}{dt}\right)^2 = u^2 - 64z^2.$$

Hence if $h$ be the extent of the vibration caused by the blow, $h = \frac{1}{8}u = \frac{3}{14} v \sin\theta$ feet. If $v$ be 88 feet, or the velocity 60 miles an hour, $h = 4$ inches, if $\theta = 1°$, or for a sudden change of 1 in 57 in the gradient of the rail. The depression will be greater or less in proportion to the change in the gradient.

The time in which the girder, on receiving the blow, passes through its depression is $\frac{\pi''}{16} = \frac{1''}{5}$. Each carriage is 25 feet long, and has two pairs of wheels. Hence the interval between successive blows $= \frac{12{\cdot}5}{88} = \frac{1''}{7}$; and therefore a second blow will occur before the girder has begun to recover itself, and will therefore still further increase the deflection; a third blow and others also will follow before the girder has begun to recover its former position, and these effects being accumulated may become dangerous. The blows will grow feebler and feebler after the first, because each is produced by the impact of only that portion of the train which has not at the moment passed the point of interruption.

If the velocity of the train be 20 miles (the sudden change in the gradient still being 1°), the intervals of the blows will be about $\frac{2''}{5}$ instead of $\frac{1''}{7}$. The result will be, that the second blow will occur just as the girder has sprung back to its original position with a momentum equal to that which the first blow gave to it, but in the upward direction; the second blow will therefore be counteracted by this. The third blow will then have its full effect; but being feebler

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than the first, will not produce so great a depression as before; and the successive results will be smaller and smaller.

The calculation in this paragraph is sufficient to show the great importance of the rail over the bridge being entirely free from every impediment or check of every kind, and the advantage of having the girder unattached to the roadway.

J. H. PRATT.

*Calcutta, April* 1865.

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# No. LXIX.

## CANAL FALLS.

*A Suggestion.* By Lieut.-Col. Fife, R.E.

In one of the early Numbers of the Professional Papers, some exceedingly interesting matter appeared on the subject of Canal Falls, and the various expedients which have been employed to prevent the injurious action of the water, but there is still another expedient which might be tried. This is to construct the work like a weir with under-sluices, large enough to pass off the Canal's full supply, without the necessity of allowing a large body of water to pass over the crest of the weir, and tumble upon the masonry with an irregular and destructive action.

In a perpendicular fall, the injurious action of the water is evidently entirely caused from the water striking the masonry, and even where the fall is a sloping or curved one, the action of the water is more severe than it should be. But if the action could be reduced to gliding only, its injuriousness would be reduced to a minimum, and the masonry which is now destroyed, would stand, just for the same reason that the earthen bank of a Canal will stand uninjured where there is a velocity of current of say $2\frac{1}{2}$ feet per second, while precisely the same material is torn away by an eddy with only one-half that velocity.

The weir might have a section like that shown in the sketch below; and to prevent the pond above the weir sinking to too low a level when the Canal is running half supply, some of the sluice openings might be fitted with gates.

By giving the openings a splay, both at top and sides, the eddying of the water below the weir could be reduced till it was not injurious. The masonry used for the face work in the sluices and for the apron immediately below them, should of course be of the very best description. Where



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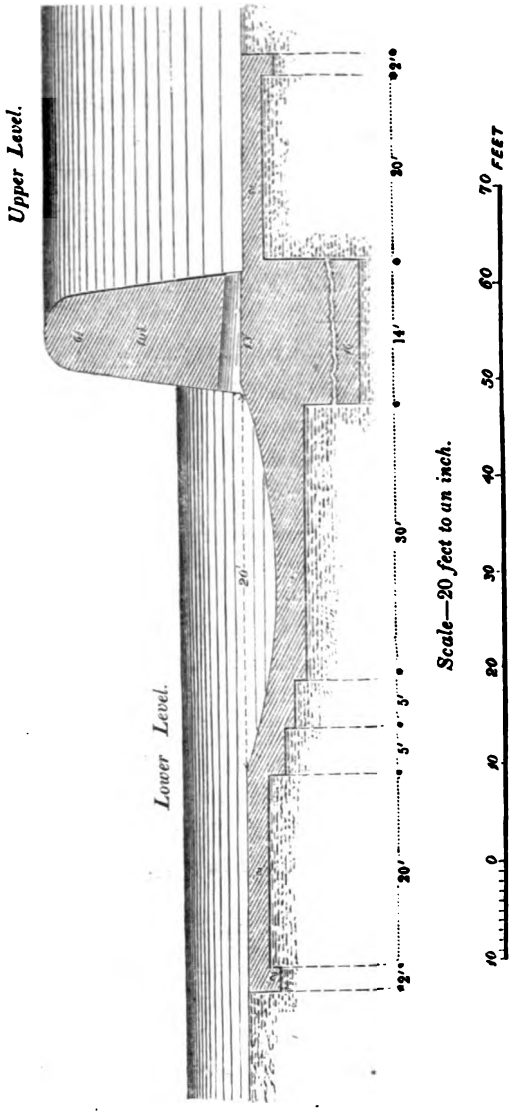
stone is procurable of course that material would be used. Where circumstances necessitate the employment of ordinary brick and lime, the sluice openings would have to be lined with either planking or sheet iron. A portion of the apron immediataly in front of the sluice would require similar protection.




This expedient will not appear new to most Engineers, but as it was not mentioned in the interesting papers referred to, it may be worth while to mention it. It evidently has the merit of concentrating action of the least injurious kind, viz., the gliding action on a small portion of masonry in the most massive part of the work.

The sketch given is intended only to illustrate the arrangements suggested. The necessary dimensions for the apron and its precise construction must depend on many local circumstances, and Canal Officers accustomed to see the effects of shoots of water at existing falls will no doubt see better than myself what length of apron would be necessary. The total length of about 47 feet suggested itself after the writer had observed the effect

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of water shooting from under sluices in a large weir. Where sand forms the bearing stratum, pitching would be necessary at the tail of the apron.

With respect to brick-work for the important parts of Canal falls it may prove economical, from securing greater permanency, to use compressed bricks of a very large size. As an experiment, the writer of this memo. made a brick 1½ feet long 9 inches broad and 6 inches thick, and when the clay was still in a tough state it was put into a strong mould and subjected to very considerable pressure from above by means of a lever. The brick so made came out of the kiln without any flaw, and from its weight and hardness was more like a stone than a brick. The mould, &c., was a very primitive one, and would not have stood much work; but iron moulds with a screw press above might be easily made, and would last for a very long time. Clay cannot be compressed with much advantage when it is in a soft state, as it expands again when the pressure is withdrawn. To make a very solid brick, therefore, the shaping mould and pressing mould must be distinct. The pressing mould should of course be a little smaller than the shaping one, and after the brick has dried a little and shrunk, it should be put into the pressing mould.

J. G. FIFF.

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NOTE BY EDITOR.

One of the Falls on the Baree Doab Canal has been built on the same *principle* as that above proposed, through differing in detail. It was I believe designed by Captain Crofton, and has been found to answer fairly. The objection to it, I understand, was the severe action of the water on the under sluices (which might, however, be prevented by the proposed method of lining them with sheet iron) and the difficulty of getting at the sluices, if anything goes wrong, without stopping the canal supply. In the open falls, one bay at a time can be laid dry and repairs executed, without stopping the supply over the rest of the fall.

The principle of the Rajbuha Falls, advocated by Captain Thomason, in his report on the Terrai (Professional Papers, vol. i. page 428), is also somewhat similar to the proposed method.

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## No. LXX.

## ON THE EXPANSION OF MASONRY BY HEAT.

*Adapted from an article in Les Annales des Ponts et Chaussèès, for March and April,* 1863, *entitled "Experiences sur la Dilation des Maconneries.* PAR M. BOUNCEAU, *Ingenieur en Chef des Ponts et Chaussèès."*

A FEW unimportant fissures which appeared during the winter of 1859-60, in certain parts of the works at Havre, when they were nearly completed, caused great uneasiness to the French Engineers.

At first they were attributed to unequal settlement of the foundation.

But on close observation it was found:—

1*st.* That the largest cracks occurred in a wall uncovered on both sides, and in which unequal settlement could not possibly have taken place.

2*nd.* That the temperature of the water in winter averged about 54° Fah.

3*rd.* In the summer of 1859, the fissures almost entirely disappeared; the temperature then varied between 77° and 88° Fah.

It was then conjectured that the fissures were occasioned by contraction caused by decrease of temperature. In order to test this hypothesis the simplest mode of proceeding was evidently:—

1*st.* To compare the width of the cracks with the lengths of the masses of masonry in which they occurred: masses which from their relative weights would crack rather than contract.

2*nd.* To apply the coefficient of expansion for masonry to them.

But as no such coefficients could be found in scientific works, the following experiments were made to supply the omission.

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