



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

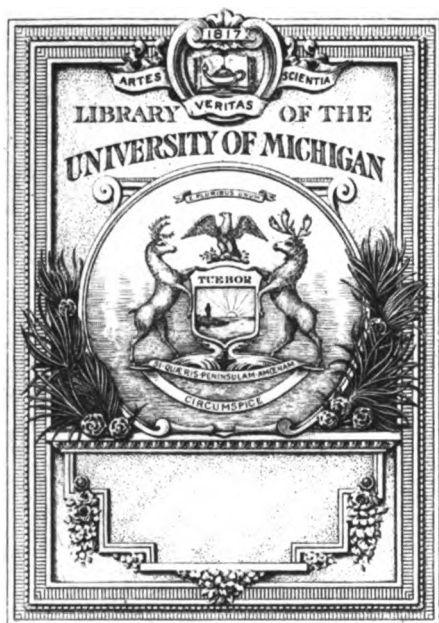
We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

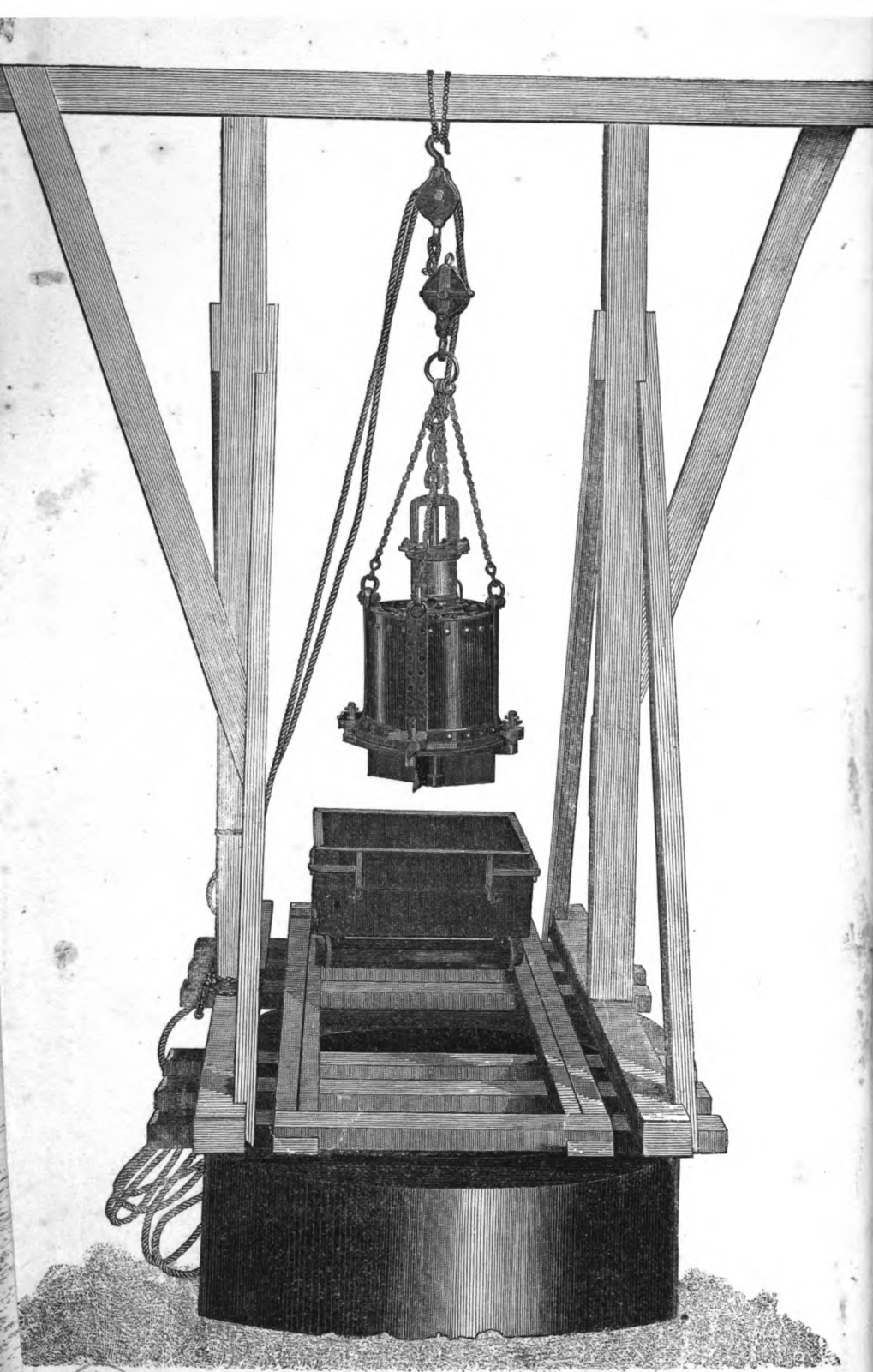
About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>

B 425882



TA
1
.P963



SAND PUMP.

Engraved from a Photograph of a Working Model.

PROFESSIONAL PAPERS
ON
INDIAN ENGINEERING.

VOL. IV.—1867.

EDITED BY
MAJOR J. G. MEDLEY, R.E., Assoc. INST. C.E.,
PRINCIPAL, THOMASON C. E. COLLEGE, ROORKEE.

ROORKEE:

PRINTED AND PUBLISHED AT THE THOMASON COLLEGE PRESS.

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

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

MDCCLXVII.

JAMES JOHNETON, SUPERINTENDENT.

14

Revisions
Done
12.12.40
L.779

PREFACE to VOL. IV.

THE Fourth Volume of these Papers is now concluded,—and will be acknowledged, I think, to be fully equal in interest to any of its predecessors.

A short analysis of the Papers that have already appeared may be interesting, if only as showing the varied nature of the work occupying the attention of the Indian Engineer.

Of the 170 Papers already published, 18 refer to Railways—15 to Roads—22 to Bridges—21 to Buildings—19 to Irrigation—4 to River Improvements—3 to Water-supply—4 to Drainage—2 to Light-houses—9 to Military Engineering—14 to Surveying—and 40 to Miscellaneous Subjects, which cannot well be classified, including 12 on the Mathematics of Engineering.

Of the above number, 72 are original contributions, written expressly for these Papers, (exclusive of the few contributed by the Editor). 12 are re-prints or translations from other works—and the remainder have been abridged or adapted from various Official reports.

No. 18, being the first quarterly No. of Vol. V, will be issued on the 1st February next, and the Subscription will be as before, Rs. 14, to those who pay in advance before that date,—*afterwards* Rs. 4 per number, or Rs. 16 for the Volume.

J. G. M.

INDEX TO VOL. IV.

	PAGE
Artillery Mess-house, Meerut,	1
Berar, Public Works in. By Henry Hooper Foord, A. Inst. C.E.,	38
Boat Bridges, Superstructure of. By Col. A. Taylor, R.E., C.B.,	407
Brick-making near Roorkee. By Captain F. D. M. Brown, V.C.,	158
Canal Modale, Carroll's Patent,	185
Canal Water, Distribution of,	899
Canal Distributaries. By Captain W. Jeffreys, R.E.,	830
Clinometer, De Lisle's,	225
Damooda River, Reservoirs for the. By Lieutenant H. W. Garnault, R.E.,	337
East Indian Railway, Floods on the,	65
Echamuttee Bridge, Eastern Bengal Railway,	209
Grand River Viaduct, Mauritius. By William Ridley,	80
Girder Launching on the Jabulpore Railway,	317
Great Trigonometrical Survey, Detail of Working on the, 808 and	143
Great Trigonometrical Survey, Pendulum Operations of the. By Captain T. P. Basevi, R.E., 97 and	199
Hindustan and Thibet Road, The. By A. Cregeen, Esq., C.E.,	373
Indian Railways, Iron Sleepers on,	45
Lime, Artificial Hydraulic. By W. H. Price, Esq., M. Inst. C.E.,	189
Madras, Drainage of. By Captain Hector Tulloch, R.E., 2 and	110
Madras Railway, The. T. H. Going, Esq., and Bryce McMaster, Esq., C.E.,	239
Milroy's Excavating Apparatus,	362

	PAGE
Mile Posts, Iron. By Leonard Roberts, Esq., A.I.C.E., ...	198
Mysore, Irrigation in. By Major Sankey, R.E., ... 143 and	212
Navigation of Indian Rivers, Improvement in. By W. H. Longmore, Esq.,	28
Reservoir Dams, Note on. By Lieut.-Col. Fife, R.E.,...	411
Road Specifications, Rajpootana. By Major Pollard, R.E., ...	92
Sand Pumps for Well Foundations. By Charles Geneste, Esq., C.E.,	251
Saint Andrew's Kirk, Bangalore,	109
Sindh, Irrigation of. By Captain Strachey, R.E.,	278
Slate Quarries, Rewarree. By Crawford Campbell, Esq.; C.E.,	257
Slide Rule, Notes on the. By Captain W. H. Mackesy,...	349
Specifications, Berar. By Captain H. H. Foord, A.I.C.E., ...	296
Steam Power in India, Economy of. By Captain C. S. Thomason, R.E.,	182
Telegraph to India, The. By Sir Charles T. Bright, M.P., M. Inst. C.E.,	166
Tree Spurs on the Ravee. By Kunhya Lall,	233
Water-works, Poona. By Lieut.-Colonel Fife, R.E.,	261
Wedge Bricks for Arches. By Major J. G. R. Forlong, C.E., F.R.S.E.,	140
Work Rates, Ganges Canal. By T. Login, Esq., C.E.,	365

LIST OF PLATES.

PHOTOGRAPHS.

St. Andrew's Kirk, Bangalore (Frontispiece).	
Launching Girders on Jubbulpore Railway,	317

ENGRAVINGS.

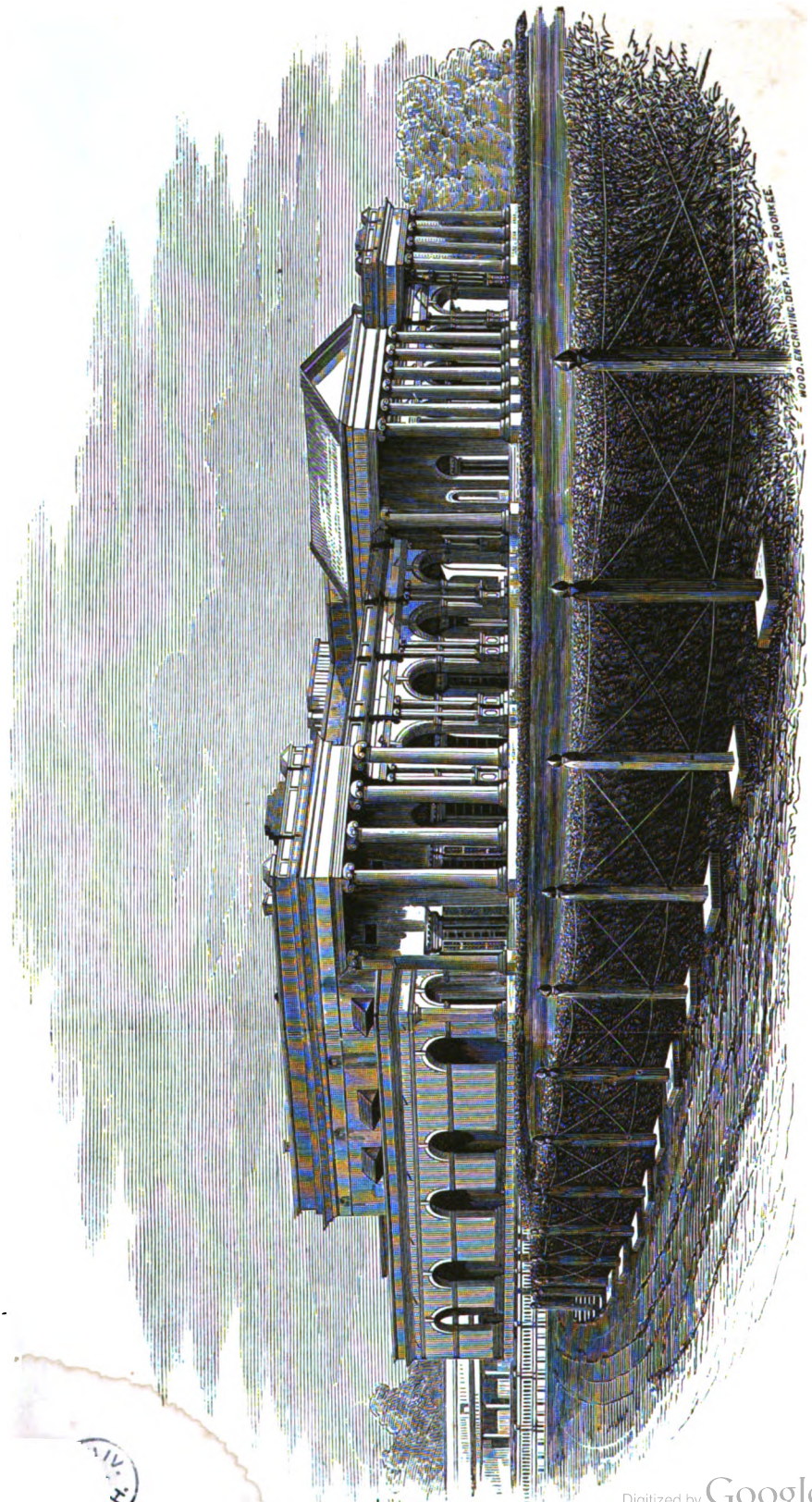
Artillery Mess-house, Meerut,	1
--------------------------------------	---

	PAGE
Echamuttee Bridge,	209
The Sand Pump,	251

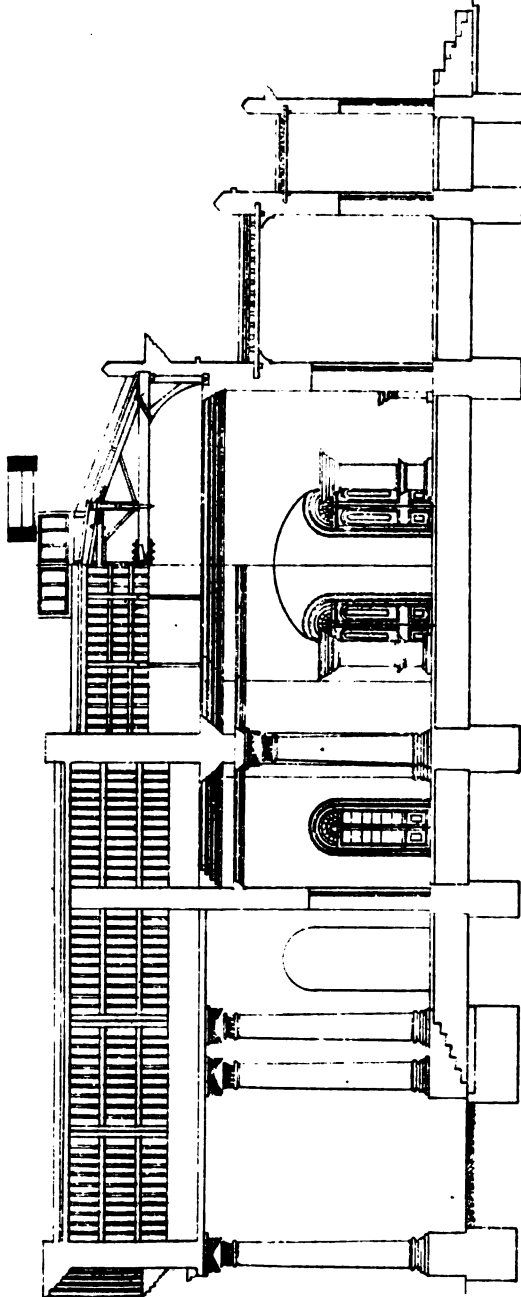
LITHOGRAPHS.

Artificial Hydraulic Lime. Kiln for Burning,	192
Artillery Mess-house, Meerut—Plan of,	1
Brick-making near Roorkee. View of field, with men at work (158)—Plans and Sections,	160
Canal Distributaries,	332 and 334
Carroll's Patent Module,... ..	186
De Lisle's Clinometer,	226
Distribution of Canal Water,	400
Drainage of Madras. Map of Madras, showing the lines of Sewers (2)—Averages of 20 years Meteorological Observations at Madras (6)—Plan of a Latrine for the use of Natives (15)— Monthly Rainfall in England and Madras (117)—Section of Main Sewer (121)—Plan of Black Town (122)—Section of Outfall Sewer (123)—Plan and Section of Manhole, Ventila- tor and Flushing Reservoir (124)—Cross Section of Sewers (125)—Perspective Section of a First Class Native House in Madras, 128)—Madras Wind Charts, 131, 132 and	133
Floods on the East Indian Railway. Map showing Drainage of Bengal Division (66)—Buckasur Bridge (68)—Drawing of Copai Bridge, showing design for Protecting it with Sheet Piling (76)—Method of Protection proposed for Bridges,	78
Grand River Viaduct, Mauritius. Mauritius Railways, 80 and	86
Iron Mile Posts. Detail,	198
Iron Sleepers on Indian Railways. Wrought-iron Roadway,	60
Irrigation in Mysore. Mysore and River System,	144
Launching Girders on Jubbulpore Railway. Drawing of Trolley (318)—Drawing of Travelling Stage (320)—Sand Box,	326
Milroy's Excavating Apparatus. Plan, Elevation and Sections,	362

	PAGE
Note on Reservoir Masonry Dams,	412
Poona Water Works. Map (262)—Plan of Cantonment (268)— Diagram for calculation of the strength of Dam,	276
Rajpootana Road Specifications—Sections,	92
Reservoirs for the Damooda River. Map of the Basin of the Damooda River (338)—Cross Sections,	340
Rewarree Slate Quarries. Lithological Sketch Map of Delhi and Goorgaon District,	258
Sand Pumps for Well Foundations. Pumps (252)—Improved Self-emptying Sand Pump (254)—Gallows and Jib Derrick,	256
St. Andrew's Kirk, Bangalore—Plan and Section,	109
Superstructure of Boat Bridges,	408
The Hindostan and Thibet Road. Map (374)—Elevation and Section of a Gallery (380)—Wangtù Bridge (382)—Plan of river at Wangtù Bridge,	396
The Madras Railway—Map,	240
The Telegraph to India. Diagram,	170
Tree spurs on the Ravee. Plan, showing state of the River in 1864—Showing state of River after the floods of 1863— Plan of Tree Spurs on the River, at Lahore (234)—Showing state of River after the floods of 1866—Showing state of River in March 1867—Nullah or Branch of River Ravee,	286
Wedge Bricks for Arches,	140



ARTILLERY MESS-HOUSE—MEERUT.



LITH.



No. CXXIX.

ARTILLERY MESS-HOUSE—MEERUT.

THIS fine building was erected from the designs of the late Captain Atkinson, R.E. (the architect also of the Umballa Church), by J. L. Parker, Esquire, C.E., and was unfinished when the Mutiny broke out in 1857. Meerut was then the head-quarters of the Bengal Artillery, but on the amalgamation of the two services, it of course lost this privilege, and the Mess-house being too large for a mere Divisional Mess, has since been sold.

The building is of stuccoed brickwork, and the dimensions of the principal rooms, will be seen on reference to the plan and section. The architectural decorations of the interior were never completed, though the walls were adorned with portraits of famous Indian military commanders, including Lord Gough, Sir Walter Gilbert, Sir George Pollock, Sir Henry Lawrence, and others.

No. CXXX.

DRAINAGE OF MADRAS.

Abridged from a Report on a Project for the Drainage of the Town of Madras. BY CAPT. HECTOR TULLOCH, R.E.

Physical Features of Madras.—The limits of the jurisdiction of the Municipal Commissioners, or *Madras Proper* as the district contained within them may be termed, extend to the south as far as the river Adyar—in a northerly direction to within a mile of the village of Trivatoor—towards the west as far as the villages of Nungumbankum, Chetput, Kilpauk and Perambore—and towards the east up to the sea. The area of this tract may be taken at 27 square miles. The strata in parts consist almost entirely of sand, but generally of alternate layers of sand and clay. There is no rock to be found except at a considerable depth below the surface, a depth which none of the sewers which it is proposed to lay down will approach. The town stands on a sandy plain—the lowest parts being from 2 to 6 feet, and the highest from 16 to 24 feet above mean sea level. The average level of the whole of Madras may be taken at from 8 to 12 feet above the datum line.* Water is found in all parts at a few feet above or below mean sea level.

If we except the western quarter of Madras, which is so thinly populated that it is not worth while considering it as a district to be drained

* The datum line for the levels used throughout the Drawings, and referred to in this Report, is what is usually understood in Madras as "mean sea level." It is taken from a bench-mark on a stone fixed in the Escarp of the North Ravelin of Fort St. George. On the stone is the following inscription:—

"Mean Level of the Sea from May to October, 6 feet 10 inches below this Line, which answers to the Tide Gauge mark.

"Ascertained in 1831 by Major De Havilland, Acting Chief Engineer."

Madras Drainage.

MAP
of

MADRAS

SHOWING THE LINES OF SEWERS

PROPOSED TO BE LAID DOWN.

SCALE 2 INCHES TO 1 MILE



— PROPOSED SEWERS

- - - PRESENT SEWERS

NOTE. RED FIGURES DENOTE LEVELS
ABOVE DATUM (MEAN SEA LEVEL)



at present, there is no single neighbourhood which is altogether elevated above the others. In each there are high and low portions which differ from each other in height from 8 to 16 feet, but in all the districts the lowest parts, or those which must regulate the direction of the main sewers, are nearly on a dead level with each other. The lowest streets in Saint Thomè, Triplicane, Chintadrapett, Egmore, Vepery, Pursewakum, Black Town, Tondiarpett and Royapooram, which are the important divisions of the Town, are, in each instance, from 4 to 7 feet above mean sea level. It will thus be seen that there is no natural line of drainage for the town of Madras, *considered as a whole*. This is an important point, and one of the truth of which it will be well to be convinced by a reference to the Map of Madras, which accompanies this Report. Each district, however, has its ridges and valleys which can be turned to account when we take it *by itself*, and lay down its branch sewers and pipe-drains irrespective of the other neighbourhoods.

Madras may be conveniently divided into four drainage divisions.

Beginning from the north, the 1st, which comprises the districts of Royapooram and Tondiarpett, is that quarter of the Town which stretches northwards from the Railway and is contained between the Canal and the Sea. A ridge half a mile broad, and from 12 to 15 feet above mean sea level, runs north and south midway between the Canal and the Sea, and slopes gradually down on either side towards these boundary lines. The soil, to a considerable depth, is almost everywhere sand. The southern portion only of this division is thickly inhabited.

The 2nd division is that bounded by the Railway on the north, the Canal on the west, the river Cooum on the south, and the Sea on the east. It contains Black Town and Fort St. George. In Black Town there are two ridges running parallel to each other, and almost due north and south. The well known street, Popham's Broadway, which is from 6 to 8 feet above mean sea level, is the valley line between these ridges. Beginning from the east, or from the road running along the sea beach, which is from 11 to 12 feet above the datum line, the ground rises to the west for about a quarter of a mile until the first ridge is reached, which at its northern extremity, is 21 feet above mean sea level. From this ridge the ground slopes downwards to the west for another quarter of a mile as far as Popham's Broadway. From here the ground rises to the west for about a third of a mile, until the second ridge along Salay Street is

reached, which varies in height from 13 to 20 feet above mean sea level. After this the ground falls rapidly to the west for about a quarter of a mile, or down to the canal. Of all the districts in Madras, Black Town offers the greatest facilities for drainage. The strata found below the surface consist of layers of different colored sand. Water is usually found at from 1 to 3 feet below the datum line.

There is nothing to note about the natural features of the Fort except a general fall of the ground towards the west.

The 3rd drainage division which comprises the populous districts of Vepery, Pursewakum, Egmore and Elembore is bounded on the south by the Cooum, on the east by Cochrane's Canal, on the north by Captain Cotton's Canal, and on the west by the villages of Chetput, Kilpauk and Perambore. The most striking characteristic of this division is a general rise of the ground from the east to the west. In the southern portion this rise is regular and almost uninterrupted. It begins from the eastern part of Vepery and Egmore at 6 feet above mean sea level, and continues as far as the western limits of Madras till it attains a height of 24 feet above the datum line. Pursewakum alone has features peculiar to itself. Although it rises steadily to the west, there is a valley line running east and west from which the land ascends towards the north and towards the south. In other words, Pursewakum stands on two slopes of ground meeting in a valley—one slope faces the south and the other the north. The top of the former is from 8 to 11 feet, and that of the latter from 10 to 15 feet above mean sea level. The valley itself is from 3 to 6 feet above the datum line. On account of its great extent, it is somewhat difficult to drain the 3rd division. The strata underlying the surface soil consists in some part of sand, and in other parts of clay. Water is found at from 1 to 3 feet below mean sea level.

The 4th division is that portion of Madras which lies south of the Cooum. In it there are three populous districts, viz., Chintadrapett, Triplicane and Saint Thomè. The former slopes down from 9 to 10 feet on the west to 5 feet above mean sea level on the east. The land on which Triplicane stands is perhaps the most irregular in Madras. It rises and falls continually, and yet there is hardly an important feature to notice. Perhaps, if I say the western quarter is generally higher than the eastern, a clearer idea will be formed of this district than by any detailed description I could give. For drainages proposes, Triplicane may considered to be a

flat about 11 feet above the datum line. Saint Thomè is the half of a little hill cut through the crest by the sea. The ground falls on all sides except towards the east, where it is abruptly terminated by a sandy cliff. The top of the hill is 21 feet, and the bottom from 6 to 10 feet above mean sea level. In this division, the strata are partly of sand and partly of clay. Water is found sometimes above, and sometimes below, mean sea level.

The natural drainage outfalls of Madras are the rivers Cooum and Adyar, Cochrane's Canal and the Sea.

The Cooum, which flows in a serpentine course through the heart of the town, may be considered an extensive tank. The bar at the river's mouth is the bund of this tank, and the water, when only at mean sea level, extends more than three miles inland, or nearly up to the College Bridge. From January to October the river has no outlet to the sea. It is only during the monsoon, and not always then even, that the bar is open. During the earlier months of the year the water stands at about mean sea level, but it falls gradually during the hot weather to $1\frac{1}{2}$ feet below the datum line, unless there is rain in the interval. The level of the river is not affected by the tides of the sea. The heaviest monsoon does not produce a sufficiently strong current to scour the bed of the Cooum effectually. At present this river forms a large cesspool for the districts of Vepery, Egmore, Chintadrapett and part of Triplicane, all of which drain into it. Owing to the constant flow of sewage into the Cooum, and to the stagnation of the water, so large a quantity of solid filth has accumulated that the bed of the river is raised considerably above its natural level. Strictly speaking, the Cooum, for the last three miles of its length, has no fall at all. In fact, if anything, the bed slopes in an opposite direction to the course of the stream. The large drain near Government House Bridge and the main sewer of Vepery near Chintadrapett Bridge have both discharged such a quantity of filth that the bed of the river between these points is actually higher than it is for the previous mile. During the monsoon the water escapes only because the river rises above the bar and forces a breach through it. It will thus be seen that, practically, the Cooum has no outfall at all. To attempt, therefore, to convert it into a sewer is simply to make it a cesspool.

The Adyar, which forms the southern boundary of Madras, is really a smaller river than the Cooum, but it widens so considerably before

reaching the sea that its waters cover a much larger area, and at its mouth it forms a small lake. Like the Cooum it has no outlet to the sea, except for a short time during the north-east monsoon. It is even less adapted for a drainage outfall than the Cooum.

Cochrane's Canal runs in a northerly direction from the Cooum to beyond the limits of Madras. At present it is the cesspool for the western quarter of Black Town which discharges its sewage into it. As there is no current to carry away the solid matter, the bed of the Canal, like that of the Cooum, is higher than its original level.

Madras has 9 miles of sea-coast. The beach throughout is flat and sandy. For the first half mile from the shore the bed of the sea slopes from 0 to about 7 fathoms or 42 feet in depth. After this the slope becomes very gradual, for at the distance of $3\frac{1}{2}$ miles from the shore, the depth is only about $10\frac{1}{2}$ fathoms or 63 feet.

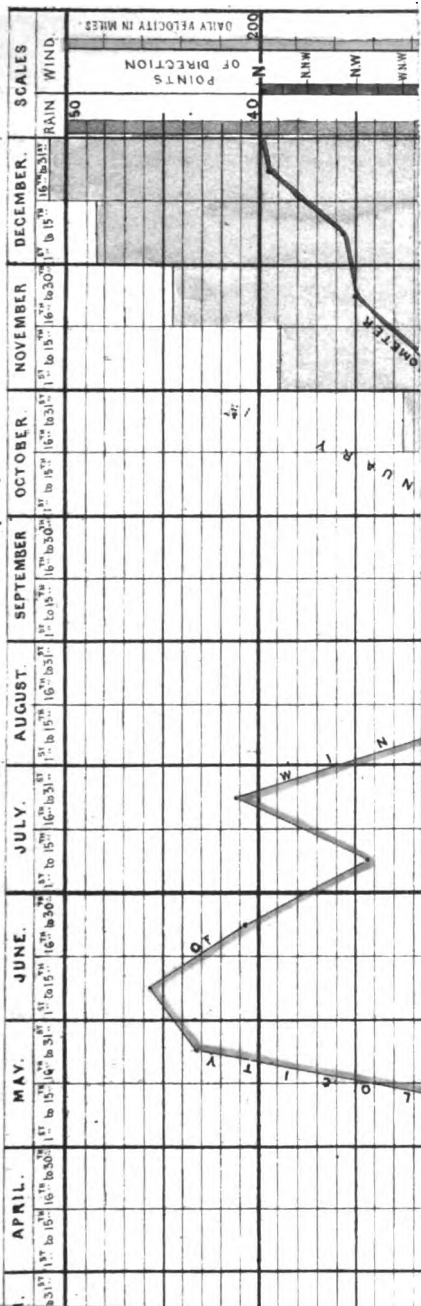
The difference of level between high and low tide is about 3 feet only, and high and low water-mark are taken in Madras at about $1\frac{1}{2}$ feet above and below mean sea level, which is invariably ascertained from Colonel De Havilland's bench-mark, spoken of before.

The two principal currents along the shore of Madras both flow in a direction parallel to the coast. The first, or that which flows from the north southwards, usually sets in about the middle of October, and continues to flow till February, or till such time as the "long shore" winds begin to blow, when the second current sets in and flows from the south northward. This current ceases about August, when variable currents and calms set in and continue till the burst of the N. E. monsoon in the middle of October. The two principal currents, following as they do the course of the winds, must, no doubt, be caused by them. If the wind, therefore, is the chief cause of the currents along the coast of Madras, I think accurate observations would prove that the currents which prevail between August and October have a tendency to flow in nearly the same direction as that which prevails from February to August. The only difference between the winds at the two periods is that there is more westing in those which blow from August to October. The velocity of the two principal currents at their full strength is computed at three miles per hour.

The general characteristics of the climate of Madras may be ascertained from the accompanying diagram.

Madras Drainage.

Averages of 20 Years Meteorological Observations at Madras.



6

rea
mo
ses
lea

the
ter
cu
th

sa
fri
be
de

ar
ar
D

di
n
ti
b
n
a
n
o
t
l
t
c
c
i
l
l

The Town of Madras.—The population of Madras, according to the last statement drawn up by the Assessor to the Municipal Commissioners, is tabulated below :—

No. of drainage division.	Position of each drainage division.	Important districts comprised in each drainage division.	No. of houses in each drainage division.	Population.	Average number of souls to a house.
1	North of the Railway and east of the Canal.	Royapooram, Tondiarpett,	3,483	70,934	20·7
2	South of the Railway, east of the Canal and north of the Cooum,	Black Town, Fort St. George,	12,363	149,004	12·0
3	West of the Canal and north of the Cooum,	Pursewakum, Vepery, Egmore, Elemboor, Chintadrapett,	5,899	57,244	9·7
4	South of the Cooum,	Triplicane, Royapett, St. Thomè,	10,915	150,589	13·8
Total, ...			32,610	437,771	13·1

In London the density of the population, with reference to the houses, is about 5. A Madras dwelling therefore, contains, more than $2\frac{1}{2}$ times the number of people which a London house does. The density of the population of the northern portion of Madras (20·7) is extraordinary, being more than four times that of London.*

A native dwelling in Madras usually consists of one or more open courtyards, each enclosed on all sides by a terraced or tiled building. There are sometimes as many as five of these courtyards running back from the street. Both the buildings and the courtyards almost invariably slope towards the entrance, and their floors are generally raised above the surface of the road—in some streets not more than a foot; in others as much as 4 or 5 feet. These facts are very important for the purposes of this project, and will be referred to when the question of house-drainage is treated.

The greater quantity of the water used by the inhabitants is drawn from wells built in one or more of the courtyards. When there is one well only, it is usually in the back courtyard. All natives who can afford it

* Even this is rivalled by some of the villages, such, for instance, as Royapett, which has a population of 10,210 and only 620 houses,—the density being nearly 81. Is it possible that a population of nearly *twenty thousand* can be living at the rate of 81 in a dwelling—and *such dwellings*? And if this is the *average* density over the entire village, how many men, women, and children must there be in some of the houses? It is not surprising that cholera should be endemic in Madras.

buy their drinking water, which is usually brought from a distance. For all other but drinking purposes, the water in the wells is made to answer. On account of the abundance of water in the Madras wells, much more is used than might be supposed. Almost all the wells in or near the thickly populated parts of the town contain more or less organic matter. This is entirely due to the sewage of the town escaping first through the badly constructed drains in the streets, and then through the sub-soils to the stratum of sand which holds the present water-supply of Madras. Sooner or later, this water-supply must become so impregnated with the sewage as to be rendered unfit for use. In many places this has already occurred, for the wells are as offensive as cesspools, and in consequence have been abandoned by the people.* These facts, which have been brought to light by the numerous borings I have made in all parts of the town, may be relied on by Government. I bring them thus prominently to their notice, in order to show the necessity for a system of water-tight pipe-drains and sewers, which while it relieves the dwellings of all liquid refuse, will, at the same time, preserve the water-supply of Madras from contamination.†

The greater portion of the water drawn from the wells by the inhabitants is used for washing and bathing, and generally in the back courtyard, where also the cleaning of the pots and pans takes place. All the refuse water, both from the yards and from the cook-rooms, is discharged by an open channel (about 4 or 6 inches square) into the street drain. There is a privy in each house, usually on one side of the back courtyard. It consists of seats formed by low walls of brick in chunam between which the ordure falls, while the urine escapes into the same open channel which conveys away the waste water from the dwellings. All solid filth is removed by scavengers, who

* Every well in the town should be closed as soon as it is disused, for foul water never ceases to give off poisonous gases, and becomes more foul the longer it is kept.

† In some places I met with pure liquid sewage. There is no mistake about this, for the smell was so overpowering as to leave no room for doubt in the matter. As a general rule, a well dug in virgin soil in Madras will produce good water—provided that it is sufficiently far removed from dwellings. By good water I mean water not impregnated with sewage. Of a town situated, as Madras is, on the sea coast, and with a sub-soil of sand, it would be impossible, unless a very great number of borings were made, to say where the water would or would not be slightly brackish. Wherever good water occurs, the sand is uncolored, sharp and sweet, while, in all instances in which sewage has percolated through the upper strata, the sand beneath is colored dark with organic matter, and is more or less offensive to taste and smell. It is remarkable that some wells dug on the *very margin* of densely populated neighbourhoods produced good water. A little consideration will explain this peculiarity. The chief supply of water being drawn by the inhabitants from wells situated in the town, the "pull" has been from the margin all round to the centre. No sewage, therefore, has flowed out of the town into these wells on the outskirts.

call at each house once or twice in the day, and deposit it in the Municipal carts which convey it away from the precincts of the town. As a rule, there are no cesspits in the dwellings. The house-drain for all liquid refuse has its outlet in the front of the dwelling, where it drops its contents into an open drain of a rectangular section (about 15 inches by 1 foot) running along the side of street. This, again, is connected further on with another drain of a similar kind, but of larger dimensions, and so on, until the last discharges itself into a sewer which lies a few feet below the surface of the ground. Both the street drains and the sewer are built of ordinary bricks set in shell lime mortar. They are as porous as they can be, and smell most offensively. Having no proper slope, they are daily choked up with filth, the removal of which is effected by manual labor only. It is for the cleansing of these drains, which are a receptacle for all the solid filth of the streets, that so large an establishment of scavengers is employed by the Municipal Department.

At present the main sewers of Madras have three outfalls—the Sea, the River Cooum and the Canal. Black Town drains into the sea, except the small portion of it lying to the west of Salay Street which drains into the Canal. Vepery, Egmore, Chintadrapett and part of Triplicane drain into the Cooum. The main sewer of Black Town has its outfall at the north-east angle of the Fort. This, being the largest, is the most offensive sewer in Madras. The main sewer of Vepery discharges its contents into the Cooum near Chintadrapett Bridge, where it has deposited a great quantity of filth in the bed of the river. The mouth of the main sewer of Chintadrapett and Triplicane is near Government House Bridge, where an effect similar to that of the Vepery sewer has been produced. Besides these main Channels which discharge both sewage and flood-waters, there are numerous small drains which have their outlets in the Cooum and the Canal.

It must not be supposed from the above that all the sewage of the Town is discharged at one or other of these outfalls. Nothing could be further from the fact. There are both individual streets and extensive areas in each neighbourhood which have no outlet at all, and where the sewage stands in open trenches round the dwellings, and stagnates from day to day, and from month to month. The only cleansing process that ever takes place is that caused by a heavy fall of rain, when the water overflows the sides of the trenches, and, in seeking an outfall, carries away some portion of the filth with it.

Dry Conservancy.—In the present state of the question of conservancy, a report on a proposal to cleanse an Indian Town by means of sewers would be very incomplete, if it did not enter into a full discussion of the new theories which have lately been started regarding dry conservancy.

Any organic substance exposed to the air is soon destroyed by oxygen of the atmosphere. The moisture is evaporated, and the body converted into new compounds of a more permanent form than those of which it was originally composed. While the body is in this state of decomposition, offensive gases are given off, but when it has taken its more permanent form the evolution of the gases usually ceases. If, however, water be poured on the substance, or it be allowed to lie in water, a second process of decomposition take place, which again ceases when all the water has been evaporated. This may be repeated many times.

The noxious smells about cook-rooms and privies arise, to a great extent, from the decomposition of organic matter promoted, in the first instance, by the action of the atmosphere, but continued by that of water. The nuisance caused by allowing refuse vegetables to lie in the streets and dry by the heat of the sun is harmless, compared with the effect that is produced by throwing them into the water lying in the drain close by.

Hitherto, in privies, all excrementitious matters have been removed by aid of water. It is now demonstrated that water can be dispensed with, and that privies can be kept much more wholesome without it. It is urged that certain substances which have the power of preventing the exhalation of foul gases should take the place of water. Of these, charcoal, ashes and clay are the most important. It is found that they rapidly absorb the moisture in excrement, and thus at once deprive it in a measure of its offensive properties. But this is not all. Even the bricks and chunam with which the walls and floors of privies are built are now objected to, inasmuch as they soon become saturated with urine or refuse water and retain for a very long time the power of exhaling noxious odours. It is proposed, therefore, either to dispense with these materials altogether by building with clay which is a deodorizer, or, at all events, to cover them with some substance, such as tar or asphalte, which does not absorb moisture—On these broad principles dry conservancy is based.

The best account of the new system is given in the Punjab Sanitary Report for 1862, by the originator, Doctor Hathaway, of the Bengal Service. The following is an extract from this report :—

"The latrines in the Punjab jails are perfectly free from any effluvia whatever, and the essential points in which they differ from the majority of those constructed for Military use are as follow:—

"A. The absence of all masonry or pukka work containing lime cement.

"B. The prohibition of all cesspools or reservoirs, and all drains or pipes, whether closed or open, leading in or out of the latrine or urinary.

"C. The prohibition of water being used to flush the ground or flooring, which is to be kept perfectly dry.

"D. The flooring being of earth, (instead of pukka masonry or stone) on which dry sand to the depth of 4 inches over a layer of well rammed clay is strewed, and the portable vessels for the reception of both fluid and solid refuse matter being deposited on the sand.

"E. The immediate removal of all refuse matter from the latrine itself, and the careful burial every evening in trenches dug for the purpose.

"F. The abolition of the practice of sprinkling powdered lime in the urinaries and latrines, or in any other spot."

The other points to be attended to are—to build urinals separate from latrines—to provide thorough ventilation for both—to make all the seats in the latrines of wood and the pans of iron or earthenware—to provide a large iron receptacle with a close fitting lid in the rear of each latrine, into which the contents of the pans are to be emptied as fast as the latter are used—to keep the seats, floor, and vessels scrupulously clean—and to use charcoal and wood-ashes as disinfectors in place of lime.

Such are the main features of dry conservancy on Doctor Hathaway's principle. It is impossible to call in question the great success which has attended its introduction. The privies are clean and free from all offensive smell, and have met the entire approval of the authorities in Bengal. Like every thing else, however, of the kind, the dry system is still capable of improvement. Some important modifications, therefore, have already been made. The chief of these is the use of clay as a disinfectant in place of charcoal or wood-ashes. The advantages of clay are—that it is easily procurable and exceedingly cheap—that in a dry state it is one of the best disinfectants for excrementitious matters yet discovered—and that after use it possesses a high value as a fertilizing manure. Another modification is the use of tar or asphalt for the floors and the walls of the privies. This has not, however, the advantage of cheapness. The last improvement yet made consists in the separation of the urine from the fæces. This idea originated with Doctor Thudichum, a physician in England.

The subject of dry conservancy is now attracting considerable attention

in England, and, from what can be gathered, still more attention in India, to which country it is much better suited. The great argument in favor of it is based on the fact that the most valuable manure known to man, viz., urine, will be saved for agricultural purposes. If the manured clay should hereafter possess a high commercial value, the argument will be all the stronger. So far as the application of dry conservancy to latrines is concerned, I am entirely in accord with the advocates of this system—provided that the cost of it is not borne by the people who could never, as will be shown presently, afford to pay for it. But some of these advocates, in the heat of the excitement caused by a new and very important discovery, will not look at the question except from one point of view. The consequence is, that the most absurd and extraordinary statements are made by them as to the efficacy of the new principles, and as to the wonderful application that may be made of them. “The old system of drainage by sewers is obsolete—is a quarter of a century behind the age—is not worthy the science of the day. Dry conservancy absolutely revolutionizes the subject of drainage. We must begin *ab initio*—the great sanitary problem of the day has been solved. We are to have no more sewers and no nuisances. The town is to be cleansed on new principles, and at little or no cost to the inhabitants.”

If it should be thought that this is an exaggerated account of the effect expected to be produced by the adoption of dry conservancy, the following extracts will prove that it is not. Speaking of the application of the dry system to large cities (and more especially to London) in which water drainage exists, and where it might naturally be supposed that the subversion of the present system of sewers would be attended with considerable expense, the Reverend H. Moule says—

“In the establishment of the earth sewage system no public works are required, whilst the three and a half millions being spent by the Metropolitan Board for the greater efficiency of the public works now existing, would have defrayed double the cost of all private works of the earth sewage system for London; and the manure saved, instead of wasted, would, on the very lowest estimate, have been produced a clear income of £50,000 a-year.” (*Society of Arts Journal*, Vol. XI.)

The same idea has been repeated in other words by a gentlemen in Madras, who has now for some years interested himself in the question of sanitary reform. In a pamphlet, called “The Cleansing of Towns,” written by Doctor Cornish, Assistant Surgeon, and Secretary to the Director General of the Medical Department, he says—

"The greatest advantage of all would be the doing away with the necessity for costly drainage works,"—and again, "Before spending some half a million of money in a system of sewers for Madras, it may be well perhaps for the rate-payers, who will ultimately have to defray the cost of the 'improvement,' to enquire whether for an expenditure of one-twentieth part of the money it may not be possible to make our chief city a model of cleanliness, and its excreta so valuable, that the cost of collection should be a mere trifle in the Municipal expenditure."

It will thus be seen that both the Reverend H. Moule and Dr. Cornish consider dry conservancy sufficient of itself to correct all the evils of a town,—those at least which arise from defective drainage. The picture has been painted in such bright colors, and has so greatly pleased the painters, that they have not cared to enquire whether it is true to nature. But the argument for dry conservancy, put in few words and cleared of everything which in any way keeps the real point at issue from view, may be stated thus :—"Because dry conservancy is the best system for privies; therefore it is the best system for towns." The fallacy arises from forgetting that in the one case, i. e., in privies, excrementitious matters only are dealt with, and in the other that the same excrementitious matters form but an inappreciable amount of the filth to be removed. It is just as if a man should attempt to clean out the dust-holes of London by crushing the bones to be found in them, and then carrying away the powder as manure. Of course, he could urge that he had taken away the foulest portion of the refuse and had utilized it for agricultural purposes, and this would be perfectly true. But it would be equally true that he had left nearly all the filth behind. And this is a case exactly parallel with that of dry conservancy, when it is insisted that this system must *supersede* that of sewers. The advocates of the former keep urging that all the urine and fæces will be carried away and converted into manure, and, of course, nobody can deny the proposition which is perfectly patent. But it is also true that almost all the sewage will be left behind. In a word, though urine and fæces are undoubtedly the most offensive part of town sewage, yet in bulk they do not amount (as in the case of London for instance) to more than $\frac{1}{100}$ th of the whole. This is so easily proved, that it can escape the observation only of persons so wedded to a new theory, as to be unable to look adverse facts in the face, but it explains at the same time why those who have to remove the sewage in England do not consider the extravagant proposition to do away with sewers worth refuting.

The average of the returns of the Metropolitan Water Companies shows that the quantity of water used in London per head of the population is 44 gallons = 440 lbs. daily. The average quantity of excrementitious matter voided by each individual may be taken at 2 lbs. of urine* and $\frac{1}{4}$ lb. of fæces,† or together to $2\frac{1}{4}$ lbs. daily. This is equivalent to $\frac{2\frac{1}{4}}{440}$ = very little more than $\frac{1}{200}$ th of the waste water. Suppose, however, that in Madras, 5 gallons only, or 50 lbs. of water are used per head of the population, then the excrementitious matter will be $\frac{2\frac{1}{4}}{50}$ = not *one-twentieth* of the water. Mr. Fraser, C.E., informs me that he proposes to supply 20 gallons or 200 lbs. of water per head of the population. If this is done, the excrementitious matters will be very little more than *one-hundredth* of the waste water to be removed. The proportion of night-soil to liquid sewage in Bombay is calculated at 1 to 775.

It might, however, be supposed, that, in answer to all this, it would be contended that, if sewage were deprived of excrementitious matters, it would not be offensive, and might lie harmless in the drains. This certainly would be an extraordinary argument to urge with any one acquainted with the mode of conservancy adopted in Madras, where already almost all the fæcal matter is removed by the Municipal carts, and the smell in the streets is, nevertheless, perfectly sickening. But still it would be taking the bull by the horns. The advocates of the dry system, however, take up no such position. On the contrary, they urge with all the force they can, that *water! water!* is the chief cause of the evils in privies—prohibit its use, and the privies will be clean and wholesome. Indeed, they insist that waste water from dwellings is only less offensive than *excrement itself*. The following extract from Dr. Cornish's pamphlet will show that I do not misrepresent the views of these gentlemen:—

"In tropical countries the putrefactive process, *when water is present*, proceeds with a truly wonderful rapidity. Not only do animal excretions decompose with great speeds, generating poisonous compounds to pollute the atmosphere, but common house-sweepings, cook-room refuse, &c., when mixed with water, become in a very short time an intolerable nuisance. Even the waste water from bath-rooms, if retained for a few hours in a cesspool or reservoir, will be almost as offensive as excrementitious matters themselves."*

Now, is it not strange that the same people who see so clearly the

* *Vide* page 679 of Fawcett's Manual of Chemistry, 7th edition.

† According to Baron Tiebig.

‡ *Vide* page 6 of Dr. Cornish's Pamphlet.

danger of allowing waste water to stagnate and poison the air, will not admit the necessity of making provision for its removal? The project now submitted to Government, like all drainage projects, has for its object the removal of this very waste water without retaining it in cesspools or reservoirs. When it is shown that this can be done effectually in all towns by a cheaper method than that of sewers, of course that method should and will be adopted, but until then there is little doubt that the system of drainage by sewers will prevail in India as in Europe.

It will thus be seen, that, in advocating the universal application of dry conservancy, it has been entirely forgotten that the use of water, which should be *prohibited* in privies, should be *encouraged* in houses. By strict supervision, water may be excluded from the former, but, so long as we are human, it must be used in the preparation of our food, and for the cleansing of our persons and our dwellings. To those who say—"no public works are required," "do away with your sewers and adopt the dry system," is it not natural, under all the circumstances mentioned above, to reply,—“in that case, what shall we do with our waste water, for you yourselves say it is only less offensive than excrement?” The advocates for the universal application of dry conservancy are bound to answer this question before they make the extravagant proposal to cleanse a town solely by building model privies.

But in order that Government may understand all that is proposed to be done in Madras, I will try to put the system of dry conservancy as a whole before them. Public privies of an improved design are to be built in all parts of the town, and at such convenient distances apart as shall induce the inhabitants to use them.

“One side of the building is for males, and the other for females, twenty of each might be accommodated at one time in the privy. The urine, voided into a channel against one wall of the building drains along an asphalted gutter (the whole of the interior, floor and walls is to be asphalted), and after being filtered through a moveable screen containing coarsely powdered charcoal, is finally received into an asphalted reservoir outside, which reservoir is to be nearly filled every day with dry earth, to allow of the urine being absorbed and subsequently carted away without decomposition or offence. The object of the filtration through charcoal is to remove the mucus of the urine, by which arrangement it will not begin to decompose for a period of 24 hours or more.

“In the privies, the following arrangement is suggested. In the space allotted to each person the toty will keep a flat, saucer-shaped chatty, painted or soaked in coal tar, and well dried previous to use, to receive the solid excrement. These chatties should always contain a little dry earth or wood-ashes, and after use the evacuation

should be immediately covered with a small quantity of *wood-ashes*, kept in readiness for the purpose within the enclosure, and the whole removed to the shed outside, where the chatty should be emptied and the mixed ashes and *fæcal* matter put into an iron tub or basket for removal. It will be observed in the plan, that separate provision is made for the reception of the urine passed during defecation, in an asphalted channel, which conveys it to the urine reservoir outside.*

It is expected that the excrementitious matter, after being converted into manure, will be gladly removed by contractors who will find it pay them to use it on the lands about Madras. It is moreover considered that, on account of the highly deodorizing properties of clay, no nuisance will be caused by the construction of the latrines even in the heart of the town, and that the removal of the manure through the streets will give no offence.

It is evident, on a *primâ facie* view of the matter, that the entire success of the scheme will depend on a universal use being made of the latrines. Because, if some people use them and others do not, we shall have both the expense of the new system and the nuisance of the old. It is not shown, though, how this end is proposed to be secured. Whether the people will be compelled by law to frequent the public privies, or whether the use of them is to be entirely voluntary. It would not much signify, however, if a dozen laws were passed on the subject, for the State, having no control over the individual in his dwelling, could not prevent his evading the law in it if he chose to do so.

We will assume, therefore, that it is intended that the question should be decided by the common sense of each individual. But common sense appears to me to be against the universal use of public latrines, so far at least as women are concerned. Can it be expected that any respectable man will permit his wife or his daughters to leave the privacy of their home—to walk, say, 150 yards in dry and wet weather along a public street to a public place for *such a purpose*—to mix there with perfect strangers—and to perform such a duty in their very presence. Yet, if the women as well as the men did not use the privies, what measure of success would attend the introduction of dry conservancy? The advocates of this system may point to the fact, that the existing public latrines are made use of by women, which is perfectly true; but is it by women of the very lowest classes, and by such of them only as have no backyard or enclosure of any kind to resort to. And even these women are driven to the public privies

* *Vide* page 18 of Dr. Cornish's Pamphlet.

AND IN WHICH THE EXCRETIONS CAN BE SEPARATELY COLL

A detailed technical drawing of a wooden roof truss (Dachstuhl) in cross-section. The drawing shows the internal structural framework, including the rafters (Dachstuhlstuhl), ridge beam (Rückenstuhl), and various supporting beams and posts. The structure is shown resting on a foundation. The drawing is labeled with various dimensions and structural details.

Excavation	
Brickwork	
Plastering	
Flooring with asphalt	
Stone work	
Teak timber	
--- reapers	 p
Zinc sheeting	
Lead pipe	
Contingencies	

A line drawing of a building facade. The roof is gabled and slopes down to the left. The main wall is composed of vertical slats or panels. Below the slats, there are several rectangular openings or windows. The drawing is simple, using black lines on a white background.

Architectural floor plan of the interior of the Church of the Holy Sepulchre, Jerusalem. The plan shows a large central nave with a series of columns, a semi-circular apse at the top, and a series of smaller rooms or chapels along the sides. Dimensions are provided for various sections: 70' for the main nave width, 61'1" for the side aisles, 40'0" for the central nave length, and 42'5" for the apse. A scale bar is visible at the bottom right.

copied from the original in Doctor Cornish's Pamphlet. "The C



Digitized by Google

only by the strict supervision of the Police. Instead, therefore, of encouraging what every one will admit is a proper sense of decency, dry conservancy proposes to lower all classes to the same degrading level. Surely this is a backward step in civilization. Let it be remembered, too, that children and young girls are to be subjected to this public ordeal. To what a state of morality must this lead?

Even in England, where every water-closet at the Railway Station is a separate room and has a lock and a key in the door, the prejudice even among men against it is so strong that nothing but the greatest necessity will induce them to use it. I am aware that this prejudice arises in a great measure from the fact that infectious diseases are easily propagated by the water-closet system, but it arises also from other causes. In spite, too, of every care that might be taken in the public latrines in Madras, it would be impossible to prevent some of those infectious diseases spreading amongst the people. They must all wash at one and the same place. It would not be possible to have large tanks in the heart of the town, and, if these were erected, the cost of the system would be enormous, as will be shown presently.

Besides, how will it be possible to arrange for the wants of the sick, who will not be able to leave their dwellings, and who, at the rate of five sick in every hundred of the population, will amount in number to $\left(\frac{430,000 \times 5}{100} =\right)$ 21,500 souls—producing daily more than 21 tons of excrementitious matter. Where, too, will the line be drawn amongst the community as to the use of the latrines? If natives *must* use them, so must East Indians, and so must Europeans. There cannot be one law for the native and another for the European. And will Europeans and East Indians submit to such an arrangement? Will they sit on the same seats with natives, and in the same manner? If not, it will be necessary to provide separate latrines for the different races, and this again will add to the cost.

In rainy weather, moreover, how will it be possible to induce the people to go to the privies? This is the very time, too, when the offensiveness of urine and fæces will be greatest. The difficulty of carrying out dry conservancy in wet weather has been partly foreseen by Doctor Cornish, but not entirely provided against. He says, "In wet weather a supply of dried earth should be kept ready prepared *under cover*."* This is all very well

* *Vide* page 18 of Dr. Cornish's Pamphlet.

so far as the clay is concerned, but what will be the use of it if people do not frequent the latrines at that time ?

In advocating universal dry conservancy, people are too apt to be led away by the success which, *under certain conditions*, has attended its introduction into India. Whenever it has been tried on a limited scale, as, for instance, in Barracks, Jails, Hospitals, &c., its success has been complete. But the reason is so obvious, that it is strange it should be so often overlooked. If Government have a number of troops, or prisoners, or invalids whom they can easily keep under discipline, every individual can be compelled to make use of the latrine. The very fact of a man entering a hospital is an admission on his part that he is willing to submit to the regulations of the place. But the question assumes a different aspect altogether when Government have to deal with a mixed population of half a million men, women, and children, scattered over many square miles of country—living in all kinds of houses—and over whom, as soon as they are within their own doors, Government can exercise no control whatever. How can a universal use of public privies be enforced under such circumstances.

But Dr. Cornish claims one great advantage for universal dry conservancy, viz., that it is much cheaper than the sewer system. This is certainly the most unfortunate mistake that has yet been made by the advocates of the new theory, and the one which will tend to damage it more than anything else. He says :—

“Before spending some half a million of money in a system of sewers for Madras, it may be well perhaps for the rate-payers, who will ultimately have to defray the cost of the ‘improvement,’ to enquire whether for an expenditure of one-twentieth part of the money it may not be possible to make our chief city a model of cleanliness, and its excreta so valuable, that the cost of collection should be a mere trifle in the Municipal expenditure.”*

It will thus be seen that 2½ lakhs of rupees is the sum set down for cleansing Madras thoroughly according to the new principles. It has always been maintained by the Engineering profession, that, whatever objections might be raised to the sewer system, it was the *cheapest* means known of disposing of sewage. A sewer, once built properly, will, with occasional trifling repairs, last for centuries. An inconceivable quantity of water may be passed through it. It will work as well in the night as in the day.

* *Vide* page 23 of Dr. Cornish's Pamphlet.

With fair play the supervision required is most trifling. It is necessary, therefore, to ascertain if dry conservancy is cheaper.

[Calculations are then gone into by Captain Tulloch, which show that the cost of the privies, urinals and earth sheds for the whole city, will be not less than 26 lakhs of rupees; that the total *monthly* cost of the establishment for looking after them will be Rs. 13,545, besides the cost of carting away the excrementitious matter, which will be Rs. 6,840 more.]

Objections to Sewers answered.—Before passing on to a description of the project now submitted to Government, it is necessary that the general objections to the system of drainage by sewers should be met. Fortunately, these objections have been very fully stated by the same Officer who has pleaded so strongly on behalf of universal dry conservancy. When the arguments on both sides of the question shall have been fully stated, it will not be difficult for Government to decide between them.

At the present time, when sanitary questions are attracting great attention, it is of vital importance that the general principles of water-supply, drainage, barrack construction, &c, should be thoroughly discussed. If mistakes are made at the outset in carrying out large and important works, the chances are that they will be repeated over and over again, and at an enormous cost to Government. Whereas, if the correct principles of any one subject are clearly defined, there is every hope of their universal adoption. As this is the first project which has been submitted to the Madras Government for the complete drainage of a large town in the Presidency, it would be a grievous error to carry it out if it should be based on erroneous theories. On this account, therefore, I have considered that I should be discharging my duty to Government better by omitting nothing in this Report bearing on the question of drainage, than by confining myself strictly to the immediate subject matter.

The reason why dry conservancy has “taken” better with the Indian than with the English public is, that the physical conditions of this country are so much more favorable to its development. England has a damp, while India has a dry, climate. The heat of the sun, which is so important an agent in the dry system, acts perfectly in India. Moisture is rapidly absorbed, and clay easily dried. In England, the damp air and the continued absence of sunshine for many days together are obstacles, though not insurmountable ones, to the perfect working of the system. In

England, moreover, it is raining more or less constantly throughout the year, while in India the entire supply of rain is obtained in a few days. The rivers in England are flowing all the year round. Those in the south of India are dry for some months. All these facts are urged as arguments against sewers.

But if sufficient water is stored in the monsoon and when the rivers *are* flowing, there need be no lack during the hot months. To prove that we have not sufficient water, it is necessary to show that the rain-fall, the source of all water in every country,* is deficient. Yet what is the case? The rain-fall in India on the average is double that of England. It is true that the evaporation is greater, but after making every allowance for loss due to this cause, there is an enormous balance of water available for the use of man. Has India, then, any reason to complain? Every effort which has been made to store water in the country is a standing protest against the statement that we have not sufficient water. The success of even small tanks is very great. Would Government otherwise keep them in repair? What works can be better adapted to the purpose of store-reservoirs than large tanks and anicuts? It is a great mistake to suppose that all the towns in England draw their water-supply from large and ever-flowing rivers, and that these large rivers are necessary to works of drainage. Numerous towns in England are supplied with water from store-reservoirs exactly similar to the tanks of India, and their success is complete.

I believe that the following extract from a letter to me by W. Fraser Esq., C.E., expresses briefly the general opinion of all Engineers in this country:—

"I have had occasion to consider this subject a good deal, and I am of opinion that abundance of water can be had everywhere in the South of India if proper means be adopted to secure it, and that it is difficult to conceive a case where money spent in this way would not be a profitable investment."

So far, therefore, as drainage depends on water-supply, is there any reasonable cause to object to sewers?†

As to the quantity of water required for flushing sewers, which Doctor Cornish supposes must be very great, the following extract from a Report on the Drainage of Bombay, by Robert Rawlinson, Esq., C.E., "who," ac-

* I am, of course, speaking generally.

† The more I enquire of my brother-officers as to the possibility of storing water for irrigation and other purposes up-country, the stronger assurance I obtain of the facilities for doing so.

cording to Sir Charles Wood, "has earned a high reputation for skill in that branch of Engineering,"* will show that very little water suffices for the purpose:—

"During the dry season in Bombay the sewers should be regularly flushed with fresh water. The volume of water used need not be large, nor the expense very great."..... "At the great hospitals on the Bosphorus, used by the British Army during the Crimean war, large wine casks were used as flushing tanks. These were placed over the heads of the sewers, and were regularly filled from the Bosphorus by laborers (natives) who carried the water to fill the casks, then an orderly suddenly opened a valve, some 6 inches square, which discharged the water, about 250 gallons, in a few seconds. These sewers were large and rudely constructed, with flat bottoms, some 3 feet wide, but they were flushed free from deposit by the means described."†

What could be better for sewers in this country than the ordinary water-carts used in Madras filled by the aid of *pecottahs*? The large sewer in Bangalore is flushed throughout the year with water supplied from an ordinary tank.

The sewers proposed in this Project will be as perfectly smooth as skill can make them, and not one of them will be so wide at the bottom as the above-mentioned, while most of them will have a diameter at bottom of only one foot. So far as Madras is concerned there need be no anxiety about a deficiency of water for flushing purposes. I could only wish that there was not so much available under the surface as there is, because the cost of building the sewers is porportionately increased. The flushing arrangement will be most complete, and will cost nothing after the sewers are once built.

The next objection to sewers is condensed in the question, "Where is the sewage to go to?" And the reply suggested is, "The rivers."

"The great rivers, the Godavery, the Kistna, and the Cauvery, which contain more or less water throughout the year, do not run near to many populous towns, and are practically unavailable for the purpose. Along the Coast, sewage might probably be pumped into the sea, but the difficulty would still remain with inland towns, such as Bangalore and Secunderabad."‡

The error in this reasoning lies in supposing that rivers, as outfalls for sewage, are a *necessary* part of the sewer system. They form no part of it at all. It is, indeed, unfortunate that in so many instances in England

* *Vide* page 97 of "Correspondence on the subject of the Drainage of Bombay."

† *Vide* page 101.—*Ibid.*

‡ *Vide* page 7 of Dr. Cornish's Pamphlet.

sewers should have been led to rivers, but this is not the fault of the sewers but of the people who built them.

All sewage, and especially in this country, should be returned to the soil—to the same place where the solid manure of dry conservancy is to be conveyed. Those who are so anxious to preserve urine and fæces as manure should not forget that, after all, they cannot manage in India without water, which must descend as rain or be raised artificially, before crops can be made to grow. The only difference, so far as the agricultural part of the question is concerned, between solid manure and liquid sewage, is that in the first case you have an article which is almost useless by itself, and in the second you have nearly all that is required to produce anything. The mistake lies in reasoning from England to India without considering the different conditions of atmosphere, soil, &c., prevailing in the two countries. In England it is raining more or less throughout the year, and the first question which the agriculturist puts to himself is, "How shall I get rid of the water?" In India it rains for about 20 or 30 days, and the first question the ryot asks is, "From where shall I get water?" The soil in England in its normal state is saturated with moisture, and every effort is made to keep it dry. The soil in India is dry, and every effort is made to keep it moist. Sewage is manure in a diluted state. But its use even in England, *now that they understand how the sewage should be applied and what crops should be grown under it*, is almost uniformly successful and is advocated by the greatest authorities.

The case of Edinburgh, where, by the use of sewage, land has risen in yearly rent value from £2 to £6 per acre to from £30 to £40 per acre (Scotch) is so well known that I need not dwell on it. About Milan land yields a net rent of £8 per acre. The meadows are mown four times in the year for stable feeding, and besides this, three crops of hay are yearly obtained by sewage-irrigation. At Clitheroe, in Lancashire, it has been proved that the fertilizing properties of sewage water are nearly four times as great as those of common farmyard manure. At Mansfield, in Nottinghamshire, land has risen in rent value from 4s. 6d. to £14 per acre. At Ashburton, and at other towns in Devonshire, liquid sewage has been applied for 50 years, and the yearly rent of land has reached £8 to £12 per acre, while land not improved with sewage yields a yearly rent of only £1½ to £2 per acre. But all these, though well known, are old instances of the effect of the application of liquid sewage. The

most recent instance, and the one which is attracting so much attention in England, and which, it is supposed, will at last decide the question in favor of the use of liquid sewage, is that of Croydon. The inhabitants have been *compelled* to make use of the sewage of their town for the irrigation of land. The result is, that enormous crops of green food have been obtained, and this without any nuisance or inconvenience, while at the same time the surplus water after irrigation is found, on entering the River Wandle, to be purer than the water of the river itself.

The application of sewage to land is, like other branches of agriculture, a science of itself. Occasional failures will occur, and many more must be expected until the subject is better understood, but these are or will be due to want of knowledge and judgment on the part of those who use the sewage and not to the thing itself. Every year the use of liquid sewage in England increases, and the *belief in its value is now general*. It is not a perfect manure, but no substance can possibly be a perfect manure. All that should be contended for sewage, is that it has great fertilizing properties.

Baron Liebig says—

"The employment of sewage in agriculture would make it possible to bring large tracts of land into cultivation, which hitherto, owing to the expense of tillage, has been laid waste and neglected: * * * * *

"It is neither fantastic nor ridiculous to believe that, without purchasing foreign manure, by a judicious utilization of the sewage of towns and villages, England would be able to dispense with the importation of food from abroad."*

If all this can be declared of England, where already there is too much moisture in the soil, what wonderful fertility might be produced with sewage in India? Pour water on the land—flood it if you like—and what is the result? A succession of crops. Would not better crops be secured with water mixed with manure? It may be granted that solid manure, bulk for bulk, is more valuable than sewage. But that is not the point at issue. The point is, whether solid manure in a dry country like India with 20 or 30 wet days in the year is worth 20 or 100 times its bulk of sewage, which, according as 5 or 20 gallons of water are used per head of the population, I have already shown, it will amount to. And even this is not putting the case fairly, because every pound of solid manure will have to be carried to the fields, and then spread and mixed with the soil by manual labor, whereas liquid sewage can be applied to the land by sim-

* *Vide* page 657, Vol. XI., of "Journal of the Society of Arts," for August 21st, 1863.

ply opening a sluice. Thus drainage works in India should be looked upon as works of artificial irrigation—that they will ultimately become so, I have no doubt whatever.* The land will make its claim good to every drop of water and every ounce of manure, in spite of all that may be done to prevent it. It will, in the proper place, be shown in how remarkably favorable a position Madras is situated for the utilization of its sewage.

The next argument against sewers will be seen from the following extract:—

“India, for many months of the year, is a dry and thirsty land, so greedy of moisture, that unless sewers be built of some less absorbent material than brick and mortar, the soil will take up all the watery parts of the sewage, leaving the solids to choke up the artificial channels. This state of things obtains in the town of Madras throughout the hot and dry seasons, and it is no wonder that, under such circumstances, the odour of our drains should have obtained a proverbially evil repute.

“Of Madras it has been averred by competent authority, that before the construction of drains, its abominations were not so noticeable as they have since become. The attempts hitherto made to follow in Indian towns the European model of sewerage, have undoubtedly had the effect of making those towns more pestiferous than they were before sewers were thought of.”†

No attempts, that can really be called such, have yet been made to follow the European model of sewerage. It is notorious that in Madras the worst kind of bricks and ordinary (not even hydraulic) mortar have been used. The mortar, moreover, is made of *shell lime*.† It is not extraordinary, therefore that the drains should be a nuisance. But to argue that because bad materials are used in Madras all sewers are objectionable, is tantamount to saying that because bad flour is sometimes used all bread is unwholesome. If proper bricks and proper hydraulic mortar are used, sewers could not be objected to. In the project now submitted, I have provided that steam-pressed bricks only shall be used, and that they shall be set in hydraulic cement, and that the sewers shall be lined *throughout* with a coating of asphalt. The subject of materials is so entirely a professional one, that I will not pursue it further in this place.

There is really no similarity at all between the European model of sewerage and the system which has been carried out in Madras. It is absurd to compare the two. In Madras the street drains are all open—in England they are always closed. In Madras the drains are near the

* Already the sewage of Bangalore fetches money; it is true a very small sum, but time must be given to enable the people to learn the full value of liquid manure.

† *Vide* page 8 of Doctor Cornish's Pamphlet.

surface—in England they are at a considerably depth underground. In Madras no attention whatever is paid to the slopes of the drains—whereas in England the inclinations are regulated on scientific principles, and the drains are laid with almost mathematical precision.

Now, when it is remembered that the whole question of drainage is one of slope—that it is necessary that every single drain and pipe should be laid with the utmost care and at such an inclination as shall enable it to keep itself free from deposit—and when nothing of this kind is attempted in Madras, where the drains are built solely with reference to the slope of the surface of the ground, and not at all with regard to the inclination which each drain should have—is it surprising that the present drainage system should be a failure and a nuisance? It would, on the contrary, be extraordinary if it were otherwise. The Madras sewerage has failed simply because it is totally *unlike* the model system adopted in England. So far, therefore, from being discouraged by the present state of the Madras drains, we should rather be encouraged by it to give the European system what it has not yet had,—a trial.

The next objection to sewers is, that they create a great nuisance, and this, if it were true of a proper system of sewers only, and not of other systems of conservancy, would certainly be a more valid one than any yet brought forward. But unfortunately, this nuisance is an objection to all systems of conservancy. Where foul matter is disposed of, there must be more or less smell. Latrines on the dry conservancy principle are not inodorous, but merely less offensive than those in which water is used.* And dry conservancy after all contemplates merely the removal of excrementitious matters, and leaves the question of the nuisance caused by refuse water untouched. So what is to be done? Sewers remove *all* liquid refuse with a little nuisance. Dry conservancy, so far as it goes, removes some of the refuse with, say, less nuisance,—but unfortunately it does not go very far, for it leaves at least nineteen-twentieths of the refuse behind. We are merely on the horns of a dilemma, and must choose between two evils. Of these, sewers are incomparably the less evil, because, at least, they do form a *complete* system, and the effect of them is known, but dry conservancy is merely a partial *expedient*, and the fearful consequences of leaving waste water stagnating about our dwellings

* If there is any doubt of this, a visit to the model latrine on the north bank of the Cooum near Poodeopet will convince the most sceptical.

cannot be foreseen. To combine the two systems, *i. e.*, to utilize excrementitious matters in public privies on dry conservancy principles and to have a system of sewers, would be impossible. The expense of such an arrangement would ruin even Bombay itself.

Those who exaggerate the nuisance caused by sewers should remember that in a very short time this will be no argument at all. The subject of deodorizing and disinfecting sewage is in a most hopeful state. Already it has been announced that the Thames *can* be disinfected for £20,000 a year. That is not a large sum for so great a sewer. Mr. Norton's experiments in Madras, moreover, have not been so unsuccessful that it can be said sewers will never be disinfected cheaply; that they *can* be disinfected, there is no doubt. The question now has resolved itself into one of expense only. Some of the greatest analytical chemists of the day have declared that it is quite possible both to prevent any smell arising from sewers, and to retain at the same time the manuring properties of the sewage. Indeed, in England, antiseptics *are already used* with the best effects. For Madras, I have arranged that the sewers shall be throughout ventilated through charcoal disinfectors, a plan which is found to answer admirably in Europe.

A great authority on Indian Sanitation (Dr. Norman Chevers, of Calcutta) has been cited as being opposed to the principle of sewers. It is best therefore to quote what he really *does* say (*vide* Indian Annals of Medical Science, No. XVII.)

"The feculent excreta and every kind of solid filth, road scrapings, and sweepings, stable-litter, the refuse of knackeries, markets, tan-yards, urinaries, gardens, cook-rooms, &c., &c., &c., being collected and carried away in conservancy carts; the fluid sewage of the city, that is, all liquid matter from manufactories, markets, gas-works, cook-rooms, &c., &c., which could not be removed in conservancy carts, being properly diluted and flushed onward with an abundant supply of fresh water, at high pressure; should be voided by a system of underground sewers of very moderate capacity, the inlets of which ought to be secured against the entrance of storm-water and of all solid refuse; while the whole rain-water, except such portion of it as may be required to flush the sewers, &c., should be carried off by a system of open surface drains."

I beg respectfully to draw the attention of Government to Doctor Chever's views on the subject of drainage as meriting great consideration at the present time. I believe them to be the true principles on which drainage works in this country should be carried out, and the only broad principles on which success can be ensured at least cost. I arrived at the very same

conclusion as Doctor Chevers has done, very soon after I commenced the preparation of this project for the drainage of Madras, and, further on in this Report, I have brought forward all the facts which I had collected to show the difficulty of following the English plan of sewerage, in Madras or in those parts of the Presidency where the total rain-fall was obtained in a few days, and the enormous expense it would entail. The proposition now made for the drainage of Madras, viz., to separate rain-water from sewage—to carry away the former by open surface drains, and the latter by sewers of moderate capacity, will, I trust, be received by Government with greater favor, now that it is put forward by an eminent man, than if it had been made myself alone.

(To be continued).

No. CXXXI.

IMPROVEMENTS IN NAVIGATION OF INDIAN RIVERS.

By W. H. LONGMORE, Esq., Assist. Engineer, Ganges River Works.

THE Navigation of our Indian Rivers has attracted a great deal of attention, and the question has often been raised whether it is possible to improve these large streams and make them more thoroughly subserve the interests of trade and commerce generally. I think this can be answered satisfactorily.

The uncertainty and danger attendant upon the navigation of the Ganges in the dry season are, as is well known,—due to the ever changing current, and shifting shoals, which abound in the whole course of the stream, and the want of sufficient depth at times for crossing these shoals. During the rains there is abundance of water for navigation, and deeply laden boats can then pass over the sand banks scattered along its bed, which are high and dry at the lowest state of the river.

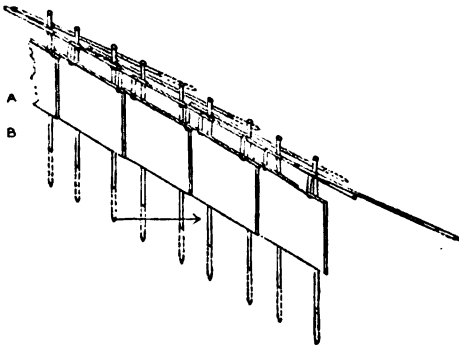
These sand banks can be seen to a vast extent at the entrance of the Bhagurruttee, extending for some miles, and forming a complete bar to it. This branch of the Ganges is rarely open even for boats of the least draught during the dry season. That it should be kept open is of great importance, and which is fully recognized by the Government expending large sums annually for this purpose, sometimes successfully, but as a rule unsuccessfully, except, so far as preventing it closing so soon as it might if left to itself. The Bhagurruttee connects Calcutta with the main Ganges, and in the rains is used by the large river steamers; and by all the country boats conveying produce from above Rajmahal to Calcutta, whose draught in many instances is three times that of the steamers. As the river falls, the larger boats are forced to go down the main stream; next the steamers are obliged to give it up, and go round the Sunderbunds,

until at last, when the river is at its lowest—supposing the entrance is open—boats of 20 or 24 inches draught can only pass through.

The works employed to keep it open, are identical with those employed for deepening shoals in the main stream, and may be called native works, as there is not a particle of English Engineering about them.

They consist of bamboos fixed at intervals in lines inclined to the stream

Fig. 1.

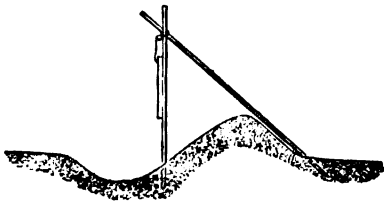


—along these others are tied longitudinally, on which mats are hung facing the stream, the rear being supported by struts. In constructing these, two points have to be attended to. The piles after being well shaken into the sand should be driven down with mallets, and in placing the mats

a space shown at AB must be left between their lower edge and the bed of the stream—the mats overlapping one another. Such a work is called a *bandel*.

The principle of its action is to collect the sand carried by the stream

Fig. 2.



and deposit it at the back of the bandel. If the mats were carried to the bottom this would not be the case, and hence a space is left for the water to pass carrying the sand with it, and which as a rule, cuts a deep trench in front of the bandel,

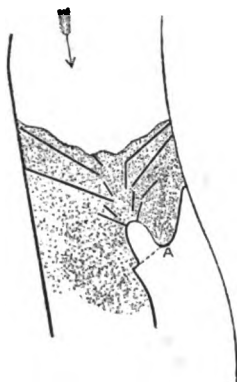
as shown in Fig. 2.

The defects of this system are—1st, its buoyancy; 2nd, its porousness; and 3rd, its limited application, due principally to the first defect. If the materials were heavier, then it might be placed in deep water; but to retain it for any length of time, even in the shallowest parts of the stream, it is necessary to have the piles constantly driven down, as they are always liable to be washed up and floated away. I have seen whole lines carried away in one night from this cause.

The second defect, arising from the openness of the mats, is not so detrimental as the former. A certain quantity of water passes through them without being of the slightest use. On the contrary, its effect is rather injurious; for it increases the current at the back of the bandel, and assists in carrying off the finer particles of sand, which would go towards the accumulations in the rear. In some cases it is requisite to stop the current altogether, under these circumstances the mats but very imperfectly perform their intended office.

Bandels are generally arranged as shown in Fig. 3, which represents

Fig. 3.



their position when first laid down. After they have been in operation some little time, the sand will commence to accumulate at the lower end and will fill up as far as A. To meet this lengthening of the channel, other lines of bandels have to be added, and continued as far as the filling up extends.

Seeing that the common bandel was utterly useless for working in a deep and strong current, I considered whether something might not be done with its materials to form a construction that would answer this purpose. The plan I adopted was very successful, and enabled me to advance

into the centre of the Ganges, and turn a part of its current in the direction it was required; and this too, when it was flowing some five miles per hour, and 15 feet deep.

The great difficulty to contend with in its construction was the same as with the common bandel—the buoyancy of the material—but when once constructed, there it remained, and gave not the least alarm about its being carried away by the current. The construction is fully shown in Fig. 4.

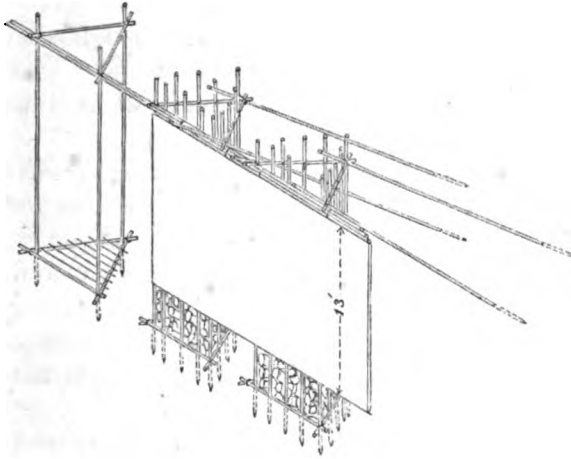
These *groins* were formed by a number of piers, triangular in shape, placed at intervals and tied firmly together.

Each pier was constructed thus—3 piles were driven to form as near as possible an equilateral triangle; over these a triangular curb, crossed with small bamboos, to form a sort of gridiron, was dropped and forced to the bottom.

The upper part was then tied to form a triangle similar to the lower, and piles were driven at intervals along all these sides and the interior filled with sand bags, made of mats rolled into a cylindrical shape and well rammed.

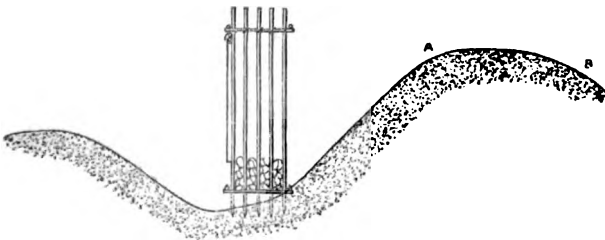
After this the mats were applied, measuring 20 feet $\times$ 3 inches, made by

Fig. 4.



tying the small mats on to a frame work of bamboos. As soon as one side of the frame was fastened to the piers, the boats carrying them were withdrawn, and the force of the current carried it close in; often with such force as to make the whole groin creak and bend again. To prevent the escape of any of the sand bags, the lower curb was fastened to the top one with stout string.

Fig. 5.



The triangular shape of the piers was found advantageous. The water rushing through the opening between the piers spreads out on either side, cuts away the sand and tends to tilt the pier over—this is counteracted by the struts, and its connection with the other portions of the

work—the sand under and in front is then cut away, and the pier sinks; in some cases inclined forwards, in others to the rear, but generally vertically, depositing a great mass of sand behind (*see* Fig. 5). In a depth of 12 feet, I have witnessed 10 feet shoaled up in the course of a couple of days, extending in one line for a distance of 150 yards, and at least 15 feet broad.

All the coarser sand is deposited at A—the finer is carried and deposited in the direction of B.

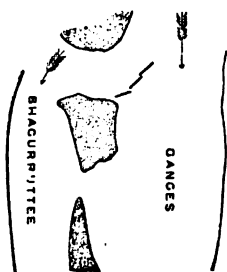
Position for Works.—It is impossible to lay down any rule or number of rules that shall be applicable to all the various phenomena of the river,—for fixing the works.

Each reach of the river requires different treatment at different periods of the same season, and in each year invariably so. In laying down any principle for guidance, the chances are that the physical characteristics on which it is based, may not be fully recognised, and it will therefore be a failure.

The contour of the banks may be safely taken for guidance when the river is high. The deepest and strongest current will run along its concave side, from whence the bed will gradually slope up, forming a sand bank or shoal on its convex side. And a shoal generally exists running obliquely across the river, from the point where the current passes, and from one bank to the other. But when the river is low, the banks afford very little indication where the current is deepest and strongest.

Before deciding upon any line of action, it is very necessary to take

Fig. 6.



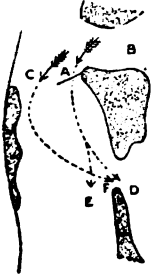
soundings regularly, to ascertain any change that may be taking place in the bed of the stream, and to what part it is likely to tend. In case it has to be diverted from one direction to another, it is best to work in curves as much as possible, that the water may lose but little of its initial velocity; but where the channel can be made straight and preserved so, it should be carried out accordingly. For diverting the main stream of the Ganges, I used curved groins, and found them answer exceedingly well. I arranged

them as shown in Fig. 6.

It is often difficult to determine the effect a proposed groin may have

when there are a number of channels and currents. This will be shown on

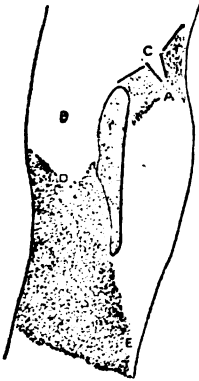
Fig 7.



reference to Fig. 7. A strong current runs down B to A, passes and divides into two currents D, E. A groin at A, it might be supposed would divert more down to E: it may however have a contrary effect, for the current at A finding itself arrested would turn off in the direction C and form a curve to F, a direction less favorable for the current down E. Then it might be urged that closing D would answer this end. Even this is problematical. For the draw on the current down B, which must be kept deep, would be slackened, and it would tend to silt up, except it was closed long before the river reached its lowest.

In deepening a shoal the two nearest and deepest portions of the upper and lower reaches should be connected, even though somewhat oblique to

Fig. 8.



the current, when the quantity of sand to be carried off is less than where the current is more direct. For, apart from the greater quantity of sand to be removed and the tendency of the stream to economise its own force, it will be found, that the relative levels in the two reaches are different (see Fig. 8). A will be lower than B, and for this reason, that in A, there is nothing to back up the stream higher than E; whereas in B, it is backed up from D, causing a head of water there which is all employed in forcing itself and its sand down to E. The difference of level is only apparent when the stream has nearly reached its lowest point.

Bandels arranged at C, before it has reached this, would aid in opening a channel, and be ready for the lowest state of the river when a current would set through it, and to assist which the bank at D should be shoaled up.

An immense quantity of sand is carried down by our Indian rivers, which travels along the bed, and is not taken into account when the sedimentary matters held in suspension are being determined; and yet, this is by far the more important of the two in forming shoals and sand banks along the course of a stream, and more particularly at its mouth. In a

current flowing at five or six miles per hour the upper 6 inches of sand on the bottom is all "alive," and moving down very fast. Resistance to anything passing through it is scarcely greater than that of water. In the course of three days, I have seen a sand bank several miles long and half a mile broad, increased 3 feet in height, and this could only be a small part of the quantity carried down in the deeper part of the stream.

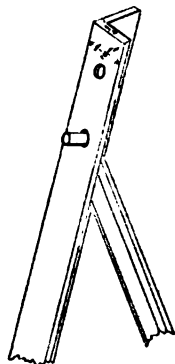
During the rains the bed is always relatively higher than in the dry season. This does not arise from the stream having greater breadth, and, consequently, less velocity; for the velocity is much greater as well as the stream being much broader. It must arise then, from the immense quantity of sand carried into its bed, and which with its increased velocity and breadth, is more than it can carry down for the time. The stream is literally overloaded, and at every favorable position we are sure to find immense deposits at these times.

On the subsidence of the river, the velocity and breadth decrease, and the depth goes on increasing, until in some cases, the bed is 6 or 8 feet lower than in the rains. This is very important in its bearing upon the navigation of the Bhagurruttee. For, if the channel leading to it is not deepened steadily to keep pace with the deepening of the main stream, it is quite evident it must be dried up.

Improved Appliances.—I have already noticed the chief defect in the native bandel—its buoyancy. To remedy this, I would propose wrought-iron sheets instead of mats, retaining the bamboo piles and struts. The weight of the sheets would keep these in their position and prevent their being washed away. In addition to which, being impervious to water, their action would be more complete, and further would afford the means of cutting off a shallow current entirely, which is often very desirable, but with the old bandel quite impossible.

For deep water, I should propose a larger bandel made principally of iron, *see* Fig. 9, which shows the junction of the strut and pile, both made of angle iron; the facing might be of mats as usual. It would act very well and be quite sufficient for all the more important works on the Ganges; and the common bandel, when improved, as suggested, would be found amply sufficient for all works on its branches.

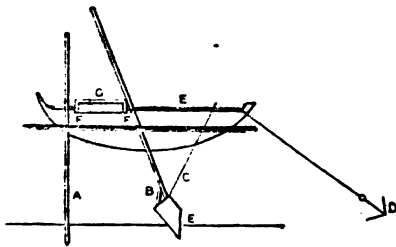
Fig. 9.



The expense could not be greater than the present system ; as one line would be as effective as three ordinary ones, and though the first cost would be a little more, still in mats and bamboos there would be a great saving, without taking into consideration the immense amount of labor that would be saved, both in construction and in keeping down, or in attempting to keep down, the old style of bandel ; and which, in spite of all precautions, causes great loss by being washed away.

Dredging on a limited scale would be of great assistance in opening a

Fig. 10.



channel through shoals when bandels had already been constructed. For this purpose a steam dredge would not be required. A simple apparatus, to be worked by hand, is all that is necessary, and which might be easily rigged up. Something like Fig. 10, perhaps

would answer ; 5 or 6 feet is all it would have to work in, and that principally at the upper end of the channel, when the current being slacker there would be the most need for it.

A—Pile for keeping boat steady.

B—Scoop.

C—Rope for raising scoop.

D—Anchor.

E—Platform on which to throw the stuff.

FF—Beams tying sides of boat.

G—Platform for men to work the scoops.

Raking up the sand, by drawing a "burrow" through it to be carried off by the stream, has been tried, but found not to answer. This would be very effective in clay, or clay and sand, but in sand alone, lying for some distance along a shallow channel, its action would be very limited.

With the view of obviating the necessity of keeping open the Bhagur-uttee by costly works, it has been considered that a cut from the main stream into this branch would be far preferable, and secure at all times a sure passage for navigable purposes. A great deal may be urged against this plan. In the first place, it is not certain that the Ganges would continue to flow near its head, for one year even ; and for many, it is pretty

certain not to do so. In the next place, the cut must be very deep to allow the Ganges, when at its lowest, to flow through. And in the rains a heavy current would rush through, dividing the banks, making it in a very short time, in all its physical characteristics identical with a natural stream. If to avoid this action, locks were placed at its head, it would make no difference to the depth, as there would be no supply of water in the dry season higher than the bed of the Ganges. Besides, these works would be of a most expensive character and liable in any single year to be swept away or left embedded in a sand bank. Making such a cut therefore appears at best hazardous—it might remain open and be very serviceable, but for how long it is impossible to say;—but the chances are against it.

A plan was once proposed to let down immense iron pontoons into the bed of the Ganges for turning the stream down the Bhaguruttee, to be pumped dry and raised again when required. How would this answer? In the first place they must have a very large base, and be of immense weight to oppose the mighty current of the Ganges, otherwise they would be carried away like a ball. If anchored, they would become buried in sand, and although in the right place this year, they would not be next, and must be removed. If under the water, this would be a difficult operation; if on a dry sand bank, there would be the pumping, dry-digging away the sand, and hauling them to the water; requiring a set of apparatus nearly as costly as the pontoons themselves, and a large amount of labor. The plan is totally inapplicable to the circumstances—cumbersome and unwieldy in the extreme—as well as being most expensive in first cost and operation.

Works for Tidal Compartment.—I have not had the means of testing the suitability of the works already described, to the tidal compartment of our rivers; but I have no hesitation in saying, that they might be found most beneficial. Their simplicity, the ease with which they can be put down or taken up in the strongest current, would be found highly advantageous for the above purpose.

To meet the requirements of a double current it would be necessary to adopt some means to prevent the sand lodged behind the groin being carried back by the return current. This might be accomplished by having a double line of works (*see* Fig. 11). The facing of which, whether of mats or sheet iron, should be fastened down securely to prevent its rising with the

return current. There would be very little current at A, whichever way the current ran, and a constant accumulation of sand would go on here under the united action of both groins. The larger class of bandel described in page 34, I think would be lost. A trial on a small scale in a shallow part of the river, of the works already described, which surpassed my most sanguine expectations when tried in the Ganges, and the results of the trial carefully noted, might lead to a further and more complete plan for the final improvement of the Hoogly. I believe we have a system, truly an Indian one, which might, by further improvement, be developed into one peculiarly adapted for Indian rivers.

Cawnpore,
August 24th, 1866.

W. H. L.



No. CXXXII.

PUBLIC WORKS IN BERAR.

By HENRY HOOPER FOORD, A. Inst. C.E.

BERAR, better known as the "Hyderabad Assigned Districts," is the northern portion of H. H. the Nizam's Dominions, assigned by the Nizam to the British Government as a guarantee for the regular payment of the Hyderabad Contingent, a force he is obliged to keep up in fulfilment of treaties. Berar has an area of 16,000 square miles, and is bounded on the north and east by the Central Provinces, on the west by Candeish, and south by the Nizam's Territories. It is divided into four Districts, under Deputy Commissioners, supervised by a Commissioner; he again is under the immediate orders of the Resident at Hyderabad. The great importance of Berar arises from the immense quantities of cotton grown in the districts generally, and in the valley of the Poorna in particular; during the American war, cotton reached prices that have enabled the cultivators to release themselves completely from the hands of the Sowkars, and to amass what, to them, have been large fortunes.

The geological character of the district is trap; this is found in the three stages of hard black basalt, decomposed basalt or moorum, and black soil. In the northern range of hills, known as the Satpoora hills, sandstone and lime-stone are found in considerable quantities; also to the south, in the Woon districts, near Oomrowutty, laterite can be obtained, but it is too decomposed to be utilized—crumbling away when exposed to the effects of the weather.

The rain-fall in Berar is very uncertain, averaging from 25 to 42

inches; this falls at intervals of about a fortnight; at times there is a heavy fall for three or four days, then a break of a fortnight, then another heavy fall. These periodical falls are called in Mahratta, Nuck-shuttras.

Irrigation Works.—With the exception of damming up a small nullah at the village of Wangolee, near Ellichpoor, little or nothing has been done in the way of irrigation; the few old works originally built by the Mahrattas, were allowed to fall into ruins long before the English Government took the districts under their charge, and since then, little or nothing has been done towards repairing the old works. Of Tanks there are none, with the exception of a few in Woon, and two or three in the Moorsee Talook, in the extreme east of the district; the soil is not suited for tanks, as it will not hold water, and no clay is procurable for puddling. A great amount of water could be collected and utilized by the building of Anicuts across the streams; many streams are already dammed year after year temporarily, by the villagers, and the water used for irrigation; as they are at the expense of these anicuts, no extra revenue is obtained. As to Drainage and Sewage there is none, but within the last few weeks, since the appointment of Major Nembhard as Commissioner, great activity has been displayed in improving the sanitary condition of the towns by surface drainage and the erection of latrines. The villages are collections of mud hovels with thatched roofs; no attention has been paid to laying out streets regularly; most villages are surrounded with the ruins of mud walls; these walls were built to protect the inhabitants against plunderers and dacoits. Of late years, owing to the better Government of the country, they have not been required, and have been allowed to fall into ruin, and should now be levelled so as to allow of the free circulation of air.

The commercial capital of Berar is Oomrowutty, situated six miles north of the Budnaira Railway Station; it is a large, walled, town; the walls, which are of masonry, are in an excellent state of repair; the houses of Sowkars and cotton merchants are large substantial buildings; the streets are very narrow; the want of air and drainage, the numerous cess-pools, the ruined houses used as latrines, cause altogether a collection of smells, that it is almost impossible to describe, and still more to imagine. The Commissioner is now opening out the town and improving the drainage. Khamgaum, in west Berar, is the second most important commercial mart. The third is Tirralah. Karunjah, formerly a wealthy and busy centre of

cotton traffic, has now lost all its importance, by the railway passing so far from it. The head quarters of all the departments is Akolah. The railway passes through the station, and Akolah is thus the best situated town that could have been chosen for the political capital of the Province. At Akolah, a large jail, court houses for the Commissioner and Deputy Commissioner, hospitals, schools, &c., have been built; a church will be built eventually. Ecclesiastical buildings appear to be put off to the last, there not being one place of Protestant worship in the whole district.

The Nagpoor extension of the G. I. P. Railway passes through Berar, traversing its whole length from west to east. With a view of placing the principal towns in communication with the railway, within the last few years, Government have devoted some funds for the formation of roads north and south from the railway. Of these six have been sanctioned as first class roads, and the remainder as fair weather roads; as yet only one has been completed, and that is from the railway station at Nandoora to Khamgaum, 12 miles in length; and even on this road the only two really large rivers have been left unbridged.

The first railway station on entering Berar is Mulkapoor, from this there are no roads, although the town is large and an Assistant Commissioner is permanently stationed there, and for whose accommodation a court house and residence, police and prison buildings are being erected; from the next station, Nandoora, a road, as mentioned above, has been completed to Khamgaum south of the railway, and another has been made to Julgaum north, the latter is a fair weather road, altogether impassable in the rains. The third station is Sheagaum; from here three fair weather roads have been made, two to the south to Khamgaum and Ballapoor, each 12 miles in length; and one to the north to Bawunbeer. The road from Sheagaum to Ballapoor is only crossed by one large nullah, and this even does not hinder traffic above an hour or two in floods; the large unbridged river, near Ballapoor on the Sheagaum and Ballapoor road, and the Poorna on the Sheagaum and Bawunbeer road, offer very considerable hindrance to traffic; besides this, these two roads run over deep black soil, which becomes totally impassable for wheeled carriage throughout the rains. From the fourth railway station, Akolah, two roads are in course of construction, one north to Akota, 30 miles in length, and one south to Mallagaum, 40 miles in length. The former road is nearly complete; but on this, as on every other

road, the large rivers have been left unbridged, viz., the Poorna and Shanoor, and a length of about 3 miles between them. At Akote, and its immediate neighbourhood, the best cotton is grown. The Akote road has been metalled throughout with sand, and is now fit for wheel traffic at all seasons of the year, with the exception of the two rivers and the space between them. The Mallagaum road has been completely bridged, with the exception of six large rivers, and the earthwork has been completed—all work on it has been stopped for want of funds—when money is available it will be metalled with moorum (decomposed basalt) and sand; sand is a good covering to moorum roads; it prevents dust rising during the dry season; and in the monsoon, the water passes through it and it affords a dry footing for pedestrians. It is proposed to carry on this road eventually to Hingolee, a large military station in the Nizam's country, 8 miles from the boundary of the Hyderabad Assigned Districts—the extension will be 40 miles in length.

From Moortoogapoor, the fifth station, two roads have been sanctioned; one a fair weather road to Unjungaum, 40 miles in length; this has been completed, but here again the Poorna crosses the road and stops all traffic in rains; the road to the south has been completed as a metalled and bridged road, with the exception of two or three of the large bridges; which, however will be built, as the road has been sanctioned as a fully bridged road.

From Budnaira the most important station on the railway in Berar, two fair weather roads have been made to the south, each about 20 miles in length, to Salode and Karinjah; the two to the north have been sanctioned as first class thoroughly bridged and metalled roads; the first from Budnaira to Moorsee passing through Oomrowutty. From Budnaira to Oomrowutty, owing to the immense amount of traffic the road is being metalled with broken stone, and from Oomrowutty to Monsee with moorum and sand. The second road is to Ellichpoor; for the first 6 miles it takes the same line as the Budnaira and Oomrowutty road, and branches off at Oomrowutty, passing close to the walls of the town, and is continued on to Ellichpoor, a further distance of 30 miles; this road is important as connecting Ellichpoor, a military station with the railway, and is also the route to the hill Sanatarium of Chickulda situated in the Sutpoora range. In the construction of the Ellichpoor road great difficulties had to be contended against in procuring material—stone was carted 20 miles,

water, three and four miles, sand for metalling, in some parts, seven miles. The average cost of the road per mile has been nearly Rs. 12,000. The Poorna, Peila, and Belgaum rivers are still unbridged, owing to the great estimated cost of bridges. The remainder of the road is bridged. Great credit is due to Mr. A. Izat, C. E., Assistant Engineer, in charge of the road, for the great skill evinced in its construction, and the indomitable perseverance and energy shown in overcoming the difficulties in procuring labor and materials. The Budnaira and Moorsee road has been many years in progress; the annual small grants prevent any works being done, or very little. No better example can be given of the draw back of annual small grants for a large work, than by comparing the progress of the Imperial Road between Budnaira and Moorsee with the railway—before the railway was completed to the Thulghat, this road was commenced; since then the Thulghat has been made, and some 350 miles of line completed to the east of it, and yet the Budnaira and Moorsee road is not completed, nor is there any chance of its being completed with the present small annual grants for another 10 years. This slow progress is no fault of the D. P. Works, but arises simply from the fact that only the surplus revenue of Berar is available for Public Works. Everything and everyone is first to be paid, and the balance given for Public Works.

The last station on the railway, within the limits of Berar, is Chandoor, from here, two fair weather roads have been completed, one north to Koora, 12 miles, and one south to Yeotmal, the head quarters of the Woon district; both roads are fair weather roads.

In addition to the above roads, the principal village tracks are annually repaired and improved by the Local Fund Engineers; but owing to the deep black soil of the country over which nearly all the roads pass, the greater part of the cart traffic is absolutely put a stop to for four or five months of each year. At several of the railway stations, dâk bungalows for Europeans, and serais for native travellers have been built; wells have also been excavated and trees planted with a view of forming encamping grounds. A few bungalows for the accommodation of travellers have been built on the principal roads, but many more are required. The public buildings in Berar are well built, and have a handsome appearance; the large Jail now in course of construction at Oomro-wutty, under Captain Burton, R.E., is a good specimen of rubble work. Government were induced to allow this to be built pukka throughout—there

is no worse economy than building with mud in Berar—the bricks are vile, the clay for building is worse. After careful calculation and a lengthened experience in building kutchas, only one conclusion is arrived at, and that is that it costs more to plaster, point, and otherwise protect a kutchas building in Berar than to build it properly at first.

No labor is procurable in Berar, the scanty population of the Province find it more profitable to work in the fields than to work either for Government or any private company, so all labor has to be imported. The greater part of the skilled labor, such as bricklayers and brickmakers, stone masons, carpenters, tile-makers, and lime burners, come from Secunderabad. Coolies are procurable in all the villages in the Nizam's country. Some now employed in Berar, brought originally from the Nizam's country, have worked for the Department three years, with occasional leave of absence during the rains. Nearly, if not the whole of the work in Berar has been done by contract; the small native contractors generally require an immense amount of watching to prevent their scamping the work; they are also very troublesome in settling with finally, denying measurements, payments, and often their own written statements and signatures; every one of them declare they work at a loss, and yet after having indulged themselves in a great deal of perjury and false swearing, on the conclusion of one job, they after a little, importune for a fresh one. The hungry vakeels that throng the courts induce these men it is believed to file suits, the arrangement being to go halves in case of winning the case, and to receive the stated fee or percentage on amount claimed if they lose; the vakeel in either case makes something.

The establishment kept up for supervising the Public Works in Berar consists of two Executive Engineers, and two Assistants, four Assistant Overseers, and a small temporary establishment of Sub-overseers; the Superintending Engineer being also Secretary to the Resident at Hyderabad, is necessarily obliged to reside at Hyderabad, visiting Berar as often as possible. In addition to the Public Works' Engineers, in each of the four Districts there is either a Local Fund Engineer, or subordinate. These officers undertake the building of police stations, travellers' bungalows, serais, town improvements, and the improvements of village roads. The wants of Berar are *roads* and *irrigation works*, a larger Public Works Establishment, and a much larger annual grant; the savings from the revenue will not approximate for years to come to what should be expended. As.

the works are emergent, a loan only will meet the difficulty; it is a fair and just method of paying for Public Works, for why should the present generation only, have to pay for works that will benefit posterity, even in a greater measure than it will them? A short time since, a Memo. was in course of being prepared, showing the cost of metalling and bridging all the roads reported as emergently necessary, and of the public buildings required for Civil officers, and of irrigation works that were certain to be highly remunerative—before one-half of the expenditure was calculated, it was discovered that the probable annual grants for the next quarter of a century would not suffice, so the list was destroyed after seeing the hopelessness of trying to concentrate the work of years in four or five, as no funds were available.

No. CXXXIII.

IRON SLEEPERS ON INDIAN RAILWAYS.

THE very heavy cost of maintenance of way on some of the Indian lines, owing to the rapid deterioration of the wooden sleepers, having attracted the notice of Government, opinions were asked for from the Chief Engineers and other Officials of the several lines, as to the comparative merits of Iron and Timber sleepers, and the advisability of adopting the former in all future cases.

The only system of Iron Way which has been employed to any extent in India is Greaves', consisting, as is well known, of cast-iron hemispherical bowls, on which a chair of the usual form is cast; each pair of bowls being connected by a wrought-iron tie, by which the gauge is actually preserved.

The following is an abstract of the most important opinions obtained on the subject. Although there is some difference of opinion, the balance of facts seems to determine that for sand ballast, for not too heavy a traffic and for not too great a speed, Greaves' sleepers answer exceedingly well. When the ballast is of hard material, such as broken brick or kunkur, there appears to be danger of the bowls breaking, especially at high speeds. Appended will be found a description of a *Wrought-iron Road* which has been patented by Mr. Sibley, Chief Engineer, E. I. R. (Upper Section), and which has been tried to a small extent with apparently satisfactory results.—[Ed.]

From W. G. Smart, Esq., Chief Engineer, Madras Railway.

The South-West Line, 406 miles, was originally laid with country timber sleepers. It was very soon discovered that the deterioration of the wood was so rapid that, unless a more durable material were substitu-

ted, a very large sum would have to be expended annually on renewals, and iron sleepers were introduced on the portion east of the Cauvery *i. e.*, 241 miles. On the Western Division, where timber of a better quality is procurable at moderate prices, the use of wood has been continued.

The Bangalore Branch and the North-West Line were originally laid with iron sleepers. The former was opened for public traffic on the 1st August, 1864, and the first portion of the latter was opened in 1861.

For the purposes of comparison, it will be best to take the statements of the cost of maintaining the North-West Line and the 4th Division of the South-West Line, as one is altogether an iron road, and the other altogether timber, and both have been open for traffic about the same time. The average cost of the first has been Rs. 54 per mile per month, and of the latter Rs. 108. The 3rd Division, of which 36 miles are iron, and 59 wood, averages Rs. 88. The 1st and 2nd Divisions are still in a transition state; the balance of iron sleepers required to complete the iron road being on the first Division 12 per cent. of the total number, and on the second 30 per cent. This circumstance accounts for the higher cost of maintenance.

As regards the effect of the iron road on rolling-stock, I subjoin extracts from two letters from the Locomotive Superintendent of this line; in the first, dated 12th June, 1863, he says :—

“I cannot well send in any official report until engines have been running long enough on the North-West Line to show appreciably what the wear and tear is on the tyres; a report sent in at this early period of its existence would be of little value, and might mislead, because we have not had a sufficient number of engines working solely on that line to enable me to deduce from their wear, fair average results.

“My own views are, like yours, decidedly in favor of the iron pot-sleeper road; and, speaking generally, I believe that our stock has suffered far more from the wooden sleeper road than from the iron road, on account of the sleepers being many of them defective and badly packed. Where the pot-sleepers are well packed, and laterite or sound ballast is used, I have always found the engines and stock to run smoothly and without jarring, and from our entire freedom from accident on the latter road, I should prefer seeing them in use throughout the line.

“The North-West Line is, as a whole, in my opinion, a less injurious road to rolling-stock than the South-West Line, and the engines and

- rolling-stock working on that line have required, if anything, less upholding than the stock generally on the South-West Line."

In a subsequent letter, Mr. Wright says:—

"No. 38 Engine ran 22,050 miles on the South-West Line, when she came in for repairs, and had her wheels turned up for the first time.

"When turned out of the shops, she was placed on the North-West Line, where she ran 27,348 miles, when she came into shed again, and had her wheels turned up.

"This result is in favor of the pot-sleeper road, more especially as engine wheels usually run a less number of miles after having been once turned up; the outer layer of metal generally being the most durable.

"It is, however, only fair to the wooden sleeper road to observe that, during the greater part of the time that No. 38 was running on the South West Line, the road between Madras and Vellore (where she ran) was, generally speaking, in very bad order."

Our rails on the North-West and Bangalore Line weigh 75 lbs. per yard. It is essential that the ballast should be of such a description as not to bind, and broken stones and coarse gravel should be carefully avoided. I find the best ballast to consist of a mixture of coarse sand and laterite gravel, or rotten granite, commonly called in this part of the country, moorum. Where the road is laid through rock cuttings and over bridges, I always use teak sleepers, as the iron requires a foundation possessing some degree of elasticity.

From the Deputy Chief Engineer, Permanent Way, to Chief Engineer, Madras Railway.—Dated 21st February, 1866.

Smoothness of road.—A road laid entirely with iron (on the Greaves' pot system) bears a very favorable comparison with one laid with good timber sleepers. It requires a smaller number of men per mile to make good "slacks" and unevenness of surface; and, if provided with a tie-bar to each pair of pots, is less liable to irregularities of gauge.

Wear and tear of rolling-stock.—Upon this subject, a reference must be made to the Locomotive Superintendent.

Proportionate number of breakages.—The number of breakages is exceedingly small. For instance, upon the first division of the South-West Line, over which there is a very heavy traffic, it amounted, during

the year 1865, to 544 pots, upon a total laid in the road of 283,559. This is equivalent to about 0.191 per cent. Some months back, I made an examination of broken pots in the road, and I arrived at the conclusion, that a large proportion of the fractures were originally due to defective loading or unloading, and not to concussions from rolling-stock after the pots were laid down.

Renewals.—During the year 1865, the cost of maintenance upon the North-West Line (an iron road throughout), including the renewals of fractured pots, averaged Rs. 61-5-11 per mile per mensem.

Upon the fourth division of the South-West Line (a road laid entirely with timber sleepers), where there is less traffic than upon the North-West Line, it averaged Rs. 132-6-9 per mile per mensem. From these figures it will be seen that, upon a road laid with iron, a saving can be effected, comparing it with a wooden road, of 54 per cent. upon the cost of maintenance.

Frequency of accidents.—Before we laid down iron-sleepers upon the South-West Line, trains were on several occasions thrown off the rails, owing to the bursting out of the wooden road. Since iron has been so extensively employed, we have been altogether free from accidents of this nature. In my opinion, an iron road laid with Greaves' sleepers is perfectly safe for trains at the highest speeds.

Ballast and packing.—The best description of ballast is sand or sand and rotten granite (moorum). Laterite is objectionable, for the simple reason that it cakes during the dry season, and retains moisture in wet weather; in the first case causing a certain amount of rigidity tending to fracture the pots; and in the second, rendering it difficult to pack them and maintain an even surface. The packing is effected by means of a rammer or crow-bar, working through the two circular holes cast in the side of the pot.

*From the Locomotive Superintendent, to Agent Madras Railway Company.—
Dated 28th March, 1866.*

With reference to your letter of 20th February, forwarding a printed Order of Government, having reference to the use of cast-iron pot-sleepers, I beg to inform you that, since their general introduction on this line, the wear and tear on engines and rolling-stock has been perceptibly

increased, the amount of injury being however, confined to the wear of tyres so far as it is appreciable.

On the opening of a portion of the North-West Line, where the pot road was particularly good, the results seemed at first very favorable, and we scarcely ever had a broken spring; whilst on the South-West Line they were continually breaking. This, however, was, no doubt, entirely due to the bad state of the wooden sleeper road between Madras and Vellore; and at that time the pot-sleeper road, judging from such limited statistics as I possessed, appeared to offer advantages as regards general wear and tear over the wooden sleeper road which then existed.

There can, however, be no question as to the superiority of the wooden sleeper road over the pot sleeper road as regards smooth running, both being alike equally well maintained; but the difficulty and expense of preserving and maintaining the wooden sleeper road in this country is so great, that, practically, I believe the pot-sleeper road to be on the whole the best and safest, and undoubtedly the cheapest description of road, and I think that these advantages will probably be found to outweigh the extra cost of repairs to rolling-stock.

I see no danger whatever in running trains at express speed, say at 50 miles an hour, upon a pot-sleeper road. Indeed, I have frequently run over it at this speed with special trains conveying His Excellency the Governor and others, and never experienced any indication that would lead to the supposition of its being an unsafe road for trains running at high speeds.

In those parts of the road where the ballast or material of which the road is formed, is of a yielding nature, there is little, if any, difference perceptible between it and the wooden sleeper road; but laterite, unless frequently opened up, is apt to cake and become very solid, in which case a harsh and unpleasant action is transmitted to the rolling-stock.

Upon the whole, however, the pot sleeper road appears to me to be particularly suitable for India.

From A. Shanks, Esq., Resident Engineer, Calcutta and S. E. Railway Company.—Dated 3rd February, 1866.

But few years having elapsed since the introduction of cast-iron sleepers

considerable difference of opinion exists as to the wisdom of bringing them into general use: for, no doubt, they possess bad qualities as well as advantages.

The short length of this line laid on pot-sleepers has not afforded me much opportunity of testing their merits or otherwise; ours are bedded in coarse sand; this being retained in position by a wall built on either side, the road is kept in order with little difficulty, and I find that, in running trains up to 45 miles per hour, the motion is smooth and agreeable, and I do not apprehend any danger from running at such a speed.

But it must be borne in mind that our sleepers are exceedingly strong, the pair weighing 210 pounds, (being, I understand, 75 per cent. *heavier* than those lately sent out for the East Indian Railway); they are, therefore, little liable to fracture; the first cost of them, as well as that of their carriage, is proportionally higher, and the retaining walls necessary in most localities raise their cost most materially over those of wood.

I am, therefore, of opinion that pot-sleepers of from 21 inches to 24 inches diameter, when made of *sufficient strength*, provided with good tie-bars, and *evenly packed* with sand or other *small* ballast, are safer and six-fold more durable than timber sleepers. The cost of the former will be nearly double that of the latter, and strict compliance with these conditions is most necessary to ensure success in their application on lines with heavy or fast traffic.

The life of a wooden sleeper, whether of creosoted pine, teak, or sal, cannot be reckoned at more than five or six years: I have found many of them perfectly rotten in much less time, and I doubt whether there are two opinions as to the danger to which traffic is exposed in being carried over them; their external appearance often leading one to suppose they are sound when they are really unsafe.

The subject of suitable sleepers for this climate has lately occupied a considerable share of my attention, and I am of opinion that much better results would be obtained from the use of *wrought-iron* transverse sleepers than any other yet tried: such a sleeper might be made 10 feet long and 10 inches broad, with its under side concave, the bearing area would thus be the same as that of the present wooden sleeper, their weight not more, and their strength much greater, while they would be five or six-fold more durable.

From reliable data, I find that such sleepers would only cost 25 to 30 per cent. more than those of wood, and the advantages which appear to

attach to such a size and shape should, certainly, warrant at least a trial of the principle.

Note by Chief Engineer, E. I. Railway, N. W. P., on the Greaves' Pot-sleepers used experimentally in the N. W. Provinces.—The Board having sent out 200,000 bowls (equal to 100,000 sleepers), it was determined that half should be used in Bengal, and half in the North Western Provinces.

Of these 100,000 bowls, 92,441 reached the Delhi District. The Store-keeper at Allahabad reported having 9,165 broken, or more or less damaged; he was directed to send forward all that would be serviceable for even temporary purposes; the result was the above number, of which 86,844 were put into the permanent road, chiefly between Khoorja and Dadree Stations.

Part was laid wholly with bowls, generally 7 pairs to the 20-foot rail; and part with timber sleepers on each side of the rail joint, and 5 pairs of bowls intermediately.

The former arrangement, though giving a little trouble at first from unequal yielding, is decidedly the best arrangement. The cross ties were at first placed only to each alternate pair of bowls, it was afterwards found necessary to put them to each pair.

The bowl road is laid wholly on kunkur ballast, and care was taken to have it broken fine for packing inside the bowls.

This length of road has, from the first, been the worst length on the Delhi District, and has taken much labor and expense to keep it in anything like travelling condition.

During the last six months, 1,410 bowls have been re-placed, but this does not at all represent the number actually broken, as, owing to the evils which arise from unequal packing, the opening of the road is deferred until it can be so no longer.

Any ballast that we can obtain, except hard clinker or stone (which would break the bowls), binds when broken and packed in the core; when a bowl is re-placed, if it be packed slightly higher than its neighbour, the latter receives a blow and breaks like a biscuit in the hollow of the hand.

With a sharp Thames sand or analogous ballast, which would give a firm bed without binding, this objection would be avoided.

Owing to the very unsatisfactory condition of the road, I had lately a

length of 345 feet of the road opened out and examined. Out of 210 bowls in the road, 90, or nearly 43 per cent. were broken, and in several cases, as many as 11 out of 14 under a pair of rails were broken.

In another portion of road subsequently examined, out of 150 bowls, no less than 79 are broken, more or less, and of these 64 are badly damaged. The ballast is kunkur, of average size and inclined to be soft. The bank is 5 feet high of good hard sandy loam. There are 5 pairs of bowls to each 23 feet rail, with timber sleepers at the joints.

The use of Greaves' pot-sleepers in the North Western Provinces must be regarded as resulting in decided failure.

I should add that most of the road has been under the charge of an Inspector who was on bowl roads in Madras.

In the correspondence forwarded from Bombay and Madras, it will be observed that the advocates of the bowl sleepers dwell less on the merits of the bowl sleepers than on the demerits of the timber sleepers. This course is no doubt admissible in discussing comparative merits; but as it is presumed that the object of this reference is rather to discover what is the best system of Permanent Way for India, it is well to note the above fact. All who have seen much of our cross sleeper road will be ready to admit the extremely unsatisfactory duration of all but the very first class of sleepers.

We have now a length in the Etawah District of inferior sleepers received from the Government Forest Agency, laid in 1861, of which nearly half have been renewed, and the majority of the remainder will probably have to be renewed within this year.

We have parts of the same district laid with first class sleepers 12 inches $\times$ 6 inches, of which scarcely any have been as yet renewed.

The avoidance of the evils attending the use of timber sleepers in this climate should not, in my opinion, lead to the use of cast-iron. Even were the behaviour of the pot-sleepers, when in the road, as comparatively satisfactory as it is decidedly the reverse, still the use of cast-iron would be most uneconomical as compared with wrought-iron.

This arises, first, from the heavy proportion which freight and subsequent land carriage bear to the original cost of imported iron; secondly, the greater weight of cast-iron necessary to obtain the same strength; and thirdly, the heavy per centage of fractures owing to the numerous transshipments and the fragile character of bowl sleepers.

It is to be noted also, that the fracture of one jaw of the chair attached to the bowl renders the whole useless.

From W. Bourne, Esq., Chief Engineer, to Agent, East Indian Railway Company.—Dated 1st March, 1866.

I deferred replying to your letter until I had received the Engineer's half-yearly Report upon the road laid with Greaves' patent bowl sleepers. The reports on the portion of the main line with these sleepers, for both the half-years ending June 1865 and December 1865, are unfavorable.

The facts upon which these reports were based are,—we laid a mile of experimental road at Undal, where our coal traffic is heavy; the road was carefully laid in and attended to. The result was that the breakage amounted to 7 per cent. per annum in the first half-year, and $7\frac{1}{2}$ per cent. per annum in the second half-year; that the cost of maintenance in the first half-year was 50 per cent. in excess of that of the wooden sleeper road, and in the second half-year 46 per cent. A portion of the Singarrun Branch line, where the traffic is not so heavy as at Undal, is also laid with the bowl sleepers; the breakages have not been so numerous, and the cost for labor in maintaining not so much as upon the main line, in fact, less than that upon the wooden sleeper road.

Both lines are laid with the same permanent-way and ballast, and it appears from the above facts, that the bowls would favorably compete with the wooden sleeper road where the traffic was light and the speed slow, but on our main line, with our heavy engines, and long heavy coal trains, that they are not so well adapted as the wooden sleeper road for the traffic.

The ballast we have used is of broken bricks and broken sandstone.

From Chief Engineer, to Agent, Punjab Railway.—Dated 3rd April, 1866.

In reply to your letter of 3rd February, and enclosure from the Government of India, relative to the use of cast-iron pot-sleepers, I have to report that, on 70 miles of the line laid with these sleepers, from Mooltan towards Lahore, only 1,000 have been removed,* while, on the 4 miles at Sher Shah, no breakages have occurred.

The laying of the permanent-way with these sleepers was commenced in

* Does this include the number broken and left in the road.—[Ed].

June 1863, and completed in August 1864, during which period material trains passed over it as the work proceeded, and since then, passengers, goods, and frequently ballast trains, have been running regularly.

The road was laid on the embankment, and earth used for boxing up; since then, for the greatest portion of the road, the earth has been cleared away nearly to the bottom of the pots, and the space filled in with broken bricks. The pots rest on, and are packed inside with, earth. The road is smooth and run over at the same speed as the sleeper road, and I am of opinion the wear and tear of rolling-stock is not greater than on a sleeper road, and that it is as free from accidents.

Mr. Nethersole, the District Engineer, reports :—" Both from personal knowledge, and from the experience of the plate-layers," I am of opinion that, " on the 70 miles of road laid on this district with iron pot-sleepers, the road will be (when boxing up is completed) equally as good for traffic as the wooden sleeper road; the trains run as smoothly over it, and it cannot, therefore, be considered a hard or rigid road." He further states, " several iron pots were put in originally slightly damaged, and owing to the rapidity with which the line was primarily linked in, many more were cracked; but, despite these disadvantages, I cannot find that 1,000 have been removed out of the 70 miles."

I may further mention, that only 1,985 sleepers have been broken in transit from Sher Shah during the construction of the line, including those taken out since the line was first laid.

From nearly eight years' experience of their use on the Egyptain Railway, between Alexandria and Cairo, I am of opinion, that with suitable ballast a good and smooth road may be maintained; and for the Delhi Railway, I propose bedding and packing the sleepers with sand, and covering the whole up with a top-dressing of kunkur or broken brick.

From Captain Sherard Osborn, R.N., Agent, Great Indian Peninsula Railway Company.

With the consent of the Directors of the Great Indian Peninsula Railway Company, I spent the interval between a mail for Bombay passing through Egypt, to collect the following information on the result of the long experience of the Railway Officials, in that country, of the efficiency and working of a line laid entirely on iron pot-sleepers, instead of the ordinary

wooden sleeper used in British India, and the following Memorandum is an abstract of a mass of notes made on the subject.

Mr. Hardcastle, Mr. Perry, and Abul Meyd Effendi, Civil Engineers in charge of different Sections of the Railway, all concurred in saying that, after eleven years' experience, the pot-sleeper, invented by Mr. Stephenson, appears equally well calculated for sandy soil, the rich black loam of the valley of the Nile (very similar to the black soil of India), or the hard unyielding surface of the country and cuttings between Cairo and Suez.

A large proportion of the pot sleepers introduced by Mr. Stephenson, some fourteen years ago, are still in excellent condition, and it appears to me that they were of a better quality than those more recently introduced into Egypt, so far as the quality of the iron was concerned, although there is no doubt that the form and shape have improved.

Edington's, of Glasgow, sleeper (pattern 1865) has a longer bearing for the rail on the crown of the sleeper, and the pot-sleeper itself is somewhat thicker in the crown than in the old pattern. This appears to be a considerable improvement; whilst Messrs. Greaves' patent pot-sleeper, from its larger area, was, in the opinion of one of the most experienced Permanent-Way Inspectors, admirably adapted for rock-cuttings, or in places where the pot-sleeper was liable to work down through the ballast to a hard unyielding surface.

But irrespective of the form of the pot-sleeper, it was very evident to me that as much depended upon the quality of the iron of which the sleeper is constructed, as the character of the wood does in a wooden sleeper.

The rule throughout the Egyptain Railway is to have seven pairs of pot-sleepers to every rail, and they average twenty-one feet in length. Of these seven pairs, four pairs are tied with iron tie-bars, and experience has shown that it is by no means advantageous to tie together a greater proportion of pot-sleepers, whether it be on curves or inclines however sharp, or however steep. The reason for this may be easily understood, when it is remembered that the great point with a permanent-way must be to preserve the gauge without destroying the necessary lateral elasticity of the road. I observed two curves of eight chains each near Cairo; the ordinary working curves on the line are twenty chains.

I allude to this point of leaving a certain number of pot-sleepers untied in every rail, because the Egyptian experience is at variance with the

opinion of the Chief Engineer of the Madras Railway in his Report, he being in favor of tying every pair of pot-sleepers in curves and on inclines.

The packing or *punning* of the pot-sleepers appears to be an important though simple measure in insuring the satisfactory construction of a permanent-way. The sleeper in all cases requires to have two holes : those with one hole only are now obsolete. Through these holes, the earth, or small ballast, is poured and rammed gently, until the interior of the sleeper is quite filled. It appears by no means desirable to ram the contents of the sleeper so as to destroy the elasticity of the road. In rock-cuttings and on hard surfaces, the pot-sleeper requires about fifteen inches of ballast to be spread before the sleeper is laid down. This will ensure the pot, if it is subsequently properly filled, not working its way down to the rock ; but I may mention that, in more places than one, I observed the edge of the sleeper quite down to the hard unyielding surface, without any injury appearing to occur to it—the interior of the pot-sleeper was, of course in all such cases well packed with ballast.

At one point, near Lake Mareotis, where the line had become perfectly rigid, and had formed from the amalgamation of lime, and sand, and iron, a hard conglomerate, the sleepers did appear to break in a great proportion than elsewhere ; the remedy for this was simply lifting the sleeper and relieving it, so as to restore the necessary elasticity to the road ; the rolling-stock, however, did not appear to suffer there more than elsewhere on the line.

On rocky surfaces, as well as where there is much lime in the soil, and the iron is disposed to bind with it, it is always best to lift the pots slightly at intervals of time so as to insure due elasticity. If this is done, they will stand for a long period. On earth banks which have consolidated, or on sand, the pot-sleepers require but little expenditure of labor, and I was informed that, with a road once in good order, one-half per cent. per annum was the average repairs of pot-sleepers.

In the main line Station of Alexandria, where there is a good deal of heavy shunting constantly going on, I was shown iron sleepers that had been down eight years, and were as good as ever.

The maintenance of the permanent-way in Egypt is in cost a mere bagatelle to that of the Indian Railways, and is carried on by a body of old soldiers who have gone through the first period of Military Service, under

the control of an old Officer. These are paid from the Railway Revenue, and instructed by the Railway Engineers.

I was told that the proportion of the Plate-layers to every five miles of road was sufficient to maintain a single line of rails after the road was once in good order. The condition of the permanent-way appeared to me to be better than the major portion of our own Railway.

From George Betts Bey, the Agent and General Superintendent of the Viceroy, as well as from the Locomotive Superintendent, I learned that they were both convinced of the superiority of an iron permanent-way over a wooden one in every respect. The Locomotive Superintendent allowed that he had been at first, like most people, prejudiced against the pot-sleeper, from an idea that its non-elasticity would injure the rolling-stock material; but both these gentlemen were convinced that the perfection of the gauge, the ease with which the road was maintained in a country where skilled labor was quite as difficult to be obtained as in India, and the safety with which, at a great speed, heavy weights were carried by Native Drivers over such a road, placed the iron permanent-way far before wooden sleepers for all Railway purposes in Eastern countries.

I was assured by all Departments that, except in collisions, the case of an engine or train running off the rails was almost unknown in Egypt, although the Drivers, even more than in India, constantly make up time by running at a reckless speed. The only explanation that could be given of this was the fact that, unless the tie-bars carry away, the road with iron pot-sleepers must always be in gauge.

I need not point out how much this is at variance with our own experience on our Indian Railways. Here trains have frequently run off, and life has been either lost or endangered, without any assignable cause. Our Permanent-way Inspectors generally declare the road laid on wooden sleepers to have been in gauge when it is very certain that it could not have been so, or the engine would not have run off.

The Alexandria express train now travels at the rate of forty miles per hour, and the road is considered safe for the speed of a mile a minute. Indeed, I was assured on pretty good authority, that the express in making up time often attained that, or a higher rate. The goods trains on the Egyptian Railway are, I suppose, the heaviest that have ever been worked on so light a permanent-way, the majority of the rails being only sixty-five pounds per yard.

Their goods engines are very large and powerful ones, some of the French engines being nearly as heavy as our Ghât Locomotives. The goods trains often comprise from forty to fifty wagons, averaging eleven tons gross weight when loaded,* and the speed ranges from twenty to forty miles per hour.

I quote this to show how severely the Egyptain line has been tested, and not at all with view of urging such a system on Indian Railways.

On Mr. Perry's section of the line I found they were taking up twenty-two miles of rails laid upon wooden sleepers, and re-placing them with iron ones. This was done to insure *the road being capable of carrying the traffic with safety, and to reduce the expense of maintenance.*

I found that wooden sleepers could have been imported from Dalmatia, Greece, or Turkey, at less cost than the iron sleepers from England, but that it was found in Egypt, as we find in India, that the wood simply decayed away when covered in earth, and subjected to the variations of temperature, and alternations of dry and wet soil.

Looking at the pot-sleeper as applied in Egypt, and comparing the road with the appearance of much of our line upon embankments in India, I am inclined to think that the thin iron tie-rod, instead of the heavy wooden transverse cross-beam, is much the surest way of preserving the gauge in countries where the maintenance of the line will always be carelessly carried out as compared with European Railways. For instance, on many of our embankments, it requires, no very critical eye to observe that the ballast is too high in the centre, owing to the constant washing away and subsidence of the embankment at the side where the chair and rail rests, and that consequently, when a train is passing over our roads in the wet season, the centre of the bank, and, of course, the centre of the wooden sleeper, becomes the fulcrum upon which the weight of the train is thrown, instead of resting as it should do, on the side of the bank along the line of rail.

Last year, between Julgaum and Mussawad, I saw a considerable length of line in this condition, leading, of course to an accident in which two or three hundred yards of sleepers were broken up, whilst the Assistant

* Engine and tender, tons, ...	...	...	...	...	...	...	...	50
42 wagons X 11 tons, ...	...	...	...	...	...	...	...	495
								<hr/>
Total tons ...	...	...	...	...	...	...	...	545
								<hr/>

Engineer and Permanent-way Inspector were ready to aver that the road was in excellent gauge, and so it was, so long as the weight of the train was not thrown upon it.

With iron tie-rods this could hardly ever occur, as they would easily cut down through the bank and preserve their position with respect to the pot sleepers, as the latter were forced down by the weight of the train.

One of the most serious objections that I have heard advanced against the pot-sleepers is the statement that, in the event of any accident, the loss of sleepers and chairs would be greater than with the ordinary wooden permanent-way. Some enquiries I made on this head lead me strongly to doubt whether this objection holds good in practice, and there are at any rate two classes of accidents to which we are liable with wooden sleepers that are totally unknown with iron permanent way.

The first I have already alluded to, that of the breaking of the wooden sleeper, owing to the centre of the bank being too high, and defective packing under the rail. The second is from the ignition of the wooden sleeper in the dry hot season, either owing to the hot ashes falling on them from the engines, or from trains catching fire when collisions occur or sparks fall on the goods.

Our losses from the burning of sleepers attributable to the second of these causes, have been very considerable. Looking therefore, at the question of iron *versus* wooden sleepers, in all its bearings, I am perfectly convinced, in the interest of the Shareholders, as well as the Indian Government, that the sooner Railways in the East are constructed of iron permanent way, the better. The losses to which this Railway has been subjected would be very difficult to estimate, especially in teak sleepers, and all the jungle-wood ones have proved to be utter failures, entailing enormous expense in renewals even before the roads have been opened to public traffic. The majority of the jungle-wood sleepers simply decayed away to dust within eight months, or within a year of being laid down. The teak last better; but every person, from the Sleeper Contractor to the coolies employed on the line, have made their profit out of them at the Company's cost.

The quantity of teak misappropriated and deficient within my own experience, has been something startling, and there can be no remedy for it so long as the wood is so precious and in such constant demand; for every bit of teak represents a certain monied value. It has been nothing

unusual in former days for a truck-load of teak sleepers to be missing and the sale of sleepers supposed to be used on the line for repairs is still very prevalent.

Now, with an iron sleeper, we have very little risk of robbery or misappropriation, the metal, even when broken up, being of no use to the natives; whereas, with a proper foundry capable of re-casting sleepers, such as every Indian Railway should possess, it will be very easy to carry the broken iron, and re-cast our sleepers; the tie-rod, in nine cases out of ten, merely requiring straightening.

Looking to the future, moreover, I see no prospect of the teak forests of India being capable of maintaining the necessary supply for either the construction or maintenance of Indian Railways.

In the tenders sent in last year to an advertisement for teak sleepers, the prices ranged from Rs. 6-8 to Rs. 12-8 per sleeper, delivered in ships at Bombay, and not including landing charges or haulage. All the teak sleepers procured in this country of late for our Railway, are young trees sawn in two half rounds, which cannot be turned, and in many places not $3\frac{1}{2}$ inches through. I have, of course, closed all such contracts. The Singapore teak sleepers are of good proportions, cut out of the solid timber, but they are costly, and, apart from haulage, stand the Company in at the rate of Rs. 5-2 per sleeper.

I am aware that certain Officers of the Forest Department in India think we should give the jungle-woods another trial, and say that, with proper seasoning, many of them would last. I utterly differ from them, for many of our eyne and babool sleepers were years seasoning before they were put into the ground, yet, sound as they appeared on being placed on the road, they decayed away, I am told, in eight or nine months.

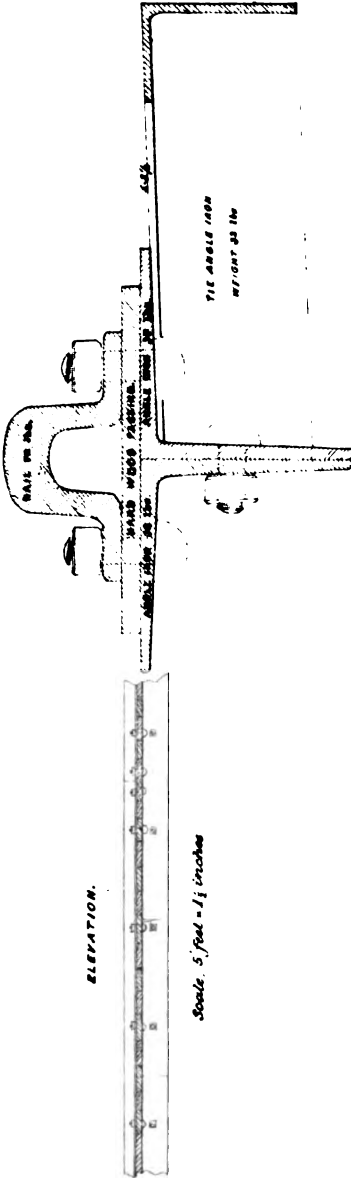
Note on Mr. Sibley's Wrought-iron Longitudinal Road.

Shortly after assuming charge of the works in these Provinces, my attention was attracted by the difficulty in obtaining sleepers, and the very defective character of many that had been supplied, and also by the defects in our fastenings, to the question of doing away altogether with so perishable and uncertain a substance as timber in this climate is.

On the 13th June 1860, I sent in designs for a wrought-iron road consisting of a lower continuous bearing, formed by two angle-irons $5\frac{1}{2} \times 5\frac{1}{2}$ in 20 feet length bolted together, breaking joint at half the length,

WROUGHT-IRON ROADWAY.
As designed and patented by Geo. Sibley, Esq., C.E.

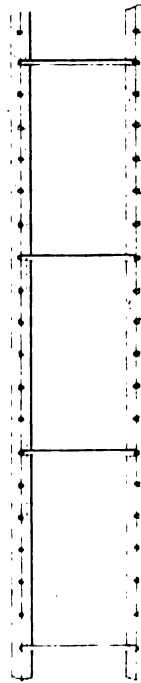
SECTION ONE-FIFTH OF FULL SIZE.



ELEVATION.

Scale 5 feet = 1 1/2 inches

PLAN OF UNDERSIDE.



PLAN.



Scale, 10 feet = 1 inch.

and carrying a bridge rail bolted to the angle-iron longitudinals with $\frac{1}{2}$ inch hard wood packing intervening. The cross transoms or ties being placed at 10 feet intervals, also formed of angle-iron, and bevelled at the end to give the necessary tilt to the rail.

The Agent, on 27th June, 1861, recommended that five miles should be sent out, and the Government of India sanctioned this on 21st August 1861.

The first portion of this reached Allahabad in February 1864, but only enough to lay $1\frac{1}{2}$ miles were delivered before the road was laid into Delhi temporary Terminus on 30th June, 1864.

A further portion, two miles over the Jumna bridge and viaduct, and up to the Jail Road Bridge was laid, and has been run over since the Jumna bridge was opened to the public on 15th June last.

The length in Allahabad yard is 1,000 feet only, which was completed on 18th May, 1865, and all trains ran over it till the opening of the Jumna bridge, since when only the Fort Branch trains have run over until a few days ago.

The plate-layer informed me this morning that, after it was finished, it cost not more than half the labor of the other road to maintain, and for the last two months nothing has been done to it. The length over the Jumna bridge stands admirably over the girders, the angle-irons, instead of being supported on ballast, rest on sleepers laid longitudinally.

The length from the Jumna bridge to the Allahabad Station yard was laid chiefly on new high bank during the last rains. The bank beds yielded, but the road has been kept in very good order, though, of course, not with so good a top as it will have when the bank ceases to subside.

The $1\frac{1}{2}$ mile laid between Ghazeeabad and Dehli, about 4 miles from the latter, has been laid and run over for more than a year and a half, stands exceedingly well, forms a very smooth road, and is remarkably free from noise.

The advantages of this road are *first*, that it contains no perishable parts except the hard wood packing, a trifle in itself, which can be re-placed without disturbing the road.

Secondly, its great strength and stiffness, forming as it does a beam 9 inches deep, and 11 inches broad.

Thirdly, its great hold of the ballast, the central web being $5\frac{1}{2}$ inches deep, which keeps it firmly in line even in curves.

Fourthly, the facility afforded for packing without opening out the road as is necessary with the sleeper road; and

Fifthly, the diminished depth of ballast required, owing to the bearing surface being only 3 inches below rails.*

When I first drew out the design in 1860, the comparative estimate showed an excess cost at Allahabad, as compared with the ordinary cross sleeper road, of £158 per mile. In that estimate, sleepers were taken at Rs. 4 each, and carriage from Calcutta to Allahabad at £3 per ton.

Since that date, the price of sleepers has risen, and first class sleepers are now Rs. 5.

I append statement of present comparative cost, taking sleepers at Rs. 5, and carriage from Calcutta to Allahabad at Rs. 18 per ton,—our present rates.

This shows that at late rates the wrought-iron road is in Calcutta absolutely cheaper than the cross sleeper road by £93 per mile, and that at Allahabad it exceeds the cross sleeper road by only £34 per mile—a practical equality.

The alterations I now propose from that sent out are trifling—

1st.—I had intended, but did not sufficiently clearly specify, that the elliptical bolt-holes for expansion should be in the rails, and that holes in the top table of the angle-iron should be punched heart-shaped with a shank on the bolt to prevent turning while tightening up; they were sent out with round holes in rails, and elliptical in angle-irons.

2nd.—I have found it advisable to rivet instead of bolting the angle-irons.

3rd.—I propose to slightly deepen the cross-ties, leaving the breadth as at present.

I strongly advise that all future permanent way material got out for doubling the line in the North Western Provinces be of this design.

* The consideration which determines the full depth of ballast required is the thickness provided below the bearing surface; this is fixed on our line at 14 inches in the sleeper road: the bearing surface is 13 inches below surface of rails, and the ballast is boxed up to within 3 inches of rail surface (giving a total depth of 2 feet), to preserve the sleepers from exposure, and to secure the road from lateral motion.

In the wrought-iron road, the bearing surface is only 4 inches (instead of 13 inches as in a sleeper road) below surface of rails, thus effecting a clear saving of 9 inches, leaving the same depth below bearing surface.

The stability from lateral motion in the wrought-iron road is effectually secured by the deep angle-irons which have a 6-inch hold in the ballast.

Comparative estimate of Wrought-iron road and Cross Sleeper road.

Quantities.		Description of Material.	Rate.	Amount.	Total.
<i>Sleeper Road.</i>			£ s. d.	£ s. d.	£ s. d.
115	Tons.	Rails, 73 lbs.,	7 10 0	862 10 0	
35	"	Chairs,	4 0 0	140 0 0	
5	"	Fish-plates,	8 0 0	40 0 0	
1½	"	" bolts,	20 0 0	25 0 0	
3	"	Spikes,	11 10 0	84 10 0	
3,200	No.	Keys, per 1,000,	5 5 0	16 16 0	
				1,118 16 0	
160	Tons.	Carriage to Calcutta,	2 0 0	320 0 0	
				1,438 16 0	
1,600	No.	Sleepers,	0 10 0	800 0 0	
				2,238 16 0	
160	Tons.	Total cost in Calcutta, ...			
		Carriage to Allahabad (excluding sleepers),	1 16 0	288 0 0	2,526 16 0
<i>Wrought-iron Road.</i>					
110	Tons.	Rails, 70 lbs.,	7 10 0	825 0 0	
110	"	Angle-iron, 70 lbs.,	8 0 0	880 0 0	
7	"	Tie-bars,	9 0 0	63 0 0	
4	"	Bolts and rivets,	20 0 0	80 0 0	
				1,848 0 0	
231	Tons.	Carriage to Calcutta,	2 0 0	462 0 0	
330	c. ft.	Hard-wood packing,	0 6 0	99 0 0	
				2,409 0 0	
Deduct 9 inches depth of ballast road = 66,000 cubic feet ...			0 8 0	264 0 0	
				2,145 0 0	
231	Tons.	Total cost in Calcutta, ...			
		Carriage to Allahabad,	1 16 0	415 16 0	2,560 16 0

In a subsequent note to the Editor, Mr. Sibley remarks :—

There is no analogy between the conditions obtaining in Egypt and those affecting our lines in Bengal. Egypt is practically a rainless country, where one half of the road is laid without ballast, in the alluvium of the Delta, and the other half on the fine gravel of the deserts.

The first course is impracticable in a country with tropical rains, and in this country (Bengal) we have no ballast at all resembling desert

gravel. Had we ballast similar to sharp Thames sand ; so clear as not to bind and so heavy as not to be washed out by the rains, our bowl road would no doubt show a different result.

The Mooltan line runs through a country of exceedingly light rain-fall, and carries a traffic of something less than £9 per mile per week ; for such a line bowls may stand, but you will observe that though they give the number taken out of the road, they do not state that they have counted the number of broken ones in the road.

Our bowls weigh 26 to the ton, and cost in England £4 per ton ; freight, &c., £2; cost in Calcutta, £6 per ton ; cost of a pair—

One-thirteenth of Rs. 66 =	.	.	.	.	5	1	3
Add 5 per cent for breakage,	.	.	.	.	0	4	0
Tie bars $\frac{1}{11}$,	.	.	.	.	0	11	0
					6	0	3
Deduct cost in Calcutta $\frac{1}{4}$ of a ton at 66, 2 chairs,	.	.	.	.	1	6	0
4 spikes,	.	.	.	.	0	6	0
2 keys,	.	.	.	.	0	2	0
Total, .	.	.	.	.	1	14	0

Balance, 4 2 3

Ours you will observe weigh only 160 lbs. the pair, the Calcutta and S. E. weigh 210 ; so that the pair cost them about Rs. 5-4.

The only general concord of opinions is that the road should be an iron one ; of the superiority of wrought-iron over cast-iron for a country like India, where the cost of carriage forms so large a portion of ultimate cost, there can to my mind be no possible question.

The only question remaining is the form of wrought-iron road. Of course I may be blinded to the defects of my own invention, but I believe it to be the best yet devised. I understand that Mr. Power considers it too light ; it is not stated how ; but seeing that it is vertically, much stronger, and laterally 10 times stronger than the double-headed rail, I do not think much of that objection. The only objection that the plate-layers make to it is, that it is difficult to "slue" over ; this, though an objection during the first year, when the new banks are settling out of line, is an advantage for ever afterwards ; the same qualities, lateral stiffness, and hold of the ballast, preventing its getting out of line.

No. CXXXIV.

FLOODS ON THE EAST INDIAN RAILWAY.

From W. D. Latimer, Esq., District Engineer, to Chief Engineer.
—Dated 18th August, 1866.

IN compliance with your letter calling for information respecting the nature of bridge foundations, and generally as to the effect of the flood of the 1st July last, on the bridges and works of the district, I beg leave to submit the following Memoranda.

On the night of the 30th June, heavy rain set in about 10 o'clock, and continued throughout the night without intermission. The down-pour was so incessant, that I was prepared to hear of heavy floods next morning. I was, however, startled to find the low country completely under water: and in the station the water was running between the platform walls in a deep and rapid current, the water being as high as the horn plates of the carriages of the Up-Mail Train when it passed at 4 o'clock on the morning of the 1st July.

Whilst waiting for an engine to be got ready, I received a telegram from the Permanent-Way Inspector at Ahmoodpoor, informing me of a part of the bank near the down distant signal having sunk: in the same telegram he mentioned that the Buckasore Nullah was bank high, as it would be in an ordinary flood.

1st July.—The engine with material train being got ready, I left to make an inspection of the line and works, before any traffic trains could pass over, the Station Masters being warned that trains were to be detained until advised by me.

The first place where I felt any reason to be alarmed for a bridge

was at the 129½ mile;—a small bridge of three 12-foot openings between the Garmorah bridge of three 60 foot spans (girder), and the Chilla of three spans of 60 feet; the small bridge being nearly midway between, is built in lower ground than the larger ones, and there was, in consequence an undue pressure upon it, so much so that I really feared it could not withstand very long, certainly not at the highest water; but, as the flood was then falling rapidly, I had hopes that nothing serious would result.

The next place where the flood was above ordinary height was at the Dwarka, where it had risen higher than any record of it since 1862. On this occasion it was 6 feet higher, at the same time passing off both in the main channel, and through the auxiliary flood openings, without apparently any great risk to the works.

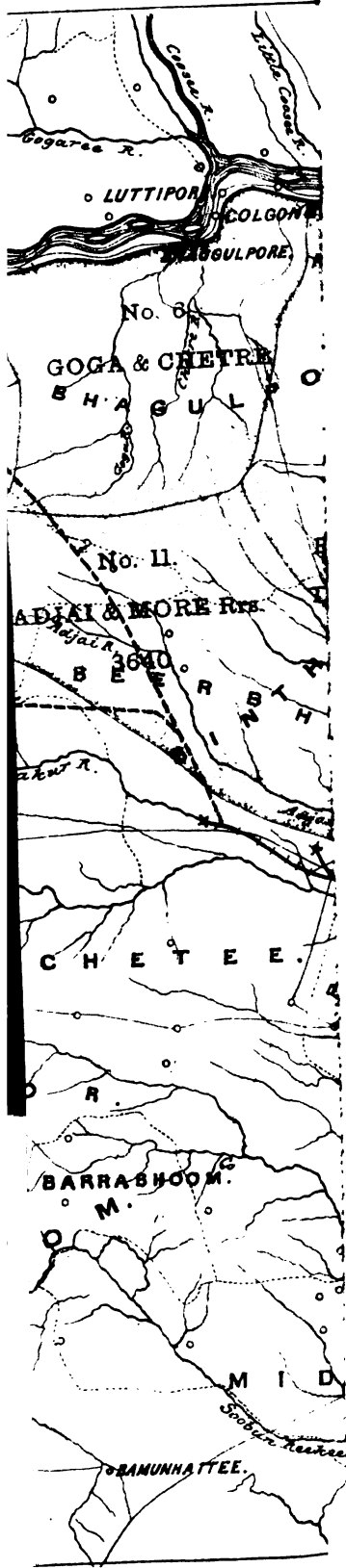
The next place where an extraordinary heavy flood was running was at the Mooneecandour bridge, where there has not been even what might be considered an ordinary discharge of water since that recorded by Mr. Perry when the works were in progress in 1855, when Mr. Perry wisely proposed having the embankment raised, and the intended water-way increased.

Again, at the bridges between the Mooneecandour and the canal, the flood was unusually high, but not sufficiently so at the bridges to cause any alarm for their safety; nor at that of the canal bridge where it was discharging with a considerable head without any apparent risk.

At the More bridge the flood was excessively high; the head of water was fully 4 feet on the cut-waters, and more at the double piers, but there was no injury being done, and nothing on Sunday, the 1st, to cause me any fear for the bridge or works.

On my way down I had a message saying something had gone wrong at Buckasore bridge. On reaching the place I found the parapet and No. 4 pier from south abutment had sunk, showing a depression of 5½ inches on the east side only; the other portions of the bridge being to all appearance sound and secure. The No. 7 Up-Passenger Train was then due; but, in consequence of the flood, it was stopped on the south side and sent back to Burdwan. The bank behind the south abutment was at the time cutting; but as the flood had subsided some 3 feet, I was of opinion it had done its worst, and, after waiting to a late hour, I left the place to again examine the bridges I have remarked upon as





being surcharged, and to make enquires and examine the bridges north of Rampoor Haut.

Before I had returned many hours to Rampoor Haut, I had a message that the west side of Buckasore bridge had fallen over. On that side there was no apparent failure whatever up to the time I left it late on Sunday afternoon.

2nd July.—On Monday morning, the 2nd July, having ascertained there was nothing to fear north of Rampoor haut, I resumed my examination of the bridges south, where I was accompanied by Mr. Sibley, who was *en route* to Calcutta by Sunday's train.

The telegraphic communication was interrupted between Rampoor and Cynthea. On our way down, we supported and put the wires right at several places where they had given way. At the River More the flood was still within about 4 feet of its highest; and although there had been a tendency to cut the embankment behind the northern abutment, it had apparently ceased: the stream returning from below the bridge, through the 1st and 2nd arches north, set in an opposite direction away from the Railway embankment in such a course as not to excite any fears for the result.

On proceeding downwards to Ahmoodpoor, the water had gone down in all the streams, leaving only slight traces of injury at some of the bridges. At the 112th mile a bridge of four 15-foot spans had the protective brick flooring washed away, as also some earth from the wing-walls.

On reaching the Buckasore, it was in the state I had been advised by telegram; the greater part of the west half of the bridge having fallen over entirely, or inclined to the up-stream side. A breach of 125 feet was made through the embankment, 15 feet in height, behind the south abutment, and the river bank at the place was scoured out to a depth of 33 feet below surface of ground, or 48 feet below rail level. The rails across the breach were suspended in mid-air with the sleepers attached: the communication was entirely cut off, except by that means. In order to make it passable I sent the train back to Rampoor Haut for a supply of planking and material required to get the Bombay Express Mail forwarded. The train on going back found the flood at the More had risen some 5 feet from the time I had passed down in the morning; the direction of the current had entirely changed: setting

against the northern bank, it cut away and scoured out in the course of two or three hours, the natural bank of the river on both sides of the Railway; the whole volume of flood water then passing through the side cuttings, and overflowing the face of the country, until it found a vent through the canal and other bridges between the River More and Mooneecandour bridge of forty-five 15-foot openings, $1\frac{1}{2}$ miles distant from the More bridge, and at right angles to its natural course.

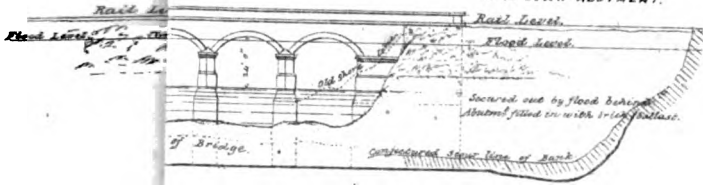
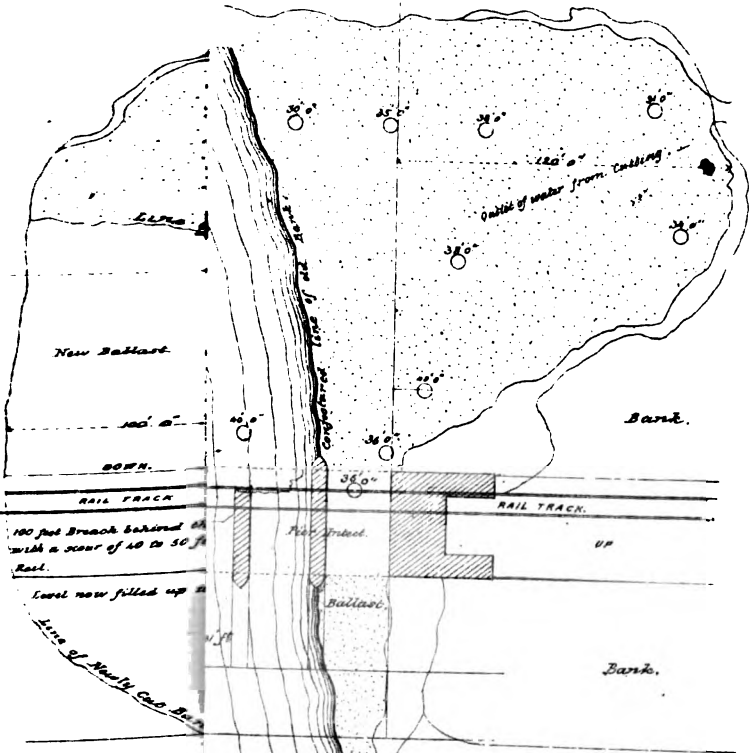
The embankment, 25 feet in height, behind the north abutment of the More bridge, was cut under the rails for a length of 105 feet; the rails and sleepers left hanging as described at the Buckasore bridge. At the More, the embankment was only cut through three-fourths of its width, with an additional length of 200 feet of cess and slope washed away.

The engine and train returning to Rampoor Haut got over the bridge and the embankment before it was breached, but unfortunately it could not get back again: and, in consequence of the Copai bridge about the same time showing indications of failure, we were left without engine power between the $101\frac{1}{2}$ miles and the 119th mile,—a distance of $17\frac{1}{2}$ miles: the only means of communication over the length was by trolly, by which conveyance the mails were forwarded.

The flood water at the More, Buckasore, and Copai rivers kept at such a height on Tuesday the 3rd, as to seriously interfere with any work towards repairing the heavy damage at the bridges: the first attempt was made at the river More, where it was an object to get an engine over the bridge to re-open the communication as far as the Buckasore, a distance of 11 miles. In consequence of the height of the water, earth-work was of no avail on the first day: the bottom and deep scour had first to be filled with heavy stone and masses of brick-work; the former was only obtainable at Koolapahar and Seetapahar, 71 miles distant. All available labor, with as many trains as engine power could be supplied for were engaged in leading and bringing material for filling in the breach. The distance and consequent delay in getting material to the place was equal to a day's loss of time. On Wednesday, the underseat of the embankment was sufficiently advanced with ballast filling to admit of earth filling being used. The embankment was in consequence made to its full height, and wide enough on the

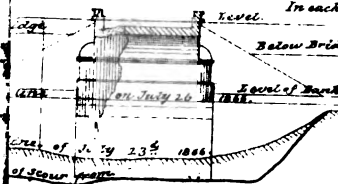
U. S. UP ABUTMENT.

S. or DOWN ABUTMENT.



Most Material removed from about 67500 C. ft. Ballast from Branch about 240000 C. ft. moved from N. B. 14000 C. ft.

- Note. South abutment crack just perceptible.
- Pier 14 Crack in Center and good.
 - Crack 6 ft. to 8 ft. of center & under the lower half of bridge.
 - 4, 5, 6 Crack in Center from 6" to 8 ft wide, the last Pier 14 5 ft over hanging the main Pier water Archies all good except N. B. 6 of which the greater part is fallen and (as shown).
 - Half entirely gone, rest good, separation of brick work quite perpendicular.
 - 9, 10 Overhang & a part from rest of the Pier. About 1 ft at water to 5 ft at Rail level, all above tottering to their fall.
 - In each case portion of the Arch (about 5 ft) has fallen in. Both piers have an inclination N. in direction of A (Plan).
 11. Gone & with it all of arch.
 12. 1/2 gone arch of N. B. 14 resting on its remains & on angle of N. B. 13.
 13. Intact. Abutment the same.



SECTION OF PIER NO. 13.
With part of N. B. 14 beyond it.

LITHO: T. C. PRESS.

evening of Wednesday, the 4th, to pass an engine with a loaded train of ballast over the breach at 8 o'clock P.M.

This difficulty, being passed, reduced the interruption to engine traffic to $6\frac{1}{4}$ miles, with the additional advantage of being able to lead stone and material to Buckasore bridge, where no earthwork could be done in the breach and stream, without first checking its force by a barrier of stone and heavy ballast.

5th July.—On Thursday, the 5th, the flood-water had considerably subsided; and, with the aid of stone, as before-mentioned, the current was sufficiently controlled to admit of an attempt being made to stop the breach by earth filling, at which over 2,500 coolies were employed.

The work of making a new road over the east side or half of the bridge left standing was at the same time being carried out:—the ballast was all removed, first to allow of clay puddling being introduced over the crowns of the arches; brick spandril walls being built to support the strong framing of longitudinal balk timbers being laid over the bridge to which the cross sleepers are bolted, the rails and road being thus continuously supported.

On and from the 4th, the passenger carriages were hand-shunted by coolies over the length between Copai and Buckasore, where they changed trains. The work at the bridge and breach in the embankment was continued; the traffic being worked as described up to Tuesday, the 9th, when the down-train was pushed over the new road made over the east side of the Buckasore bridge, and the breach in the embankment filled in. After which the engine was taken over, following up the hand-shunted train in its slow progress; in a short distance it was overtaken and pushed on to the Copai bridge. The engine being kept between the two bridges, for which sidings were put in at each place, the great delay to traffic was thus overcome on the 9th, when the up and down-trains were passed over the bridges with only a delay at each place in hand-shunting of from 10 to 15 minutes.

On the morning of the 10th, a second engine was taken over Buckasore bridge, and on the 11th, a third one was brought over to replace the first one, a passenger engine, considered too light for goods traffic.

From that date (the 11th) the goods traffic might have been resumed over the entire district, and worked as it has been since the 15th

without any delay or interruption to the ordinary traffic trains, as has been since proved by extra trains being passed on the first two or three days, to clear off coal and other trains detained at stations on the 1st of July.

Similar work to that described at Buckasore was being carried on at Copai, where a new road was laid on timber framing, by which the traffic will be carried over on the east side of the bridge.

When that work is completed, and the arches are supported by centres, as is being done both at Copai and Buckasore, the engines and traffic will work over both of them as heretofore. The work of bringing stone and ballast to Copai was undertaken by Mr. Cockburn: the communication being cut off from the north, no material could be sent to it from this side.

In giving an opinion on the course of the disaster at Copai and Buckasore bridges, there can be no question as to the extraordinary height of the late flood and its sudden rise. We have evidence of the height being greater than any flood since 1833 in the district westward of the Railway. At the Railway itself, the only record we have of any flood approaching the last one is that of 1862, when the water was at the Buckasore bridge as follows:—

Up-stream side from rail level	..	..	..	..	..	9-35
Down ditto ditto	..	..	..	..	..	11-25
Showing a head of						2-00

In the late flood, the surface of water above bridge was—

Below rail level	..	..	..	..	..	4-09
Below bridge from rail level	..	..	..	..	..	9-34
Showing a head of						5-25

At Copai bridge, the difference between the two floods was even greater than that of Buckasore.

In the face of such evidence, the proximate cause of failure must be attributed to insufficient water-way. There is, however, another element of failure I would refer to, that is, in the coffer blocks sunk under the arches at Copai and Buckasore bridges. The blocks are built 16 feet from clay strata to dry-weather bed of nullah. The resistance of such a mass of solid masonry opposed to a depth of 40 feet of flood-water, running at a velocity due to a head of 5 feet 3 inches at

the Buckasore bridge, and that of 4 feet 5½ inches at the Copai bridge, where there was a similar obstruction, must not alone have acted injuriously, but may have been directly the cause of the two bridges failing.

Without such an obstruction as that offered by coffer blocks, the effect might have been reduced to a scour, even as deep as the clay bottom, without further affecting the stability of either of the bridges.

I am strengthened in the foregoing remarks concerning the two bridges, Copai and Buckasore, by my experience of the results at other bridges where no similar obstruction exists in the bed of the streams, and where, in many instances, the bridges were subjected to an equally severe test, without leaving any indication of failure after the floods had subsided.

From J. F. Cockburn, Esq., District Engineer, to Chief Engineer, E. I. R.—Dated 18th July, 1866.

Having now had time to examine the bridges between the Junction and Bhulpoor with some degree of care, I beg to report briefly the effect of the flood upon them :—

Khurri Nullah Bridge, nine 24-feet arches at 78½ miles, platforms and drop-walls both sides, and convex wing-walls supporting slopes at abutments, with slopes of ballast and turfed earth in front of them, and continued through against the abutments.—In putting in the protective works here, the water-way was nearly doubled, and the channel of the river above and below the bridge was widened and straightened.

I also put cut-waters to the up-stream ends of the piers: the flood here rose to springing, or 8 feet higher than I had known it before, with a strong current, but has not done the slightest damage to the bridge, protective works, or slopes.

Two sets, each of ten 15-feet arches, at 85 and 86 miles, splayed wing-walls; the latter set protected with platforms and drop-walls.—There was a great deal of water here, but very little stream; no damage has occurred.

Fifteen 12-feet arches at 87½ miles, concave wing-walls, platforms, and drop-walls.—This bridge carries the surplus flood-water of the Koonoor.

There was a strong rush through it, but no damage has been done

beyond the cutting out of a piece of the bank behind each of the up-stream wings, which holes have now been re-filled with large ballast.

Koonoor Nullah Bridge, seven 20-foot arches at 88 miles, platforms and drop-walls on up-stream side, with convex wing-walls supporting slopes also on the up-side; the southern one flush with the abutment, and northern one flush with the first pier.—The flood here was up to within 3 feet of the soffit of the arches with a very strong stream. The earthen slopes in front of the wing-walls, &c., carried through the abutments, have been almost entirely washed away, but the walls have stood well: the platform is about 7 feet below the head of the channel, and in former years the hollow had silted up flush with the bed. This has scoured out down to within 2 or 3 feet of the platform, but not lower. The slopes above the tops of the wing-walls have been a good deal cut away, and a hole has scoured down behind the northern wing-wall, but not to any serious depth. This and the slopes are now being filled up with ballast, and the best plan will be to pitch them with pukka brick-work up to the level of the soffit of the arches.

Ten 12-foot arches at 89 miles,—no protective works.—Here the Ad-jai water was running back from east to west into the Koonoor flood with a moderately strong stream, but no scour or damage has taken place.

Five 10-foot arches at 92 miles,—no protective works.—Deep scour both above and below the bridge, down to below the foundation, but, as far as I have yet been able to ascertain, not underneath it. As soon as I have settled this point with certainty, which I hope to do to-morrow, I shall fill up the scoured holes with large ballast.

Three 10-foot arches at 93 miles (Beddiah Station).—This is the bridge which fell. I am having the water baled out in order to examine the foundation, and will then send full particulars.

Two sets, each of three 10-foot arches, just above Beddiah Station.—At the latter of these, there is deep scour, but, so far as I have yet been able to ascertain, not under the foundation.

Through all these four sets of 10-foot arches there was a very violent rush of water.

Ten 20-foot arches at 94½ miles, platforms, drop-walls, and pitching to slopes on both sides of bridge.—On the up-side, the lower part of the pitching was pukka: the upper 5 feet kucha-pukka: this latter portion has entirely gone, but the lower pukka portion is intact. Platform

and drop-walls sound, and the scour in front of the drop-wall nowhere more than about 2 feet below top of platform (all the drop-walls here and elsewhere are 6 feet deep). The slopes above top of pitching have been a good deal cut away, but not dangerously. Down-stream side no damage.

Ten 20-foot arches at 94½ miles, protective platforms, drop-walls, and pitched slopes (all pukka) on both sides of bridge.—At this bridge, the rush of water was even more violent than at the last. There were long rolling waves of considerable height opposite the centre arches, and a large curling wave at the south-west corner. The effect of the latter was to scour out a hole 20 feet diameter and 8 feet deep; but except this, there is no scour much below the top of the platform and drop-walls. Both these are quite perfect all along: at the south-west corner, a portion of the slope, and a small bit of the upper outer corner of the pitching, have been carried away: the rest is perfect; at the north-west corner of the bridge, a very large piece of the slope has been washed out, forming a nearly perpendicular face at the end of the abutment wall, and all the upper part of the pitching has gone. The lower part, however, where it joins the platform, has remained unmoved, and a good deal of the upper part has fallen down behind it in large masses, which have formed a support to the foot of the remains of the slope, and a protective cover to the end of the platform. I propose at this bridge, and the last, to fill up the slopes with large stone rubble and ballast, and partially to re-build the pukka pitching. Down-stream side no damage.

The Adjai bridge has suffered no damage.

Three 20-foot arches at 95½ miles, platforms, drop-walls, and pitching to slopes both sides.—Here also the upper part of the pitching was kucha-pukka, but the whole of it has stood uninjured, though there was a very strong rush of water through the bridge.

Three 28-foot girder openings at 96½ miles, splayed wing-walls, platforms, and drop-walls to centre opening and half of each side ditto, with retaining walls to support road-way.—There has been some scour at the corners of the wing-walls and retaining walls, but not serious.

At this, and the last bridge, I have not yet had time to sound the platforms, but will do so as soon as possible. I have, however, every reason to suppose that they have stood as well as the others.

From S. Power, Esq., Chief Engineer, E. I. R. Lower Division, to Chairman, Board of Agency, E. I. R.—Dated 28th August, 1866.

This office letter of 7th July, described the failure of the Buckasore, Copai, and Beddiah Bridges on the 1st July, and the consequent stoppage of the traffic; also the remedial measures which were at once adopted, and by means of which the passenger traffic was re-opened on the 10th July, and the goods traffic a few days later.

In compliance with the wishes of the Government of India, the accompanying drawings and the Reports of Messrs. Cockburn and Latimer are now submitted. They exhibit and describe in detail the structure of these bridges, and the injuries which they have sustained; the remedial measures which have been extensively adopted with success, and those which have been tried in a few cases, and have failed; and also the proposed improvements.

There is also appended a Tabular Statement which shows the areas of the basins drained by the great rivers and their tributaries which are crossed by this Railway: the water-way afforded by the existing bridges, and the velocity with which the water must have passed through them, assuming that they have, during recorded floods, discharged a rain-fall of half an inch per hour; this being half the quantity which was ascertained by Mr. Levinge's careful experiment, to have fallen in the basin of the Gerooah during the great flood of 1861. No other trustworthy record of the rain-fall has been kept by the Railway Officers.

The cause of the failure of the bridges must now be considered.

It might have been a defect in construction or in design, a deficiency of water-way, or insufficient depth of foundation.

It did not arise from any defect of construction, because both workmanship and materials are indisputably excellent; nor from a faulty design, because the general plan is perfect of its kind, and that which has been almost universally adopted with success.

It must, therefore, have arisen from a deficiency of the water-way, or from the insufficient depth of the foundations.

A sufficiency of water-way is generally supposed to include the following conditions:—

1st.—That the floods shall not rise above the embankments.

2nd.—That the extent of inundated land shall not be injuriously increased.

3rd.—That the velocity of the water passing through the bridges shall not be so great as to scour away the clay or other material on which their foundations rest.

If this definition be assumed to be correct, it must at once be admitted that the failure was caused by the non-fulfilment of the third condition, because the clay was certainly scoured from beneath the piers, which settled or fell when the ground on which they rested was carried away; and, moreover, it is shown by the annexed Tabular Statement, that the velocity of the water from a rain-fall of half-an-inch, must necessarily have been such as to produce this effect, being nearly five times that which most recent and careful observations show to be the safe velocity, viz., $2\frac{1}{2}$ feet; and finally, it is shown by the levels since taken by Mr. Latimer, that the head of water exceeded 5 feet, which must have produced a velocity of 16 feet per second.

It is scarcely necessary to point out that this investigation entirely confirms the truth of Mr. Turnbull's opinion, that the water-way was insufficient, and that every addition to it must have increased the chances of safety.

But unhappily the enquiry also proves that the deficiency is so great that no moderate addition to the bridges will insure, or, perhaps, on the whole, appreciably increase their safety; and that, although for several reasons, a large addition to the water-way will, in many particular places, be advisable, the chief remedy for the dangerous condition of the bridges must be sought,—not in this extension alone,—but in rendering them, as nearly as practicable, safe from the effects of the most violent scour.

4th.—The insufficient depth of the foundations is another cause which has to be considered.

The surface of the clay, which underlies the sand or silt in the beds of these rivers, appears to have been assumed to be the limit of the scour, because the latter (viz., the sand or silt) was probably deposited by one flood, and liable to be removed by another; while the surface of the clay had not been disturbed, and therefore, marked with certainty the limit below which the scour of the rivers had not formerly extended. But any departure from the normal condition of the drain-

age must alter this limit, and when the Railway bank was constructed, and all the rain-fall was forced to pass through the bridges, instead of flowing over the ground, the surface of the clay ceased to be the limit of the scour, or the safe depth of foundations.

It would, of course, be possible to calculate approximately the additional depth to which the foundations should be sunk, *i. e.*, that to which the river channels must be deepened, in order that they may be enabled to carry, with a given velocity, the additional water forced through them by dams across the valleys; but, as sinking blocks into the clay was almost impracticable with the implements formerly in use, it is useless to enter further into this matter. The best remedies for the existing evils form a far more important subject of consideration, and they must now be discussed.

In consequence of the excessive quantity of water which has to be discharged through the bridges on this Railway, their position has become somewhat similar to that of canal locks, and the means which have always been found adequate for the security of the latter will certainly be found efficacious in protecting the former: these means are a flooring, which cannot be injured by any possible velocity with which the water can move over it, and the prevention of the passage of water under the flooring, or behind the walls of the lock-chamber or sluices, by means of sheet-piling, or their more permanent, but less effective, substitute, drop-walls, sunk to a sufficient depth in the clay.

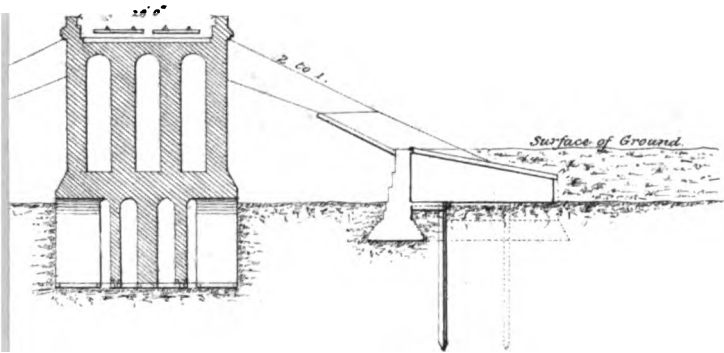
In bridges having invert resting on the clay, this method of protection (*viz.*, a solid flooring and drop-wall) has been easily applied, and has been perfectly successful, except in the case of a small bridge at the 109th mile, where the drop-walls were sunk only 4 feet. But although thus far successful, it exhibits defects which require attention; they are,—the insufficient width of the aprons, the insufficient depth of the drop-walls, and the want of adequate protection behind the wing-walls and abutments. In reference to the first, it was formerly observed that the eddies by which the foundations of the bridges are generally damaged, have been usually produced close to the upper-faces of the bridges. Major Hovenden and I had an opportunity of seeing that the sod covering the surface of the ground had not been disturbed at a distance of 10 feet from the face of the Beddiah bridge, which was, nevertheless,

WEST INDIAN RAILWAY,

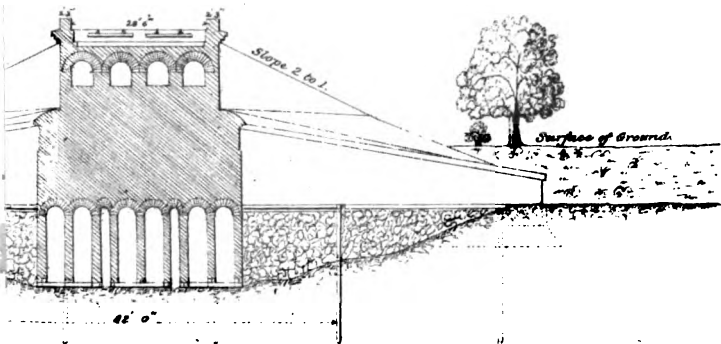
*Drawing of Copai Bridge, showing original Structure and
plan for Protecting it with sheet piling.*

Estimated Cost 1,30,000 Rs

CROSS SECTION THROUGH A B.



CROSS SECTION THROUGH C.D.



so completely undermined, that it dropped into a hole scoured under its bottom. On account of the narrow limit within which the scour thus appeared to be confined, the aprons have hitherto been made only 15 feet wide. No mischief has as yet been caused by this limit—no invert bridge, protected in this manner having been damaged; it was, however, I now think injudicious economy on my part, and the aprons should extend to the foot of the slope, and the drop-walls should be sunk to a greater depth (10 feet) where practicable. Moreover, the wing-walls have not in all cases been underpinned to the same depth as the drop-walls; this should now be done in every case, and the bank behind the wing-walls, and for some distance beyond them, should be covered by a solid pavement. These additional precautions will add much to the security of bridges having inverts or floors.

The block bridges and others without floors present far greater difficulty: the Copai and Buckasore belong to this class. In Plate IX., is shown the method of protection tried at Buckasore and other bridges of this class: it fails altogether to prevent the passage of water beneath the platform. Before a trial of this plan was decided upon, an estimate was made of the cost of enclosing the bridge by sheet piling, as shown in Plate VIII.; but this latter design was necessarily abandoned, as the cost was prohibitory in the then existing condition of the Railway; and, indeed, it would rarely be expedient, as a new and better bridge would be far less expensive.

The conclusions to be drawn from the foregoing considerations appear to be these:—

- 1st.—All the bridges on the Railway should be secured as quickly as possible without waiting for any evidence of scour.
- 2nd.—The aprons and drop-walls shown in drawings, with adequate protection to the wings, will add much to the security of bridges having inverts and floors which are accessible.
- 3rd.—An attempt must be made to remove the water from the foundations of all the bridges without flooring, and to protect them also by flooring, aprons and drop-walls sunk at least 6 feet into the clay. When this is found impracticable, as appeared to be the case at Buckasore, the sheet-piling shown in Plate VIII., must be adopted as the last and unfailing resource.

4th.—No decision respecting the exact treatment of the Copai and Buckasore bridges can be arrived at until the dry season, when all available pumping power must be employed to remove the water from their foundations, repair them if practicable, and secure them with flooring, aprons, and drop-walls sunk into the clay. If this be impracticable, or the state of the piers should not warrant the retention of these bridges, new bridges must be erected.

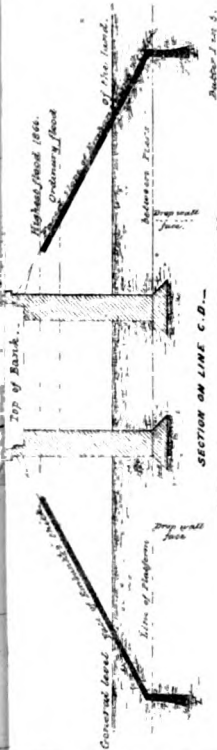
5th.—The water-way must be increased in many places as an adjunct to the protective measures.

EAST INDIAN RAILWAY.

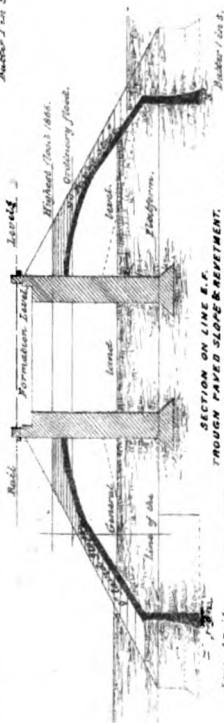
Method of Protection proposed for abutment and floor of Bridges and steps of Embankment.

BRIDGES WITH BLOCK ABUTMENT.

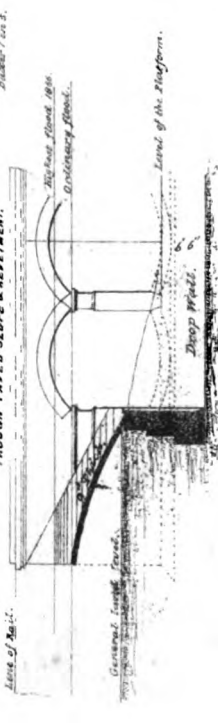
Estimated cost Abutment 2006-10-2.
One foot level of Platform 17-11-8.



SECTION ON LINE C.D. -

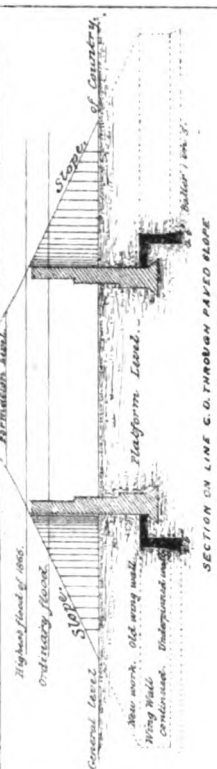


SECTION ON LINE E.F. THROUGH PAVED SLOPE REINFORCEMENT.

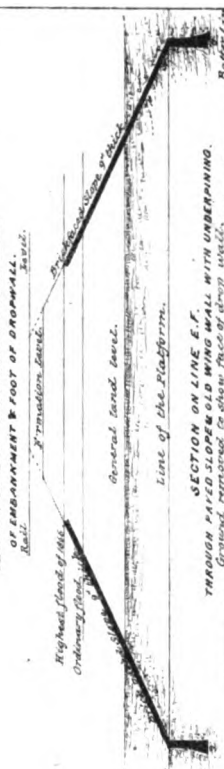


BRIDGES WITH WING WALLS.

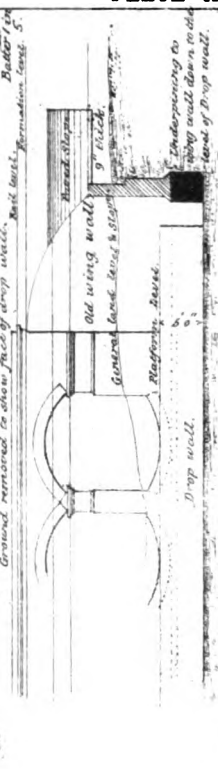
Estimated cost Abutment 1465-13-6.
One foot level of Platform 17-11-8 rail level.



SECTION ON LINE G.D. THROUGH PAVED SLOPE OF EMBANKMENT & FOOT OF DROPPING WALL.



SECTION ON LINE E.F. THROUGH PAVED SLOPE OLD WING WALL WITH UNDERMINING.



EAST INDIAN RAILWAY. **Comparative Statement of Water-way on the several Districts of the Main Line in the Bengal Division.**

NAMES OF RIVERS.	Area of basin to be drained.	Linear feet.		Square feet below recorded flood-level.	Area of water-way below recorded flood-level, per square mile.	Estimated amount of rain-fall to be carried off through the Railway, vertical inches per hour.	Quantity of water to be discharged per square foot of off this estimated rain-fall.	Cubic ft. per sec.	Linear ft. per sec.	Mean velocity at which water must have passed through the Railway openings if this estimated rain-fall has been carried off.	Estimated addition to existing water-way required to reduce this velocity through bridges below 2.5 feet per second, existing water-way being 1.	REMARKS.
		Sq. miles.	Linear feet.									
1. Kurrunnassa	3,400	4,000	39,000	11	25	162	6	15	6	The rain-fall over these districts is comparatively light.		
2. Soane river	23,000	14,200	172,500	8	125	81	4	10	4			
3. Poon-poon and Hulohur valleys	9,000	11,086	123,648	14	25	162	4	11	4			
4. Keel river	1,100	1,542	11,002	10	25	162	6	16	6			
5. Hill streams west of Jamalpur	240	1,670	7,385	80	5	323	4	10	4	The rain-fall over this country is much heavier than in the districts west of Monghyr.		
6. Ditto from Jamalpur to Sahelgung	2,650	6,796	59,486	23	5	323	4	14	5			
7. Ditto from Sahelgung to Teenpahr	52	1,641	7,952	155	5	323	2	2	1			
8. Ditto from Teenpahr to Bahawa	66	1,176	2,476	144	5	323	1	2	1			
9. Gomancee river	520	1,639	10,165	20	5	323	6	16	6	* The drainage area is uncertain, owing to the river Damoodur being embanked and liable to overflow.		
10. Hill streams between Gomancee river and Mullarpoor	1,200	5,824	53,301	44	5	323	3	7	3			
11. Adjal and More valleys	3,640	7,752	120,300	30	5	323	4	10	4			
12. Khanoo to Howrah	...	14,000	65,000	...	...	...	...	...	...			

NOTE 1.—Much doubt exists as to the effect of running water on different substances.

It was formerly supposed that a velocity of 6 inches per second moved ordinary clay. Mr. Blackwell's experiments in 1857 appeared to show that a velocity of 24 per second would move a brick-bat weighing 9 oz.

Major Crofton, however, considers 2½ feet to be a safe velocity on clay, and it has been adopted in this Statement lest the Table should appear exaggerated.

NOTE 2.—No attempt has been made to divide the drainage of the great basins, and to show the discharge of each tributary separately, because the inoculation of many of the rivers renders a correct division impossible. The Kandour, one of the southern tributaries of the Adjal, may be taken as an example of this difficulty; the Adjal burst its south bank, filled the valley of the Kandour, topped the Railway bank, and swept away the Beddiah bridge. Colonel Short, whose authority cannot be questioned, informs me that this irruption of the Adjal took place on the 1st and 2nd July.

CALCUTTA, }
 28th August, 1866. }
 S. POWER, }
 Chief Engineer.

No. CXXXV.

GRAND RIVER VIADUCT—MAURITIUS.

Abridged from the Minutes of Proceedings of the Institution of Civil Engineers for 1865-66. BY WILLIAM RIDLEY.

THE viaduct to be described in this Paper was erected over the Grand River Ravine, on the Midland line of the Mauritius Railways. It was designed by Mr. Hawkshaw, the Consulting Engineer to the Government of Mauritius, and was constructed by Messrs. Thomas Brassey and Co., the Contractors for the above-named railways, under the superintendence of Mr. Longridge (M. Inst. C.E.), their Agent in the Mauritius.

The total span of the viaduct, from abutment to abutment, is 620 feet, and this distance is divided into five openings of 116 feet each in the clear. The height from the surface of the water to the level of the rails is 129 feet 9 inches. Plate X., Fig 1.

Each pier is composed of two cast-iron cylinders, each 10 feet in diameter, resting on masonry foundations, and filled with concrete. The method of constructing the piers is shown in Plate X. Cylic rings, 9 feet high, were divided into five segments each, and were bolted together by internal flanges. The horizontal joints were "rusted up" with iron cement, well beaten in.

The works were commenced May 4th, 1863. The abutment on the Port Louis side was built upon hard tufa, and contains 370 cubic yards of masonry. No. 1 pier was commenced in July 1863, upon a rock projecting on the side of the ravine. The part upon which the pier stands was truly levelled, and the rock well faced up with masonry set in cement. The total amount of masonry in this pier is 92 cubic yards. During the excavation for the foundation of No. 2 pier, considerable trouble was caus-

Fig. 2
TRANSVERSE SECTION.

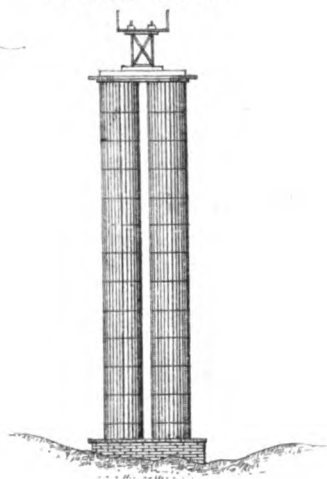


Fig. 4.
SECTION OF DAM.

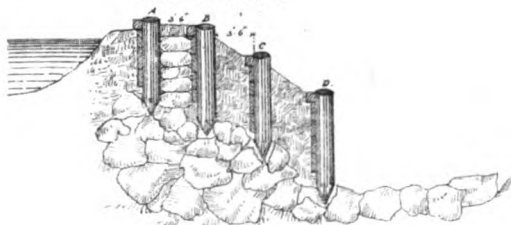
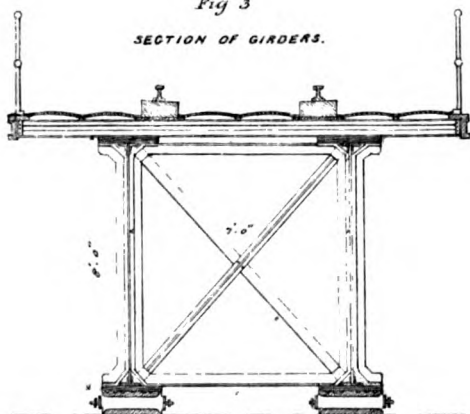


Fig. 3
SECTION OF GIRDERS.



ed, owing to the pier being situated close to the edge of the river, and from the nature of the ground, which consisted of large boulders and fine river gravel, the water freely percolating on all sides of the excavation. This foundation was commenced August 8th, 1863, and was completed September 31st in the same year. At first it was thought, that the water might be kept out by a series of dams [*Plate X., Fig. 4*], and with that view a mass of stiff red clay was thrown into the river, and piles were driven as far down as possible, at intervals of about 18 inches; and in front of these were placed a waling piece and sheet piles. When the work was so far completed, a similar row of piles was introduced at a distance of 3 feet 6 inches from the former, the space between the two rows being well puddled, and made as water-tight as possible. The excavation was then continued, and a third and a fourth row of piles were driven, and the excavation again carried down.

It was intended, had it proved practicable, to proceed in this manner, placing each dam successively lower than the one in front of it, until the required depth was arrived at. This method proved insufficient, for although the water was, to a great extent, prevented passing through the dams, yet it found its way through the bottom in such quantities, that the employment of steam power became necessary. A centrifugal pump, on Woodford's plan, was now introduced, and was worked by an engine of 14 horse-power. When the excavation had reached a depth of 5 feet below the level of the river, the water increased so much, that another similar pump was placed by the side of the first, and in order to render the working of the pumps more effectual, the four straight discharge-pipes, of 4 inches in diameter, were widened out at the discharge ends to a diameter of $8\frac{1}{2}$ inches, giving together an area of 224 square inches. The effect of this alteration was, that nearly twice the amount of water was discharged. The pulley sheaves fixed on the spindles of the pumps were 18 inches in diameter, and were rotated by belts passing over the fly-wheels of the engine, which were each 5 feet in diameter. The number of revolutions made by the pumps was 300 per minute, and the amount of water discharged by the two pumps (after the pipes had been widened out) was nearly 3,000 gallons per minute, or 8 cubic feet per second. [*Plate X., Figs. 5 and 6.*]

It was next resolved that the foundations should be laid in blocks of concrete, and that sufficient excavation for one block only should be taken out at a time. The bed of the river adjacent to the pier was of the same material as that which had been excavated—that is to say, it was composed

of boulders and gravel; and the river just opposite to the pier was 20 feet deep. Hence, and from the general appearance of the neighbouring ground, it was conjectured that it would be useless to attempt to seek for a foundation upon the solid rock. It was therefore decided, that the excavation should be continued to a depth of 10 feet below the lowest water level, and that the bed of the river should be raised with large stones, so as to be from 3 feet to 4 feet under the same level. In justification of this decision it should be mentioned, that although the depth of the water immediately opposite the pier was, as before stated, 20 feet, yet that depth was quite exceptional, and existed only for a short distance above and below the pier. It was, in fact, a pool of comparatively stagnant water, and might therefore, safely be filled up, without fear of increasing the scour in other parts of the river bed.

The excavation for the first block of concrete was carried on and piled as shown in [*Plate X., Fig. 5*]. A row of close piling, 8 inches square, was driven as far as possible. This was a tedious and difficult operation, from the quantity and size of the boulders, and from the strong springs of water which came up through the bottom. Owing, however, to the limited area exposed at one time, and the considerable amount of pumping power, the piling was at length got down to the full depth, and was shored horizontally in both directions. A waling piece, 12 inches square, was next bolted to the top, and the whole of the inside of the dam was planked horizontally, and caulked. Drains were cut at the bottom of the excavation to allow the water to run off to the well sunk for the pumps. Tarpaulins were laid in the bottom, and for 4 feet up the sides of the excavation, for the purpose of preventing the numerous springs of water from washing out the cement, and also to turn the water into the drains leading to the pump-well. This plan was found to answer, little cement being washed out. When this block was filled with concrete, a second was excavated and treated in the same manner, the piles between it and the first block being drawn as the concrete was put in.

The whole of this foundation was thus successively laid, five blocks of concrete, each 7 feet deep, and measuring respectively 10 feet by 18, 10 feet by 10, 13 feet by 18, 10 feet by 4 feet, and 10 feet by 4 feet, being employed. The concrete was composed of Portland cement 5 parts, sand 6 parts, and broken stone 20 parts. It was laid in layers of 12 inches thick, well punned down, and after every two or three layers it was grouted

with cement. *Plate X., Fig. 6,* shows a section of the excavation, and the position of the pumps, which were on the site of No. 5 block of concrete. This block, which was the last, was not laid until some days after the others, which were kept dry until well set by working the pumps; when the latter were removed the space occupied by them was filled up with concrete. On this bed of concrete, a block of ashlar, 30 feet 6 inches long, 17 feet 6 inches broad, and 3 feet deep was set in cement, the upper surface being carefully chisel-dressed and levelled to receive the sole-plates of the piers.

The foundation for No. 3 pier was commenced August 5th, and was completed September 30th, 1863; the work being carried on at intervals only. It was of the same description as that of No. 2 pier. A double-acting pump, worked by hand, was sufficient to keep the excavation dry. A bed of concrete, 33 feet by 18 feet by 5 feet thick, was deposited in layers, and treated in a similar way to that already described, and on this a slab of ashlar, 1 foot deep, of the same length and breadth as that of No. 2 pier, was set. The concrete in this case was composed of 5 parts of lime, 5 parts of sand, and 20 parts of broken stone.

No. 4 pier was founded upon rock and hard tufa, some little distance up the side of the ravine; the surface being levelled with cement concrete, on which, as in the other piers, was laid a course of ashlar, 14 inches deep. This foundation was commenced October 14th, and was completed on the 20th of the same month.

No. 2 abutment contains 650 cubic yards of masonry. It was built upon hard tufa, and was commenced August 4th, 1863.

The cast-iron cylinders rested on sole-plates, $2\frac{1}{2}$ inches thick, which were bolted together with turned bolts. These were levelled and well beaten in with iron cement, between the top of the masonry and the underside of the plates, as were also the joints. The lower ring of each cylinder was $2\frac{1}{2}$ inches thick, increased at the bottom edge to 3 inches. The other rings were only $1\frac{1}{2}$ inches thick. After the segments were cast, they were bolted together in rings, and mounted on a frame, consisting of two large wheels and a spindle 7 inches in diameter. At first the ring remained fixed, and the spindle, with an arm 5 feet long, to which was attached the cutting tool, was made to revolve; but this not proving satisfactory, the ring was made to revolve on a new cast-iron hollow shaft 12 inches in diameter, whilst the cutting tool remained fixed at the bottom of the frame.

The segments for the first rings of each pier were lifted into their places on the works by means of "sheer-legs" and tackle, and in two cases the second rings also; but afterwards a plan designed by Mr. Longridge, was used for lifting the remaining rings [*Plate X., Fig. 7*]. A mast, 23 feet 8 inches long, with a cross-tree and struts, was mounted on a frame, inside the cylinder, the frame resting on the flanges of the segments, and being supported by small side frames. There was another frame, acting as a guide to the mast, which passed through it in a collar. At the foot of the mast was a pivot, which worked in a foot-piece resting on the top of the frame, thus enabling it to revolve easily when required. A chain, passing over and lashed to the cross-tree, was secured at one end to an eye-bolt fixed through one of the bolt holes in the top flange of the ring already completed, whilst to the other was lashed a three-sheave block. The segments were then lifted in the following manner. An eye-bolt and shackle, to which was fixed a two-sheave block, was fastened through a bolt hole in the top of the segment, a $4\frac{1}{2}$ -inch "fall" was passed round these blocks, and led away to a gin crab fixed in the bottom of the ravine. When it was required to raise the mast, a light frame holding two sheaves was laid on the top of the ring just completed, and bolted to its upper flanges; a rope fastened to it passed down under a sheave fixed for the purpose in the foot of the mast, returning up, and passing over the sheaves of the frame to the crab, and the mast was thus raised, taking with it its supporting frames, which had been previously loosened and lashed to the hooks at the sides of the mast; guy ropes being secured to the top, and gently eased away whilst the mast was being lifted. The time occupied in raising these masts was about four hours and a half. In this manner all the piers were erected without a single accident. The mast was 10 inches square, but tapered and rounded at the foot to allow it to turn freely. The cross-tree consisted of two planks, each 10 inches by 4 inches, and between the planks, and at their ends, were fixed two sheaves. All the timber work was of teak, and the mast, complete, weighed about 2 tons.

Eleven pairs of rings were thus lifted on No. 1 pier, thirteen on No. 2, thirteen on No. 3, and ten on No. 4. The heights to the top of the last ring on each pier were respectively, 99, 117, 117, and 90 feet, and the weight of each segment lifted was 32 cwts. One set of men in one day lifted the mast and one complete ring. After the cornice pieces of the piers were fixed, the masts were removed.

When the piers were in progress, the most convenient method for filling them with concrete was considered. Piers Nos. 1 and 4 were filled from the adjoining abutments; but at piers Nos. 2 and 3, the concrete was lifted by means of an endless ladder. This ladder, with its framework, was worked by a small engine of 5 horse-power. A frame was fitted between the columns of the pier, which were 3 feet 6 inches apart, and upon it was mounted a drum, 4 feet in diameter, having cams round its periphery, which caught against the links of the ladder and turned it. A cog-wheel fixed to the spindle of the drum was turned by a pinion on the shaft of the belt wheel. On the top of the cylinders rested another frame holding a similar drum, but without cams. The ladder passed over these drums. The links were each 2 feet long, and were connected together by bolts $\frac{3}{4}$ ths of an inch in diameter. At every alternate joint was fixed, by angle pieces and diagonal stays, a light deal shelf, sufficiently large to hold a basket containing nearly a cubic foot of concrete. The ladder was of iron 1 inch by $\frac{3}{4}$ ths of an inch. The concrete in the cylinders consisted of 2 parts of lime, 3 parts of sand, and 10 of broken stone. When mixed it was put into baskets, which were carried to the tops of the piers by the ladder, where it was lifted off and thrown into the cylinders, the baskets being returned on the underside of the ladder shelves.

Piers Nos. 1 and 4 were filled by a different plan. A frame, 3 feet 9 inches high, was fixed on the top of the columns at the far side of the pier; a similar frame, but 7 feet 6 inches high, was placed on the abutment, and over these two frames a single contractor's rail, weighing 23 lbs. per lineal yard, was suspended. A box, with a false bottom, was conveyed under the rail, by a sheave rolling over it. When filled with concrete, the box was set loose, and travelled along the rail till it arrived over the centre of the pier. A small line was fixed at the back by which it could be prevented moving too quickly and striking the frame on the pier. The weight of the box, when filled, was $8\frac{1}{2}$ cwts., and it contained 7 cubic feet. A chain was fixed from the frame on the pier to the foot of the next pier, to guard against any undue strain which might be thrown on it from the concrete box. When the box arrived over the pier, the catch which held up the bottom was withdrawn, allowing it to fall back upon its hinges, and discharge the contents into the cylinders. The box, when emptied, was drawn back by the rope attached to it. The average amount of work done daily in this way was 50 cubic yards, whilst by the endless ladder, at the other

piers, about 40 cubic yards were deposited, with one hundred men working at each.

A cylinder, 6 feet long, and 9 inches in diameter, was bedded into the concrete at the top of each column, to serve as a holding-down bolt for the bed-plates, which were lifted in pieces, weighing each 2 tons, by a fall fastened to a slight scaffold made of timber 9 inches square; the ends of the upright posts fitting into the holding-down cylinders. The bed-plates for the tops of the piers weighed 16 tons each, complete, and were cast in eight pieces, bolted together with turned bolts. The upper surfaces upon which rested the expansion rollers and bearing pieces were planed. The bed-plates extended across both cylinders, and were 23 feet 6 inches long by 10 feet wide, and 18 inches deep, the thickness of the metal being $2\frac{1}{2}$ inches. These, when *in situ*, were wedged up to their proper levels, and beaten in underneath with cement concrete. The concrete was carried up to a height of 3 inches above the tops of the cylinders, and bore the whole weight resting on the piers, the cylinders merely serving the purpose of a casing, and preventing the concrete from crushing laterally [*Plate XI., Fig. 11*].

It was originally intended to erect the piers in the following manner:— A length of girders braced together and with roadway plates complete, of about 300 lineal feet, was to have been built at the proper level on the bank of the ravine, and to have been trussed by a standard and by suspension chains (*Plate XI, Fig. 8*), and a jib crane fixed at the end. The girders were then to have been pushed forward, until the crane commanded the site of the first pier, when the segments and bed-plates of the piers were to have been run along the girders on bogies, and have been lowered into their places. The concrete was in the same way to have been filled in from the top, and the top bed-plates fixed. Whilst this was in progress, additional lengths of girders were to have been added on the land end, and as soon as the first pier was finished, the girders were to have been advanced another span, and so on till the whole of the piers were completed. But the girders were not ready for shipment till many months after the whole of the cast-iron segments for the piers had arrived in the Mauritius, and therefore the erection of the piers was proceeded with by a separate process, as has already been described. The girders were sent from England in sections of about 12 feet long, which on arrival were transported to the Mahébourg side of the ravine, and were riveted together in lengths of from 36 to 48 feet. A gullet, extending backwards to a distance of about 280 feet was excavated to the



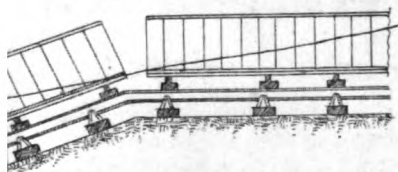
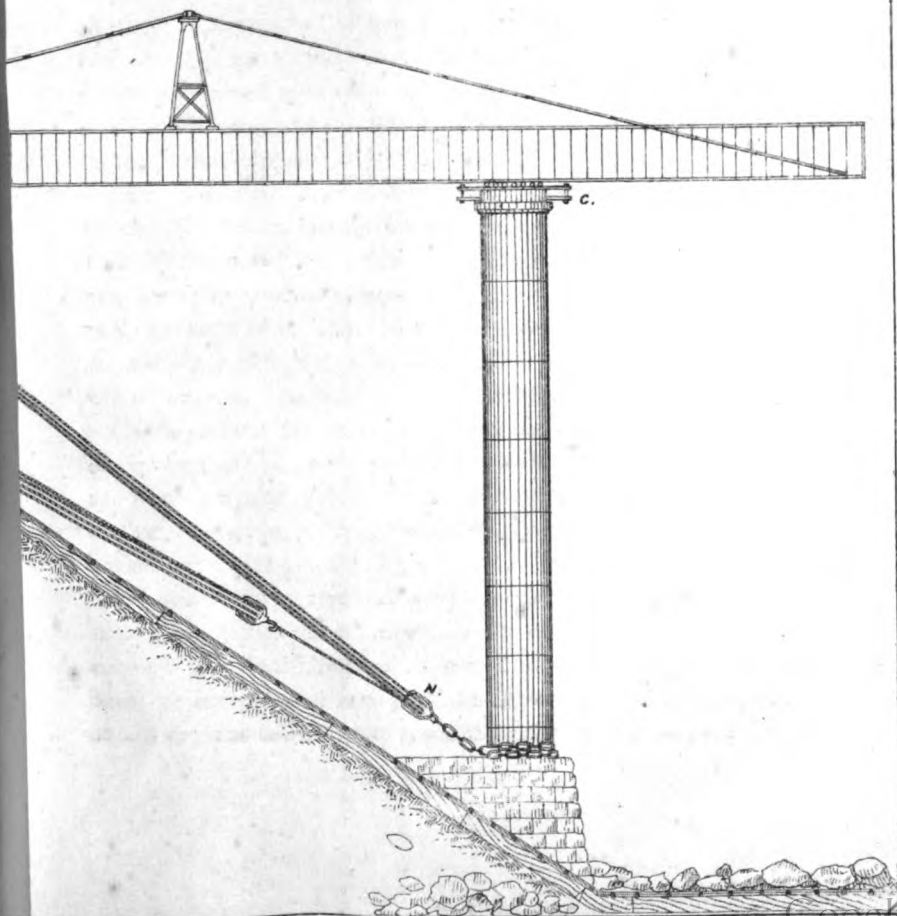


Fig. 12.



level of the abutment; and it rose at a slope of about 1 in 5 to the formation level [*Fig. 8*]. In this gullet the first lengths of the girders were to be built, and the succeeding sections of 36 or 48 feet were to be brought down the incline into the gullet and added as the first were pushed forwards.

The arrangement for launching the girders was, however, considerably modified in England. This modification may be described as follows :—A keel plate, $3\frac{1}{2}$ inches wide by 1 inch deep was fixed under the centre of each girder, to which it was fastened by countersunk bolts, and this plate passed over shallow grooves turned in the tops of rollers, for the purpose of receiving them, as well as of acting as guides to keep the girders perfectly straight whilst travelling. The rollers were 7 inches in diameter, and rested upon bed-plates [*Fig. 9*]. On one end of them a ratchet was cast, and a space was left outside, to receive a cast-iron lever head; and outside this again an iron ring was bolted, to prevent the lever head from sliding off: a similar ring was fastened on the other end of the roller, to prevent its travelling laterally along its bed-plate. The bed-plates of the rollers were laid upon and bolted to timbers 8 inches deep by 16 inches broad, the latter being laid on a course of ashlar masonry. The rollers were placed 36 feet apart, and were turned by levers each 9 feet long, and between them three lines of rails were laid, upon which a sufficient length of girder for launching was built. The girders were next lowered down upon the rollers, and the levers fixed in their places; a steel pall was bolted to each lever head, which worked in the ratchet cast on the roller, and thus caused it to rotate. The levers were connected together by a rope, securely lashed to their top ends; the lever on the abutment being made in the form of a bell crank, and the rope passed over the ends of its two arms to the winches below, placed in front of the abutment; the whole of the levers, thus connected, worked together simultaneously. The other end of the rope was attached to a crab, which pulled the levers back again when the stroke was completed. As the girders were launched, sections, each 36 feet long, were joined on at the back end.

The launching was commenced on Thursday afternoon, April 18th, 1865, and the girders were propelled forwards a distance of 2 feet 6 inches, at the rate of 1 inch per minute. No further attempt at launching was made until the following Saturday, when the girders were only advanced 1 foot 8 inches, during the whole day. The cause of this failure was due to the keel-plates rolling out; for a portion, 4 feet in length, was elongated 2 inches, and thus jammed against the roller. At first only three sets of rol-

lers were laid, [Fig. 8,] but four more sets were subsequently added. The length of girder moved, when the launching was first commenced, was 252 feet, and it weighed about 190 tons, including the tension chains and standards, which trussed the girders during the construction of the piers. One of the great difficulties was the irregularity of the underside of the lower flange of the girder, arising from the cover plates of the joints and the strengthening plates, and also in some measure from the camber of the girder itself.

When the keel plate rolled out, serious doubts were entertained as to the practicability of launching by rollers, on account of the great friction from their turning in their bed-plates, and from the probable continuous elongation of the keel-plates. To overcome this last objection, it was resolved to place loose keels under the fixed ones, to keep them off the rollers. These were made in short lengths of about 4 feet, each $3\frac{1}{2}$ inches wide, and varying in thickness as required by the camber and other irregularities on the under side of the girders.

On Saturday, April 22nd, another and more successful attempt at launching was made. The introduction of the short keel-plates was found to be a great improvement, ample space being thus afforded for their elongation, in case of rolling out. Some were tapered off at one or both ends, to allow of easy entrance and progress. The launching commenced at 11:30 A.M., and was successfully carried on till 4:15 P.M., the girders being propelled a distance of 39 feet in the four hours and forty-five minutes. In addition to the two double-purchase winches working the levers in front of the abutment, a 9-inch rope, reeved round a pair of three-sheave blocks, was fixed to the back end of the girder, and was moved by the means before noticed, the strain being reduced by a smaller set of blocks with a 6-inch fall. The number of men employed was 18 at the winches working the levers, 18 at the winches hauling the levers back, 28 at the rollers, following up with the small keel-plates, 14 at the levers, attending to the palls, &c., and 1 engine driver; in all 79.

On the Saturday following, the girders were launched a further distance of 40 feet 6 inches, which was accomplished in five hours; one being spent in re-adjusting the keel-plates, levers, &c. At each stroke of the levers, the girders were propelled a distance varying from 3 inches to 4 inches.

On Monday, after another launch of 12 feet was effected, the keel-plates over the first rollers completely failed, by buckling over. The strain was very great, for a length of 95 feet of girder was overhanging, whilst the

rollers were supporting the weight of nearly twice this length. The iron of the keel-plates was crushed by the weight, the rollers in front surged at each stroke, and the lever heads broke across the bottom.

The girders had now to be lifted; the damaged keel-plates to be removed and replaced, as also the broken lever heads. Another attempt was then made, but with little success, the lever heads again breaking, and the keels crushing. These were repaired, and on the following day the girders were propelled 10 feet, after the application of an additional power of two 8-ton jacks at the back end of the girder, when failure again ensued from the same causes. In order to relieve, to some extent, the weight on the first rollers, which were the only ones that failed, 30 permanent way rails, weighing 5 cwt. each, were placed at right angles, lever-wise under each girder, as near the rollers as possible. Each of these rails acted with a force of 15 cwt., and, together, were to a great degree effective. But still, the launching was unsatisfactory, and was followed by successive failures and breakages, with the additional failure of the front rollers, through their ratchets being stripped of nearly all the cogs or teeth. The girders were, however, finally but with considerable difficulty, landed on the first pier. The deflection of the end of the girder just before it touched the pier was 7 inches.

It was now unmistakeably evident, that this mode of launching, simple and effective as it had appeared to be, and good as it was theoretically, was practically a failure, and that the original plan must be resorted to. The following method was now introduced for the portion of the girder resting on the abutment and in the gullet. Throughout the gullet, and up to within 5 feet of the face of the abutment, a line of flat-bottomed permanent way, (the underside of the rails being level with the masonry,) was laid under the centre of each girder, and on longitudinal timbers, resting on cross-sleepers. At every 12 feet a baulk of timber, 9 inches square, forming a skid, was placed transversely across the rails; upon these baulks the girders were wedged up. A thin plate of iron was fixed on the underside of each skid, over that part which would bear upon the rails; two bolts passed through it, the heads being let in flush with the surface of the top, whilst the nuts, projecting underneath, came close up to the inside edges of the rails, and acted as guides to keep the girder in line when travelling.

When the girders were ready to be moved, the rails were well greased, and men were placed at the ends of each skid with sledge-hammers to

keep striking it to prevent sticking, as well as to assist in starting. The skids, after arriving successively, gently pressed over the ends of the rails, dropped, and were removed.

The following was the manner of placing the rollers on the piers. [*Figs. 10 and 11.*] On the top of the bed-plates, the bearing plates for the permanent expansion rollers were bolted. These plates were $2\frac{1}{4}$ inches thick, and were tapered off at the ends, to allow the rollers to enter and pass freely in and out. The latter were linked together, and after travelling over, the plates were taken out, returned, linked on to the rollers just entered, and were gradually drawn in under the girders. Short pieces of keel-plate, in 4 feet lengths, were followed up on the rollers, as the girders advanced, by men stationed on a scaffold.

On May 15th, everything was again ready to launch; a $\frac{3}{4}$ th of an inch chain, doubled, was secured to the back end of the girders, and passing over a sheave on the edge of the abutment, was fastened to the blocks [*Fig. 12*]. The rope was reeved round a pair of large blocks, that at N being fastened to the foot of the pier, as shown, and led away again to the smaller blocks, over which was reeved a $6\frac{1}{2}$ -inch fall, leading to the rope roll on the top of the bank through a snatch-block at F. The chain broke after the girders had been moved a few inches. This however, was removed and replaced by a chain cable $1\frac{3}{4}$ inches thick, and the day following the girder was launched a further distance of 31 feet 6 inches, when the large block at L broke. This was soon replaced, and the next day, between 1-15 and 4-30 P.M., the girders were advanced a distance of 62 feet 6 inches. The rate of travelling was 12 feet every fifteen minutes, when it became necessary to overhaul the small set of blocks, which occupied twenty minutes each time.

On Thursday, May 18th, the girders were on No. 3 pier. On the 24th, No. 2 pier was reached, the greatest distance travelled, as yet, in one day, being 108 feet in four hours. On Saturday, June 10th, the girders were landed on the Port Louis abutment, in six hours and twenty minutes, the entire length of the girders, 630 feet, moving quite easily. Another rope was secured to the other end of the girders on its reaching No. 1 pier, and passed round a double purchase winch placed on the Port Louis abutment. Thus an additional motive power was added and the whole of the launching was completed most satisfactorily.

The roadway girders, plates and permanent way, were soon and easily laid; and fourteen days after the launching was finished, trains were run-

ning over the viaduct. The entire work was completed on Saturday, the 29th of July.

The total weight of the superstructure is 560 tons, of which 142 tons is the weight of the roadway; and the total weight of iron work in the piers, including bed-plates, expansion-rollers, &c., is 933 tons.

The total cost of this viaduct was upwards of £30,000, or about £50 per foot forward. The cast-iron columns which were sent from England, cost, in erecting, about 28s. per ton. The expense of launching the girders was considerable, owing to the disasters that were, in the first instance, met with; it amounted to nearly £5 10s. per ton, including the riveting up of the sections of the girders, plant, cutting out the gullet and labor. Had the plan that was subsequently adopted been proceeded with in the first instance, the launching would probably not have cost more than £3 10s. ton, as was shown by the fact that one complete span was launched, with the whole weight moved, in about seven hours, by the labor of not more than 100 men. The cast-iron columns delivered cost £8 per ton, and the cost of transport to the place was about £1 per ton, which added to 28s. per ton for erection, made nearly £10 10s. per ton in place. The wrought-iron work delivered in the Mauritius cost £16 per ton, £1 per ton transport, and £23 per ton in place. The land carriage was about 4 miles, over some very steep hills.

In all the large bridges on the Madras Railway, the mode of getting the girders in place was similar to that above described. The spans of the girders were however less, being 70 feet from centre to centre, while those of the Grand River Viaduct were 116 feet. The Madras girders were continuous, principally with the object of getting them into place in this simple and efficient way; they were connected in lengths of 140 feet, or enough to cover two spans, each length consisting of three pieces, one central piece 36 feet long, and two end pieces, each 52 feet long. By means of strong tackle, no difficulty was found in bringing the girders over the piers by rollers, from one end of the bridge to the other, successively continuing them, one after the other, till the whole series was completed. In the first instance, that of the Palar bridge, planks and wooden rollers were used, and some difficulties were met with in consequence. But by employing inverted rails fixed to the bottom of the girders, and cast-iron rollers on the piers, the superstructures of the bridges over the Cavery, Thoota, and Chey-Air, were erected with perfect success.

No. CXXXVI.

RAJPOOTANA ROAD SPECIFICATIONS.

General specification for Roads in Rajpootana and the Native States in Central India. Drawn up by MAJOR POLLARD, R.E., Superintending Engineer.

Preliminary Remarks.—In preparing a scheme of communications, and opening out a comparatively new and vast tract of country with varied, and often unprofessional and untrained agency, the necessity of a standard of reference to ensure uniformity is too obvious to require argument. Such a standard will save many references, and perchance some misunderstandings, as to the style of work projected; and the general details will be of great assistance to the Political Agents, in their dealings with the Native Chiefs on the subject of roads, enabling them to give a distinct and prompt reply to all questions regarding the quantity of land to be surrendered; but the general specifications here given can never supersede the more detailed specification which should accompany an Estimate for the elaborated scheme.

It may probably be urged against the adoption of the standard, as here proposed, that the specification for the minor lines of communication is of too high an order, and that metalling, for instance, is superfluous on a 3rd class road. The reply is, that the specifications are intended to apply to completed roads of their several classes; and it must be admitted that every line of communication, deserving the name of a finished road, should be passable at all seasons and in all weathers for the style of traffic, whether wheeled vehicles, or beasts of burden, for which it was constructed.

CIFICATION.

YHIR

OF A SECOND CLASS ROAD.

ordinary value.

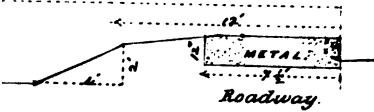


Fig. 4.
of extraordinary value.

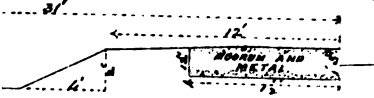
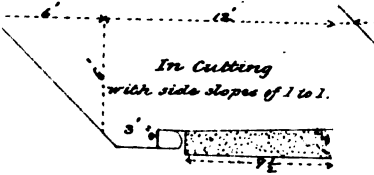
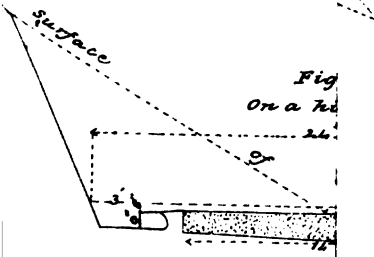


Fig. 5.



c
t
c
t
s
t
l
a
s
t
t

p
t
c
c
e
b
w
s

Every completed road necessarily consists of three main items:—

1. Earthwork (including embankment, excavation and drainage).
2. Bridging.
3. Metalling.

If any of these are omitted, the road is liable to obstruction, and is an "incomplete" road of that class according to which it was projected.

In cases where it is not desirable to undertake the full expenditure necessary to complete the road according to the specification of its class, it will be sufficient to specify it as a "2nd class road, unmetalled;" or a "3rd class road, unmetalled and unbridged, &c., &c."

Such a sub-division of the classes will convey an accurate idea of the style of road projected; and by ensuring uniformity, will admit a comparison in point of cost with others of a similar character.

General Description.—Roads will be divided into four classes. Classes 1 and 2 will be metalled up to a certain fixed water-way, and will differ merely in width, both being adapted for quick traffic in all weathers.

A 3rd class road will likewise be available for traffic in all weathers; but the metalling of the road-surface will be inferior, and the larger bridges suited for a single line of traffic only.

A 4th class road will be unmetalled and unbridged; in fact merely a fair-weather road on which the ground has been cleared, and the nullahs made passable. It may be regarded as a commencement of a 3rd class road.

Width of Land to be taken up for Roads.—The surrender of land for communication is always distasteful to the rulers and cultivators of a Native State, but doubly so when the ground required is capable of producing valuable crops,—such as opium, sugar-cane, tobacco,—for which special qualities of soil are required. When such land is of necessity absorbed within the road limits, it is advisable to reduce the width to a minimum, without prejudice to the absolute requirements of the highway. This is simply managed by diminishing the side gutter, and giving up its exterior slope altogether. In the specifications, therefore, two breadths are shown,—the narrower of which should be adopted where the land is of more than ordinary value.

Specification of a 1st class Road—[See Figs. 1, 2, 3].—For a 1st class road, in ordinary land the width required is 108 feet, divided as follows:—

Roadway,	..	..	..	..	30 feet.
Side slopes, 2 × 4,	..	..	..	..	8 "
Berm or cess, 2 × 15,	..	..	..	..	30 "
Side trenches, 2 × 20,	..	..	..	..	40 "
Total,	..	..	..	..	108 "

This has been calculated from the requirements of a 2-foot embankment, with the slopes of 2 to 1. If the embankment exceeds 2 feet, the extra width for the base of the slopes must be taken from the cess.

In valuable land the width may be reduced to 78 feet as follows:—

Roadway,	..	..	..	..	30 feet.
Side slopes, 2 × 4,	..	..	..	..	8 "
Berm or cess, 2 × 15,	..	..	..	..	30 "
Side trenches, 2 × 5,	..	..	..	..	10 "
Total,	..	..	..	..	78 "

The general specification of a 1st class road is:—

Embanked roadway to be 30 feet wide, with side slopes of 2 base to 1 height.

Gradients not to exceed 1 in 25.

Drains and Culverts, up to 10 feet water-way, to be 30 feet between parapets.

Bridges and Culverts, above 10 feet water-way, to be 20 feet in the clear between parapets.

Metalling in black soil, or where moorum is procurable, to consist of a foundation of 12 inches of moorum, 18 feet wide, well consolidated with a top layer of 6 inches of broken stone or kunkur. Where moorum is not obtainable, and the soil hard and firm, the metalling will be 9 inches of broken stone or kunkur, 12 feet wide.

The Estimate for a 1st class road should include all bridges up to 150 feet water-way. Beyond this, they should be taken up as independent works, and form the subject of separate Estimates.

Specification of a 2nd class Road—[See Figs. 4, 5, 6].—For a 2nd class road, in ordinary soil, the width to be taken up is 80 feet, divided as follows:—

Roadway,	..	..	..	..	24 feet.
Side slopes, 2 × 4,	..	..	..	..	8 "
Cess, 2 × 12,	..	..	..	..	24 "
Side gutters, 2 × 12,	..	..	..	..	24 "
Total,	..	..	..	..	80 "

In valuable land the detail will be as follows:—

Roadway,	24 feet.
Side slopes, 2×4 ,	8 "
Cess, 2×12 ,	24 "
Side gutter, 2×3 ,	6 "
Total,	62 "

The specification of a 2nd class road is:—*Roadway* to be 24 feet wide, and in embankment, to have side slopes of 2 base to 1 height.

Gradients not to exceed 1 in 20.

Drains and Culverts below 10 feet water-way, to be 20 feet wide between parapets.

Bridges and Culverts exceeding 10 feet to 18 feet between parapets.

Metalling in black soil to have a moorum foundation 12 inches thick, 15 feet wide, and a top layer of broken stone or kunkur 9 feet wide and 6 inches thick. In firm soil, where broken stone or kunkur is used, the width will be 9 feet, and thickness 9 inches. The Estimates of a 2nd class road should include all bridges up to 100 feet water-way.

Specification of a 3rd class Road—[See Figs. 7, 8, 9].—The land to be taken up for a 3rd class road, under ordinary circumstances, is 72 feet, reducible in valuable land to 54 feet.

The detail of the various parts are:—

Roadway	20 feet.
Side slopes, 2×4 ,	8 "
Cess, 2×10 ,	20 "
Side gutters, 2×12 ,	24 "
Total,	72 "

And the decrease, when necessary can be made by reducing the width of the side gutters to 3 feet, as has been shown in the specification of 2nd class road.

The general specification is *roadway* to be 20 feet wide, with side slopes of 2 to 1.

Gradient not to exceed 1 in 20.

Drains and Culverts up to 10 feet water-way to be 18 feet between parapets.

Bridges and Culverts, above 10 feet water-way, to be 14 feet between parapets.

Metalling, where moorum is obtainable, to be of that material exclu-

sively, 14 feet wide and 9 inches thick. Where broken stone or kunkur is used to be 9 feet wide and 9 inches thick.

The Estimate for a 3rd class road should embrace all bridges up to 75 feet water-way.

Specification of a 4th class road.—For a 4th class road, land should be taken up 54 feet wide, and the boundary marked by a small trench. It will not be embanked, but should necessity demand it, it can hereafter be completed as a 3rd class road, of which it is only the commencement.

Its specification is :—

All ground between the boundary trenches to be levelled and cleared; nullahs to be rumped, and made passable for wheeled traffic. All hills or ghâts to be reduced to a gradient not exceeding 1 in 18.

Probable cost per mile.—The cost of these roads will naturally vary according to localities, but it may be set down roughly as follows :—

					RS.
1st class road per mile,	..	..	..	..	14,000
2nd class road ditto,	..	..	..	..	10,000
3rd class road ditto,	..	..	..	..	6,000
4th class road ditto,	..	..	..	..	1,000

A 1st class road being expensive, is only adapted for an artery, connecting the principal Military Depôts; for a main Postal line; or the chief Commercial outlet of the country, where the traffic is such as to warrant the outlay.

A 2nd class road may be adapted to connect the smaller Military Stations with their Reserves, and with each other. It is also suitable for connecting Commercial Marts with the main line, or the chief outlet for their exports, whether this be 1st class road or Railway; whilst

A 3rd class road will be found to suffice for the internal communication of the country between the more populous towns. It will also be found a useful style for short Railway feeders; and where a road is required as an outlet for an isolated district.

A 4th class road must be looked on merely as a preparation for a 3rd class line. Unless greatly favored by Nature, it will be impassible in the rains; but for eight months of the year, it will be found a useful adjunct in many ways, not the least of which will be its habituating the people of the country to the necessity of setting apart a portion of their land for communications.

No. CXXXVII.

PENDULUM OPERATIONS OF THE G. T. SURVEY.

An account of the Pendulum Operations about to be undertaken by the Great Trigonometrical Survey of India ; with a sketch of the theory of their application to the determination of the earth's figure. BY CAPTAIN J. P. BASEVI, R.E.

WHILST Lieut.-Colonel Walker, R.E., the Superintendent of the Trigonometrical Survey, was in England last year, General Sabine, the President of the Royal Society, solicited his attention to the importance of making a series of Pendulum observations at the stations of the Great Indian arc, of a similar nature to those made by Captain Kater at the stations of the English arc, and by himself, Captain Henry Foster, and others in various parts of both the Northern and Southern hemispheres. Pendulum observations were made on the French arc by Arago, Biot and Mathieu early in this century ; it is also the intention of the Russian Government to have them made at the principal stations of the Russian arc : moreover there is hardly an instance of the measurement of an arc which has not been accompanied by such observations.

General Sabine offered to assist, by placing at the disposal of the Indian Board the pendulums, clocks, and apparatus which he had employed in his own operations ; and he added that, should the India Board desire any opinion from the Royal Society on the subject, he would assemble a Committee for the purpose.

Colonel Walker drew up a scheme and estimate of the probable expense, and submitted it with General Sabine's letter for the approval of the Secretary of State for India, who, acting on General Sabine's

suggestion, requested the Royal Society to report on the plan of operations proposed by Colonel Walker.

The President accordingly called for opinions from several distinguished Fellows, viz., Professors Challis, W. H. Miller, Stokes, H. J. S. Smith, Dr. Robinson, Sir G. Everest, and Sir John Herschel; all in their replies were agreed on the scientific value of the operations, and all, with the exception of Sir George Everest,* approved of the proposed plan of carrying them out; several made very valuable suggestions.

The Secretary of State in Council consequently sanctioned the experiments, and on Colonel Walker's recommendations he directed Captain Basevi, R.E., who was then in England on furlough, to proceed to Kew to learn the use of the Pendulum and apparatus, with the view of his conducting the experiments in India.

Before detailing the proposed operations, a sketch of the theory, and of what has hitherto been done in the way of Pendulum experiments, may be interesting. The application of Pendulum experiments to determine the figure of the earth, is based upon a theorem demonstrated by Clairaut, which may be stated thus, that the sum of the ellipticity† of the earth, and the fraction expressing the ratio of the whole increase of gravity to the equatorial gravity is a constant quantity, and is equal to $\frac{2}{3}$ of the ratio of the centrifugal force to the force of gravity at the equator. Hence by ascertaining the difference between the polar and equatorial gravity, or, which is the same thing, the progressive increase in the force of gravity in going from the equator towards the pole, the ellipticity of the earth is at once determined.

It is proved in mechanics that the forces of gravity, at any two stations on the earth's surface are proportional to the lengths of the seconds Pendulum at those stations, or to the squares of the number of vibrations made by the same pendulum in any given time, one solar day for instance. Here is at once an easy means of determining the variations in the force of gravity; and the solution of the problem of the earth's ellipticity is reduced to the measure of the length of the seconds pendulum at a

* Sir G. Everest proposed to employ only the Pendulum of an astronomical clock, but this method is objectionable, as the Pendulum cannot be said to be acted on solely by gravity.

† The ellipticity or compression, as it is sometimes called, is the fraction whose numerator is the difference between the polar and equatorial semi-diameters, and the denominator is the equatorial semi-diameter.

number of points on the earth's surface, or, as has been most generally done, to the observation of the number of oscillations made by the same pendulum in a mean solar day.

This theory, however, supposes the pendulum to be a "simple pendulum," that is, to consist of a material point suspended by a string without weight, which is, of course a practical impossibility; but as it is always possible to calculate the length of the simple pendulum which would vibrate in the same time as a given compound pendulum, the latter may be used for precisely the same purposes as the former.

Beside this, there are several other conditions supposed to hold good, which in practice are never attained, viz., the arc of vibration has been assumed to be indefinitely small, the length of the pendulum to be constant, i. e., unaffected by temperature, and the oscillations made in vacuo and at the level of the sea. Corrections have therefore to be computed and applied to the observations, for each of these assumptions.

The time of vibration* in a circular arc is expressed in terms of the length of the pendulum, the force of gravity, and a series of ascending powers of the arc of vibration. The arc is always small, but still not so small that the terms depending on it can be wholly neglected; the first term, however, of the series is all that is ever appreciable in practice. Again, the observations are generally continued for a considerable time, and the change in the arc of vibration has to be taken into account. It has been shown mathematically, on a certain supposition regarding the resistance of the air, and found to be the case practically, that the arc decreases in a geometric ratio, whilst the times increase in an arithmetic ratio, and on this principle the correction † to the observed time of oscillation is computed.

$$* t = \pi \sqrt{\frac{l}{g}} \left\{ 1 + \left(\frac{1}{2}\right)^2 \sin^2 \frac{\alpha}{2} + \left(\frac{1.8}{2.4}\right)^2 \left(\sin^2 \frac{\alpha}{2}\right)^2 + \dots \right. \\ \left. \dots \left(\frac{1.3.5. \dots (2n-1)}{2.4.6. \dots 2n}\right)^2 \left(\sin^2 \frac{\alpha}{2}\right)^n \right\}$$

in which t = time of one oscillation.

π = semi-circumference of a circle whose radius is unity.

l = length of the pendulum.

g = force of gravity.

α = arc of semi-vibration.

† The formula for this correction is

$$\frac{M}{n} \cdot \frac{\sin(A + \alpha) \sin(A - \alpha)}{32 \log \sin A - \log \sin \alpha} \text{ in which}$$

n = number of oscillations made in a day; M = logmic modulus = 0.4342945; A the initial and α the final semi-arcs of vibration. Correction always additive.

Secondly, a correction must be applied for the temperature of the pendulum: a change of temperature will, of course, by altering the length of the pendulum, affect the time of its vibration. This correction* must be determined experimentally. Captain Kater immersed his pendulum in fluids of different temperatures, and measured with a micrometric arrangement the alterations in its length. Captain (now General) Sabine observed the change in the number of vibrations made by a pendulum in different temperatures. This is the most direct method of obtaining the correction undoubtedly, but everything depends on the perfect compensation of the clock pendulum with which it is compared.

Thirdly, the formula is only true for observations in a vacuum, and as observations have generally been made in air, or at all events only in a partial vacuum, the effect of the air has to be taken into account. This effect is to diminish the weight of the pendulum by the weight of the air displaced, or to diminish the apparent force of gravity in the same proportion. In the very large majority of observations, the correction has been computed on this consideration solely; but Bessel demonstrated in 1828† that this correction was insufficient, inasmuch as a portion of the surrounding air was set in motion by, and moved with, the pendulum so as to become part of the moving mass. The correction for this can only be determined practically, as by swinging the pendulum in "media" of different densities. It depends chiefly on the form of the pendulum. As this correction "reduction to a vacuum" or "buoyancy correction" as it is called, depends also on the state of the

* According to Kater's method—if τ be the standard temperature which is generally taken as 62° Fahrenheit; t the observed temperature of the pendulum; f its factor of expansion for 1° Fahrenheit, then correction = $\frac{1}{2} \pi f (t - \tau)$, positive when $t > \tau$.

† This circumstance was most clearly pointed out by the Chevalier du Buat in 1786, who made a number of experiments with pendulums formed of different substances, but his researches, which created a great sensation at the time, appear to have been completely lost sight of, and to have been unknown even to Borda who was conducting his experiments, little more than ten years after the publication of Du Buat's results.

The true correction for buoyancy Mr. Baily has shown to be (Phil. Trans. 1832)

$$C \times \frac{\beta}{1 + .0023 (t - 32^\circ)}$$
 where β is the height of Barometer, and t , the temperature during the interval of observation. C is a constant for the same pendulum, and is determined from the formula

$$C = \frac{N'' - N'}{\beta' - \beta''} [1 + .0023 (t'' - 32^\circ)]$$
 in which N' is the number of vibrations in a mean solar day, β' and t' the barometer and thermometer readings, in air; and N'' , β'' , t'' , the same quantities in a highly rarified medium, $t'' \approx \frac{1}{2} (t' + t'')$.

atmosphere, it is necessary for its calculation, to record the readings of the barometer, when the observations are taken in air.

The last correction is for the height of the station of observation above the mean sea level. The force of gravity varying inversely as the square of the distance from the earth's centre, a pendulum swung at a certain elevation above the sea, will make fewer oscillations in a day than at the level of the sea, and a correction has to be added on this account. Dr. Young, however, demonstrated that the correction computed on this consideration alone, was too large, as it neglected the attraction of the elevated mass itself, and he showed how this might be approximately allowed for.*

The general principle followed in determining the length of the seconds pendulum, is to observe the number of vibrations made by a pendulum of known length, in a mean solar day: then the length of the seconds pendulum is found by multiplying the length of the given pendulum, by the square of the number of its vibrations in a day, and dividing by the square of the number of seconds in a day.

The number of vibrations is generally determined by the method of coincidences. The detached pendulum is placed in front of a good clock, and adjusted to such a length as to gain or lose, (the latter generally,) two beats upon the clock in some convenient time, 5 to 10 minutes. Suppose the pendulums to be started together, then the longer one of the two will be left behind by the other, the distance between them continually increasing, until at length they will be at opposite extremities of their arcs of vibration at the same moment: the longer pendulum has now lost one oscillation on the shorter one, and both are apparently going at the same rate, but in opposite directions; after a short time they will begin to approach each other, the distance between them gradually diminishing, until they both appear to coincide. It is clear that between two consecutive coincidences the longer pendulum will have lost two oscillations on the shorter one. Hence all that is requisite in practice, is to observe as accurately as possible the intervals between

* This correction is given by the formula $\frac{n^2}{r} h x$, where n denotes the number of oscillations in a mean solar day, r the radius of the earth at the given station, h the height of the station above the mean level of the sea: x is an unknown quantity determinable from theory; on the assumption that the mean density of the earth is 5.5 and that of the surface 2.5. Dr. Young (Phil. Transactions, 1819) showed that the correction for a station on a tract of *table* land would be reduced by $\frac{1}{3}$ rd or that the correction = $\frac{2}{3} n A$.

the successive coincidences; the number of vibrations made by the clock pendulum is determined by observations of the sun or stars, and then the number made by the detached pendulum is computed by simple proportion.*

The first pendulum observation of which any account is preserved are those made by Picard at Paris, and Uranienburg (Tycho Brahe's observatory) and those by Richer at Cayenne in 1672. These last observations are said to have attracted Newton's attention, as they proved the variation in the length of the seconds pendulum in different latitudes, and it is generally stated that Richer made the discovery by accident. But it appears from Picard's address to the French academy in 1671, that a variation had been already observed, and it is probable that Richer's mission was undertaken partly with a view to throw light on the subject. Picard stated that "from observations made at London, Paris, and Bologna, it would seem as if the seconds pendulum required to be shortened in approaching the equator, but that on the other hand, he is not sufficiently convinced of the accuracy of those measurements, because, at the Hague, the length of the seconds pendulum was found to be quite the same as at Paris, notwithstanding the difference of latitude."†

Near the end of the 18th century, Borda made his celebrated experiments for determining the length of the seconds pendulum at Paris. His apparatus, which is named after him, consisted of a spherical ball of platinum attached by grease to a brass cap which had been truly ground, so as to fit it perfectly. The object of this attachment was to enable the observer to turn the ball round in the cap at pleasure, so as to destroy the effects of unequal density in different parts of it. A fine wire carrying the cap was fastened to the lower end of a small cylinder, passing through the knife edge, which carried on its upper end a small moveable weight, by adjusting which, the knife edge and cylinder could be made to vibrate independently in the same time as the pendulum, so that their effect might be neglected in computing the length of the simple pendulum. When in use, the knife edge

* If r = daily rate of the clock, and I the mean interval of the coincidences, then the number of oscillations made by the pendulum in a day $\approx n$

$$n = \frac{1-r}{1} (86400 \pm r) \text{ the lower sign is to be used when the clock is losing.}$$

† Coamos, Vol. IV., page 25, Sabine's translation.

rested upon a steel plate. The number of vibrations per diem, were ascertained by means of a clock, but Borda made a great improvement on the old method of *counting* the coincidences. He fixed a straight edge vertically, so as to coincide with the pendulum wire at rest, when seen through a telescope placed opposite. A cross was made on the bob of the clock pendulum, and the observation consisted in noting the times when the wire and cross disappeared together behind the edge. After a series of coincidences had been observed, the length of the pendulum was measured by means of a horizontal steel plate, which was screwed up from below, so as just to touch the ball: then the pendulum was removed, and a bar, whose length had been carefully compared with a standard, inserted in its place. The bar had a T head, of which the lower surface rested on the upper steel plate, and a graduated rod, sliding on the bar, was adjusted to contact with the lower plate. The diameter of the platinum ball was then measured by means of the same slider, by placing it on the steel plate for the purpose; the brass cap and wire were then weighed. The apparatus was enclosed in a glass case, and the temperature was carefully recorded. All necessary corrections were applied, excepting the true one for buoyancy. The whole process, which required very great delicacy, had to be repeated, and the length of the corresponding simple pendulum computed after each series of observations. Borda's pendulum was about 12 feet in length.

His method was followed by M. M. Arago, Biot, and Chaix, at Formentera, the southernmost station of the French arc, with this exception that they used a pendulum of only 3 feet in length. These observations were extended by Biot in 1817 to Leith, and Unst in the Shetlands, and in conjunction with M. Mathieu, he observed at Dunkirk, Paris, Clermont, Bordeaux, and Figeac. From these operations, Biot deduced an ellipticity of $\frac{1}{254}$.

In about 1809, Captain Warren made some observations at the Madras observatory with a pendulum formed of a leaden ball suspended by a fibre made from the plantain leaf. The vibrations were counted and an assistant noted the times, from an astronomical clock. In order to measure its length, he attached some glass plates to a wall, and set off on them a scale, transferred from Colonel Lambton's scale; the length was then measured by a pair of beam compasses. The length of the

seconds pendulum was found to be 39 0263 inches of this scale *in air*.

In 1818, Captain Kater published his determination of the length of the seconds pendulum in London at Mr. Browne's house, Portland Place, taken for the purpose of fixing the standard of English measures. His method was founded on the dynamical theorem due to Huyghens, that the centre of oscillation, and axis of suspension, are reciprocal in the same body; that is, if the body be suspended at its centre of oscillation, the former axis of suspension will pass through the new centre of oscillation, and the body will vibrate in the same time as before. The distance from the axis of suspension to the point called centre of oscillation, is equal to the length of the simple pendulum.

Captain Kater's pendulum consisted of a bar of plate brass 16 inches broad and $\frac{1}{8}$ th of an inch thick: two knife edges of the hardest steel, attached to solid pieces of brass, were fixed to the bar at a distance of rather more than 39 inches from each other; when the pendulum was in use, these knife edges rested on horizontal planes ofagate. At one end of the bar, immediately below the knife edge, was a large flat brass bob firmly soldered to it: and on the bar, between the knife edges, were two sliding weights. The plan of operations was to observe the number of vibrations per diem, made by the pendulum when suspended, first, by one knife edge, and then, by the other; and if these numbers were not identical, to make them so, by means of the sliding weights. The distance between the knife edges, that is, the length of the corresponding simple pendulum, was then measured by a micrometric arrangement. The method of observing the number of vibrations was as follows: to each extremity of the pendulum, a light deal tail-piece, well blackened, was attached; and on the bob of the clock pendulum a white paper disc, equal in diameter to the breadth of the tail-piece, was fastened; the detached pendulum was now placed in front of the clock, and both pendulums being at rest, a telescope was aligned, so that the blackened tail-piece exactly covered the paper disc. The telescope was also fitted with a diaphragm, consisting of two perpendicular cheeks which could be adjusted so as to become tangents to the disc. Now, if both pendulums be set in motion, the detached pendulum vibrating slower than the clock one, the tail-piece will be seen to pass across the diaphragm, followed by the

white disc; at each succeeding vibration the disc follows closer and closer, first touching it, and at last becoming completely eclipsed by it. The exact time of this event, called a "disappearance," is noted; after a few more vibrations, the disc will re-appear *preceding* the tail-piece; the time of this event, called the "re-appearance," is also noted; and the mean of the disappearance and re-appearance, is taken as the true time of coincidence. It is immaterial in this method of observation, whether the detached pendulum vibrates faster or slower than the clock pendulum, but it is a *sine quâ non* that its arc of vibration be less. The result, introducing all corrections, except the true one for buoyancy, was 39.13929 inches, which is still the received length, although General Sabine in 1831, showed, by swinging the pendulum in air and in vacuo, that the buoyancy correction was different, according as the heavy weight was above, or below, the plane of suspension.

Captain Kater, in the following year, 1818, made a series of experiments at the principal stations of the English Survey, from Shanklin in the Isle of Wight, to Uist in the Shetlands. He used in these observations a pendulum of a different pattern, known as "Kater's invariable pendulum." With it, it is not possible, nor was it intended, to determine the length of the seconds' pendulum, but it is essentially a differential instrument, and is used for measuring the differences in the number of vibrations at different stations. With these differences, if at any one station the length of the seconds' pendulum has been already determined, the corresponding lengths at the other stations can be ascertained. The invariable pendulum is of the same dimensions as the convertible one, but is without the second knife edge, and tail-piece, and the sliding weights. The mode of observation is exactly the same. Captain Kater deduced values of the ellipticity, from consecutive pairs of stations; he considered $\frac{1}{804}$ as a probable value (the same as M. Biot's); but he remarks on the difficulty of deriving a satisfactory determination, unless the extreme stations comprise an arc of sufficient extent to render the effects of irregular local attraction insensible.

In 1821-22, some very good observations were made by Mr. Goldingham, at Madras, and afterwards at a small island called Pulo Gaunsah Lout, lying nearly on the equator in East Longitude $98^{\circ} 50'$. The pendulum used was an invariable one, and observations were first taken

with it in London, by Captain Kater. From the observations at Madras and London Mr. Goldingham deduced an ellipticity of $\frac{1}{317}$.

Captain Basil Hall, assisted by Captain (then Lieutenant) Henry Foster, made a series of experiments with an invariable pendulum in 1820-23, at Galapagos, San Blas (Mexico), Rio Janeiro, and London (Mr. Browne's house). Comparing the results at each of his own stations, with each of Captain Kater's, he deduced ellipticities of $\frac{1}{315}$, $\frac{1}{314}$, and $\frac{1}{313}$.

In 1822, Sir Thomas Brisbane took with him to Paramatta (near Sydney), an invariable pendulum that had previously been swung in London, at Mr. Browne's house. He deduced ellipticities of $\frac{1}{316}$ and $\frac{1}{314}$, comparing his observations with those of Kater in London and at Unst.

In 1817, the French Government fitted out a scientific expedition under the command of Captain Freycinet, who was furnished with three invariable brass pendulums, one of which was similar to Captain Kater's pattern, and the other two had solid cylindrical rods instead of a flat bar. He had also a fourth pendulum, with a wooden rod formed of two plates of deal firmly clamped together. Instead of a clock he used an astronomical counter, ("compteur astronomique,") whose beats could be adjusted to synchronism with those of the pendulum. The counter had a dial, which showed hours, minutes, and seconds, so that by comparing the time shown by this "compteur" with that of a chronometer, he obtained the number of vibrations made by the pendulum in a certain interval, generally an hour or 40 minutes. The pendulums were first swung at Paris, and afterwards at Rio Janeiro, Mauritius, Guam (one of the Ladrone Islands), Mowi (one of the Sandwich Isles), Cape of Good Hope, Port Jackson, Rawak (an island under the line, north of New Guinea) and Malouine or Falkland Isles. Rejecting the determinations at the Mauritius, Guam and Mowi, as they appeared affected to a remarkable degree by local influences, Captain Freycinet deduced an ellipticity of $\frac{1}{315}$ from all four pendulums.

On the return of Captain Freycinet, the French Government sent out another expedition under Captain Duperry. He was supplied with two of Captain Freycinet's brass pendulums, viz., one with a cylindrical rod, and the one on Kater's principle. He observed at six

stations, viz., Ascension, Mauritius, Port Jackson, Falkland Isles, Toulon, and Paris. In deducing the ellipticity, he combined his results with those of Freycinet only, and obtained values varying from $\frac{1}{288}$ to $\frac{1}{289}$.

During Ross' voyage to Baffin's Bay in 1818, some observations were taken at Brassa, in the Shetlands, and at Hare Island, with a clock fitted with an invariable pendulum vibrating on a knife edge, which rested on hollow agate cylinders. Observations were repeated at these stations, and a further set taken at Melville Island, on Captain Parry's first voyage to the North Pole in 1819-20. Captain Sabine conducted both these experiments, using the same instruments.

In 1822, the English Government sent out an expedition under Captain, now General, Sabine, for the purpose of extending the enquiry commenced by Captain Kater; for both Kater and Biot had come to the conclusion, from a discussion of their experiments, that no decisive result of the earth's ellipticity could be obtained from them, on account of the smallness of the comprised arc, and the variations of local density. Captain Sabine visited thirteen stations between Bahia, S. Lat. $12^{\circ} 59'$ to Spitzbergen N. Lat. $79^{\circ} 50'$. He had with him three pendulums of Kater's invariable pattern, which were all swung at each station. Besides these he had the two clocks and attached pendulums which he had already used on his arctic voyages. His method of observation was similar to Captain Kater's; all the pendulums were swung in London at Mr. Browne's house, both before and after the expedition.

The ellipticity deduced from the experiments at Captain Sabine's stations was $\frac{1}{288 \cdot 4}$, from the same combined with Kater's $\frac{1}{288 \cdot 6}$, and combined again with Biot's $\frac{1}{288 \cdot 7}$, and from a general combination of all of these, $\frac{1}{288 \cdot 1}$. The observations of the *detached* pendulums only were used in these determinations; for though the clock pendulums gave closely coinciding values of ellipticity, still being acted on by other forces than gravity, their results are less reliable, and are only valuable in so far as they afford an independent corroboration of the other results. Captain Sabine was not at first aware of the strict expression for the reduction to a vacuum, but after the publication of Bessel's observations in 1823, he had an apparatus specially constructed, and ascertained the proper correction practically, by swinging his pendulums in air, and in vacuo.

The error from this cause, however, proved to be trifling, owing to his observations being strictly differential, so that only the differences between the corrections by the old and new formulæ entered.

The most widely differing buoyancy corrections at any of his or Captain Kater's stations of observation, computed by the old formula were + 5.75 vibrations at Sierra Leone and + 6.27 vibrations at Spitzbergen, in a mean solar day. These corrections, multiplied by the proper factor, 1.65, to reduce them to the new formula became + 9.52 and + 10.38 vibrations, so that the number of vibrations in a mean solar day at Sierra Leone required to be increased by $(9.52 - 5.75)$ 3.77 and at Spitzbergen by $(10.38 - 6.27)$ 4.11 vibrations. But the acceleration between the stations would only be *increased* by the difference between these numbers, or by 0.44 vibrations. It so happened, however that even this difference was too large, for in the deduction of the temperature correction, the old buoyancy formula had of course been used; on applying a correction on this account, the above difference required to be *reduced* by 0.36 vibrations, so that the whole error on the acceleration of the pendulum between Sierra Leone and Spitzbergen was only + .08 vibrations.

Captain Sabine subsequently determined the difference in the number of vibrations made by an invariable pendulum between London and Paris, London and Greenwich, and London and Attona. He also determined the true buoyancy correction for Kater's convertible pendulum.

(To be continued.)



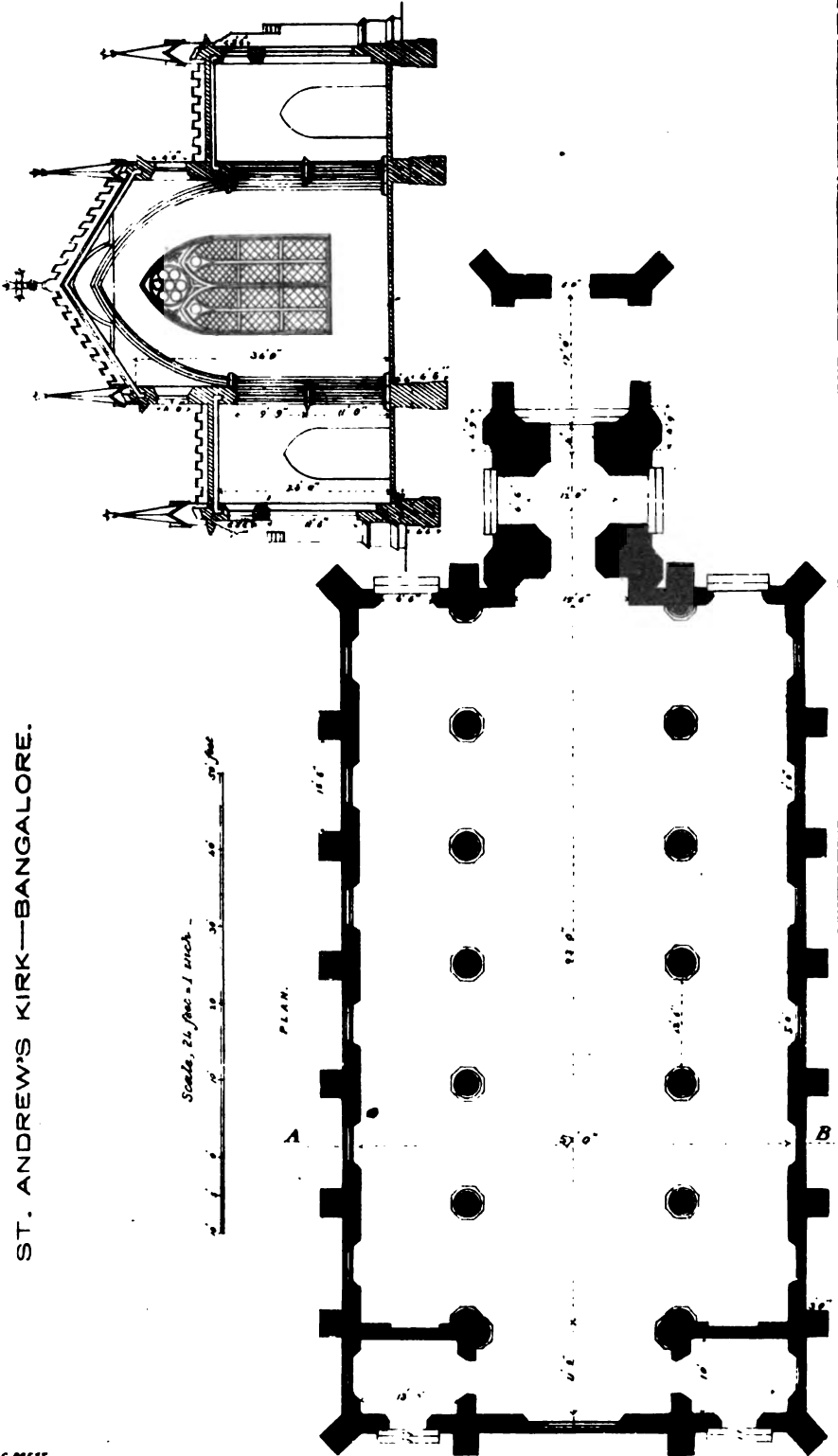


ST. ANDREW'S KIRK—BANGALORE.

Section on A.B.

Scale, 2 1/2 feet = 1 inch.

PLAN.



No. CXXXVIII.

SAINT ANDREW'S KIRK—BANGALORE.

THIS structure, lately completed and opened for divine service, was commenced in November, 1864. The body, having a length of 93 feet by a width of 57 feet, consists of a nave (covered with a pent roof, slated) and side aisles (roofed with Bengal terracing), the whole affording accommodation to a congregation of 500.

The height of the tower, which was originally intended to bear a steeple, is 90 feet; of the nave, to wall plates under roof trusses, 34 feet; and of the side aisles, 23 feet.

Ample light and ventilation is afforded by the clerestory windows of the nave, as well as by the main and circular windows of the side aisles; and as the building has no transept to break up the voice, it is a remarkably good one for hearing.

The style of architecture, which, while being effective, is sufficiently unpretending, can be best judged of from the annexed photograph, with plan and section.

The work consists throughout of good brick in chunam, plastered; and the total cost was Rs. 40,000 (including all fittings and furniture), of which one-half was raised by private subscription in this country and at home. Exclusive of furniture and fittings, the cost of the building was nearly Rs. 5 per square foot of plan over all.

R. H. S.

No. CXXXIX.

DRAINAGE OF MADRAS.

(2nd Paper.)

Abridged from a Report on a Project for the Drainage of the Town of Madras. BY CAPT. HECTOR TULLOCH, R.E.

Description of the Project.—It is proposed to drain Madras from the south to the north—to separate the sewage from the rain-water—to carry the former by sewers of small capacity to *one* central spot, north of, but near, the Madras Railway, and in the neighbourhood of the village of Coorookoopett—to lift it there by steam pumps—and, according as Government may decide, either to discharge it by an outfall sewer into the sea at a point two miles north of the Railway, or to utilize it on some thousands of acres of waste land lying to the north-west of Madras.

In order to render the description of the Project clear, I shall, for the present, defer the consideration of the proposition to utilize the sewage for agricultural purposes, and treat the subject of drainage as if it were necessary to take the sewage away from Madras altogether.

The first point to settle in every project for drainage is the locality of the ultimate outfall for the sewage. Everything hinges on this. At present the sewage of the town, as before mentioned, is discharged partly into the Cooum, partly into the canal, and partly into the sea; and these are all the outfalls available for Madras.

It is unnecessary for me to dwell on the present disgusting state of the Cooum or on that of the canal. To say that they are mere cesspools, from which the sewage cannot possibly escape, is to bring the subject

with sufficient clearness even to the minds of those who have never visited Madras. It should be an indispensable condition of every project for draining the town, that the Cooum and the canal should not be converted into sewage reservoirs. Until this is acted upon, all attempts to render Madras healthy must necessarily be only partially successful.

The only outfall, then, left for consideration, is the sea. The abominable stench from the mouth of the sewer at the north-east angle of the Fort, which drains a portion of Black Town only, is convincing evidence that it is not sufficient merely to discharge the sewage into the sea. No description can convey to the minds of those who have never lived within the influence of the smell from this sewer, its overpowering offensiveness while the outlet is open. The Fort would hardly be habitable from October to February, or while the north-east winds prevail, if this outlet were kept open during the whole day. Fortunately, the sewer is large enough to hold all the sewage which flows into it, for a day or two, so that it is unnecessary to open the mouth except for about a couple of hours during the night. This is done, too, at a time when the wind is blowing from the west, in order that the smell may be driven out to sea.

In some instances in England, no nuisance arises from the outfalls of sewers being placed on the coast and opposite to towns. But this is due to causes which do not prevail in Madras. In England, the tides rise and fall considerably. In London, the difference between low and high tide is 20 feet—in Liverpool, it is 32 feet—in the Bristol Channel, as much as 47 feet. The velocity of the ebb stream, or that which conveys the sewage away from the coast is, under these circumstances, very great. But in Madras, the tides rise and fall three feet only, and the water is exceedingly shallow. The consequence is, that the velocity of the ebb stream is trifling, and the sewage keeps floating by the coast instead of being carried out to sea at once. The prevailing currents, too, for 10 months in the year, follow the line of the coast, *i. e.*, run north and south. Sewage, therefore, discharged opposite the Fort, flows directly in front of Black Town or Triplicane, the two most important, because the most densely populated, neighbourhoods of Madras.

The nuisance at present from the drain near the Fort is as nothing compared with the nuisance which would ensue, if the main outfall for the drainage of the entire town were situated in the same locality. Under the present imperfect arrangements for drainage, the quantity of sewage which

ultimately reaches the sea is small, and it is sufficient if the mouth of the main discharging sewer is opened occasionally. But under a complete system of water-tight sewers, and street and house pipe-drains, the quantity of sewage would be considerable, and it would be impossible to pond it up for many hours together without incurring great expense. The line of coast, too, for a quarter of a mile or so on either side of the outfall, would be so covered with filth of every description, that the sea breeze, instead of being, what it now is, a great source of health to the inhabitants of Madras, would be deprived of all those pleasant associations which we at present connect with it. No outfall so situated as to contaminate our sea breeze should be permitted.

If this is granted, it follows that no sewage should be discharged on the sea-board of Madras Proper, *i. e.*, within the limits of the inhabited strip of coast land from Royapooram in the north to St. Thomè in the south. The question, therefore, so far as the outfall only is concerned, resolves itself now into this, "Shall the sewage be carried into the sea north, or south, of Madras?"

In order to decide this satisfactorily, several points should be considered. "Is the town, with regard to its physical features, more favorably situated for a southern or for a northern outfall?" "What is the direction of the prevailing winds?" "What that of the prevailing sea current?" "What particular advantages does a northern or a southern outfall offer in itself?"

The most important of these considerations is, without doubt, that which relates to the general configuration of the ground on which the town stands. Now, it has already been explained that, practically, there is no natural line of drainage for Madras, considered as a whole. But if this point admits of dispute, then the only line of drainage, which it is possible to call such, is the valley along which the canal runs. And, certainly, although the greater part of Black Town and all Royapooram drain into the sea, yet the portion of Madras lying to the north of the Cooum, may, in some respects, be considered as two slopes of ground inclining towards the Canal. The fact, too, of the districts south of the Cooum being generally on a higher level than the valley itself, may strengthen this view—viz., that there is a natural drainage line. But this very fact shows that the southern portion of Madras, if it is the higher, must be drained towards the north, *i. e.*, if the valley of the canal is taken as the drainage course.

And the northern portion cannot be drained to the south, because, in that case, the outfall into the sea must be situated somewhere between Triplicane and Black Town, which, it has already been shown, would be highly objectionable, because the sea breeze would be contaminated. The only course left to adopt then, is, to drain the whole of Madras to the north. And this is exactly what is proposed to be done. So far then as the question is affected by considerations of the natural position of the town, the advantage of the northern outfall is clear and decided.

Now, with respect to the winds, the situation of the two outfalls is about equally favorable. The prevailing winds* are those which blow between south and west, and these winds in *either* case would convey the smell of the sewage out to sea. The winds which would bring the smell into Madras, are, in the case of a northern outfall, those between N. N. E. and E. N. E., and, in the case of a southern outfall, those between S. and S. E. Both the former and the latter blow for about 80 days in the year.

With reference to the sea currents, the advantage lies decidedly with the northern outfall. The current which flows from the north southwards begins about the middle of October and ends in February, or runs for about $4\frac{1}{2}$ months in the year. This current would, in the case of a northern outfall, bring the sewage in the direction of Madras, and, in the case of a southern outfall, would carry it away from Madras. The current which flows from the south northwards begins in March and ceases in August, or continues to flow for about six months. During the remainder of the year, *i. e.*, in September and the first half of October, the prevailing winds are from the south, and if, as is most probable, the currents run in the direction of the wind, this second current will have a northerly direction. Thus, for about $7\frac{1}{2}$ months, the northward current would, in the case of a northern outfall, carry the sewage away from Madras, while, in the case of a southern outfall, it would bring it to Madras. There is no doubt, therefore, that, so far as the currents of the sea are concerned, the outfall should be placed to the north of Madras.

The special advantages which the northern outfall offers are very great. There are no Engineering difficulties to be overcome in the construction of the works, or to render them expensive. If the sewage were taken to the

* *Vide* "Chart showing the number of days in the year the wind blows in Madras from each point of the compass," which is given further on.

south, the outfall should be placed at least one mile south of St. Thomè, in order to prevent any nuisance to the inhabitants of this locality. This would make it necessary to carry the sewage either by a tunnel beneath the river Adyar, or by an aqueduct over it. Either of these works would cost a large sum of money. In the south, the sewage could not be utilized for agricultural purposes so judiciously as in the north, for the prevailing winds would blow the smell to the town. The lands, moreover, are not well situated, whereas, in the north, there are upwards of 20,000 acres of waste ground situated on the most favorable level possible, and in the direction from which the wind blows least often during the year. All these considerations render it advisable to adopt a northern outfall for the drainage of Madras.

Having settled this point, it next becomes necessary to decide *how far* north the sewage should be discharged. And this admits of some difference of opinion. The arrangements made in this Project are to place the outfall, *for the present*, at a point two miles north of the Railway Station. This is $1\frac{1}{2}$ miles from the nearest dwellings in Royapooram. I believe no nuisance will arise from this arrangement. When the northerly current is running, the sewage will have flowed a distance of more than two miles before it comes opposite to the nearest part of Black Town. Should it, however, be found hereafter that the outfall is not far enough away to the north, I have arranged so that it may ultimately be removed to a point three miles north of the Railway. Without positive evidence that the outfall at this distance would prove a nuisance, it would not be desirable to place it higher up on the coast. The question is one of expense only, for, so far as the Engineering difficulties are concerned, it would be as easy to carry the sewage four miles to the north as to discharge it where it is now proposed to place the outfall.

Having now arranged about the direction in which Madras is to be drained and the distance from the town at which the outfall should be situated, the next question requiring an answer is, "Can the sewage be discharged into the sea simply by gravitation, *i. e.*, without lifting it at any intermediate point between the town and the outfall?" An examination of the Map of Madras,* which accompanies this paper, should convince any one that this is impossible. The present system of open drains is a practical attempt to answer this question in the affirmative. But what

* Given above p. 2.

the effect is, is known well. Hardly a single drain has sufficient fall to keep itself free from deposit, and the consequence is, that the work which the drains should do, has to be done by the scavengers of the Municipal Department, and at a tremendous cost to the people. It is, indeed, impossible to drain a place like Madras, which covers 27 square miles of country, and many parts of which, in all quarters of the town, are elevated from 3 to 6 feet only above the sea, by simple gravitation, and without raising the sewage artificially.

If this, then, be admitted, the next point to settle is, "Where shall the sewage be pumped up?" This is almost altogether a question of Engineering. If the ground were very favorable, *i. e.*, if the soil were hard and there were no water to interfere with the construction of the sewers, it might be best to take the sewage right away to a spot near its ultimate outfall on the coast, and to pump it up there at once into the sea. But this is not the case. The strata beneath the surface soil consist chiefly of sand, and water is found in almost all parts of Madras at about the sea level. It becomes, therefore, positively necessary to raise the sewage at some intermediate point. I have selected a point very near the Madras Railway, but lying to the north of it and in the neighbourhood of the village of Coorookooppett. This will necessitate the construction of a tunnel under the Railway. But a tunnel would have been necessary, even if the site for the pumps had been to the south of the Railway; for the sewage of Tondiarpett and of the neighbourhood to the north of the Railway must, in that case, have been brought to the site by a tunnel crossing the Railway. It will thus be seen that, under any circumstances, a tunnel was unavoidable. The site selected for the cesspool and pumps is situated in that quarter of the town from which the wind blows least often in the year, and it is near the lands on which it is proposed to utilize the sewage.

I have considered whether it might not be advisable to have two cesspools and two sets of pumps—one for the portion of Madras lying to the north of the Railway, and the other for that lying to the south of it. But the first cost of such an arrangement would be even greater than that of the tunnel now proposed, and the working expenses of such a system of sewerage would be nearly double that in which all the pumping work was concentrated at one point.

I trust that it has now been satisfactorily shown that Madras should be drained towards the north,—that (putting aside for the present the ques-

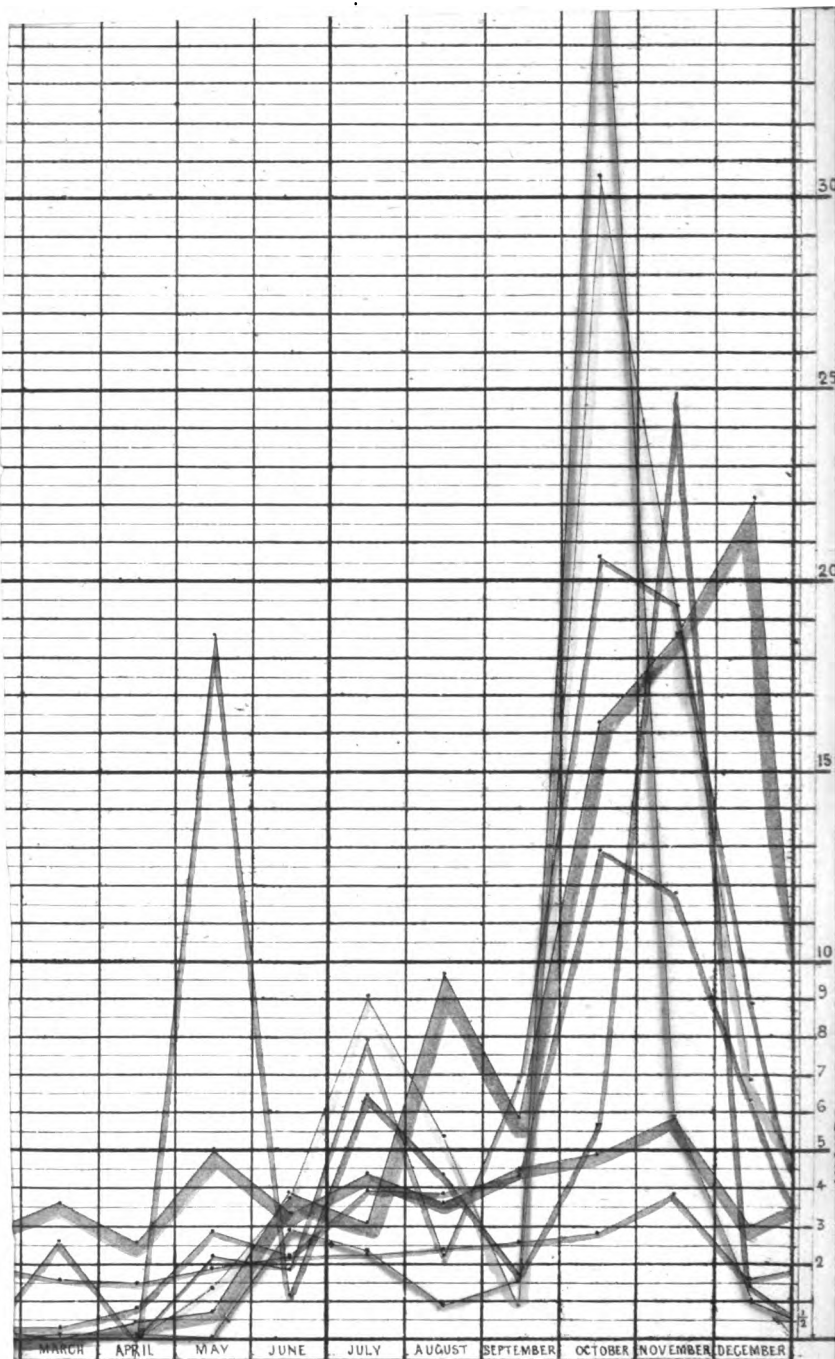
tion of utilizing the sewage) the best outfall is the sea,—that it will be sufficient if the outfall is placed on the coast three miles north of the Railway,—that it is not possible to drain the town by gravitation,—and that, consequently, the sewage must be pumped up at some intermediate point between the town and the ultimate outfall.

Separation of Sewage from Rain Water.—So far, this Project does not differ from the system of drainage adopted in many towns in England. I beg now to draw the attention of Government to a point which appears to me to demand the greatest consideration. In England, it is usual to have one and the same system of sewers to carry off both rain-water and sewage. I propose, however, that in Madras, sewage shall be carried away by a system of underground sewers and pipes of very small dimensions, and that rain water shall be removed by a system of open surface drains unconnected with the underground sewers and pipes. To justify such a departure from the stereotyped system of sewerage which has the sanction of European Engineers, it will be necessary that full and sufficient reasons should be given.

In designing sewerage works, the dimensions of the sewers are regulated almost entirely on considerations of rain-fall. The sewage proper forms so small a proportion of the total amount of fluid matter to be removed, that if a sewer is large enough to discharge the rain which falls on the district for the drainage of which it is constructed, it is hardly worth while to consider the small quantity of sewage which may flow into the sewer. In fact, sewers in England are constructed, *first*, for the removal of the rain-fall, and then for the removal of the sewage.* In a country, however, like England, where the rain-fall is pretty evenly distributed through all the months of the year, and where there are no extraordinary falls of rain such as we so often have in India, this principle of carrying off both rain water and sewage by one set of channels is not perhaps objectionable. It rains off and on throughout the year. Sometimes for days together there is no cessation at all. The consequence is, that the amount of water in the sewers does approximate to *some* extent to a constant quantity. In heavy rain-falls the amount is somewhat in excess of this quantity, and in light rainy weather it is somewhat below it.

But in India the conditions of rain-fall are totally different to those in

* In London the sewage proper is calculated at about $\frac{1}{4}$ th of the ordinary rain-fall.—*Vide page 305 of "Neville's Hydraulics."*



1851
MADRAS

Monthly Rainfall in England and Madras

Digitized by Google

England. In the first place the yearly rain-fall in India is double that of England. And while in England the supply is received in small monthly instalments all the year round, the supply in India is often received in 10 or 12 days only.

The accompanying diagram has been prepared with the view to explain the extraordinary difference between the rain-fall in England and in Madras. The first fact to which I beg to direct attention is the marked evenness of the line which represents the "mean" rain-fall in England.* The greatest difference in the quantities of rain which fall in any two months is between those which fall in April (about $1\frac{1}{2}$ inches) and in November (about $3\frac{1}{2}$ inches). But even this difference amounts to only $2\frac{1}{4}$ inches. So evenly distributed is the rain-fall, that if it were said of England that the quantity of rain which falls in every month of the year is 2 inches, there would really be no great error made.

The second fact to which I would draw attention is the parallelism between the thick and thin red lines. The former shows the maximum quantity of rain that has been known to fall in England in each month of the year. It runs throughout about 2 inches above the thin line and thus indicates that the maximum quantity of rain in each month is 2 inches only more than the mean quantity.

Now, let me turn to the rain-fall in Madras, the yearly quantity (about 50 inches) being double that of London (about 25 inches). The thin blue line represents the mean rain-fall of 20 years' observations. It will be seen that in the first four months of the year there is, practically speaking, no rain at all—that in the next 5 months the rain-fall is only slightly in excess of that of England—but that in the months of October, November and December, it is considerably in excess of it. Now, if sewers are to be constructed for the removal of rain water, it is very evident that in Madras they must be large enough to discharge the rain-fall in the months of October and November, when the heaviest quantity of rain descends. Suppose that the dimensions of the sewers in Madras are regulated by comparison of the mean monthly rain-falls in London and Madras. Then, the mean rain-fall in Madras in October (about 13 inches) being more than three times the mean rain-fall in London in November (about 4 inches), it is evident that the sewers must have three times the discharging capacity. A single

* Vide Page 311 of "Neville on Hydraulics."

mile of sewers laid down on this principle would cost more than the entire project now submitted to Government.

The difference between the maximum monthly rain-falls in Madras and in England, is even still greater than that between the mean monthly rain-falls in the two places. The maximum quantity which has fallen in one month in England is, as shown by the thick red line, nearly 6 inches. But the maximum in Madras is, as shown by the green line, nearly 38 inches, or upwards of six times the maximum of England.

Together with the mean and maximum monthly rain-falls in the two countries, I have projected on the accompanying diagram the monthly rain-falls in Madras of some of the most interesting years. From these it will be seen that it is far from an unusual occurrence to have upwards of 20 inches of rain in a single month of the year.

If we compare the *daily* rain-fall in England and in Madras, the difference becomes still more striking. The following are the greatest daily rain-falls in England of which I can find any record :—

Locality.	Date.	Rain-fall in 24 hours.	Remarks.
Little Bridy, } Dorsetshire, }	July, 1858	Inches. 2·06	<i>Vide</i> page 332 of "Beardmore's Manual of Hydrology."
Oxford, . . .	July, 1858	1·82	<i>Vide</i> page 333, <i>Ibid</i> .
Wandsworth, .	12th June, 1859	2·17	<i>Vide</i> page 293 of "Neville's Hydraulics." This fell in two hours.
Manchester, .	7th Aug., 1859	1·849	Do. do.
Southampton, .	26th Sept., 1859	2·05	Do. do. This fell in 2½ hours.
Truro, . . .	25th Oct., 1859	2·4	Do. do.
Holborn, . . .	1st Aug., 1846	4·00	} Do. do. These quantities are stated to have fallen in one hour.
Highgate, . . .	Do.	3·5	
Greenwich, . .	Do.	·95	

The following is a table of some of the heavy daily rain-falls in Madras in the years from 1822 to 1857 :—

Date.	Rain-fall in 24 hours.	Remarks.
4th November, 1822	Inches. 7-88	
29th October, 1825	8-87	
9th May, 1827	12-08	
27th November, "	7-77	
31st October, 1836	7-50	This fell in the night only.
20th November, "	9-65	* It appears to have commenced raining on the 18th October. Up to 6 A. M. on the 20th, however, only $2\frac{1}{2}$ inches fell. It then progressed very steadily for about 20 hours, till the maximum rate of $2\frac{1}{2}$ inches per hour was attained: after which it gradually decreased again till at the expiration of about another 12 hours when the monsoon was over. In this storm, Madras received, in 24 hours, i. e., from 10 A. M. on the 30th to 10 A. M. on the 31st, about as much rain as falls in London during the whole year.
27th December, 1845	7-20	
21st October, 1846	20-58*	
4th May, 1851	11-45	
4th November, "	7-90	
20th November, 1856	6-22	This fell in 5 hours.
24th October, 1857	18-04	Before sunrise 5-83 inches—before sunset 12-21 inches.

It will thus be seen that while 4 inches are the utmost that has been recorded to have fallen in England during the day, upwards of 20 inches have been known to fall in Madras in the same period of time. How could Madras afford to pay for sewers constructed to discharge five times the quantity of water which the London sewers discharge?

It will naturally be asked, "If the sewers are not to carry away the rain water, how is it to be got rid of?" The answer is—"by open channels." I propose, however, at first, to make use of the existing large drains as the outlets for storms. This will, no doubt, cause surprise to many, considering how much the present drains have been abused. It is well known, in drainage engineering, that when the quantity of water is great, the form of the sewer is of little consequence. Whether it has a rectangular section or an oval section, the velocity is still sufficient for all possible purposes. Now, the section of the Madras drains is certainly very far from faultless. Nevertheless for storm waters they will answer admirably. When Madras can better afford it, it will be time to reconstruct these channels, but having

them now at hand, I am decidedly of opinion that they should be used. The drains which I propose to keep are not, of course, the open *street* drains in all parts of Madras, but the few large underground and open channels which discharge immediately into the sea, the Cooum, or the canal. All the street drains should be taken up, for the bricks of which they are constructed are of the worst possible kind and so saturated with liquid filth, that every effort to cleanse the town without the removal of these drains will be ineffectual. At present, all that would be necessary would be to re-place these drains with broken granite, down which the rain water would flow until it ultimately entered, as it now does, one of the large outlet drains. The Municipal Commissioners, who spend yearly about 20,000 rupees in new drains, would have that sum available for this work, inasmuch as no new drains would be required in the town if this Project were carried out. Ultimately it might become necessary to have open channels of stone set in mortar, similar to those in use in England.

On this question of the separation of rain-water from sewage, I understand that it will be urged by the advocates of universal dry conservancy against me—"So, after all, your sewers will not get rid of the rain water." But these gentlemen forget that this argument tells, if possible, much more against them than against me. For, at all events, I do propose to dispose of all liquid refuse *except* storm waters, whereas the advocates of universal dry conservancy propose to get rid of 100th part only of the liquid refuse, and moreover of none of the storm water. If, therefore, it is necessary for the advocates of sewers, so also must it be necessary for the advocates of universal dry conservancy, to dispose of storm waters. It is no use to find fault with a sewer system from which storm waters are excluded, unless some mode of removing these storm waters, better than that suggested by me, is put forth by the objectors. All that I maintain is, that it will be unadvisable to adopt the European system of sewerage in its entirety in Madras, simply because, if rain water is to run in the same channel with sewage, the discharging capacity of the channel in Madras must be *four* times what it is in London for the same area to be drained—that sewers laid down on this principle will be perfectly useless for eleven months in the year—and that the cost of them will ruin the Municipality.

Details of Sewers.—The general system of sewers proposed to be laid down will best be understood by reference to the map of Madras given

at
y 50
1910

S F

70
6.32

13.4
18

13.4

13.4

13.4

13.4

13.4

13.4

13.4

13.4

13.4

13.4

13.4

13.4

13.4

above (p. 2), from an inspection of which the exact course of each sewer can be seen.

All the sewers proposed to be laid down in this Project are to be egg-shaped,—the diameter of the upper arch being double that of the invert. As it is now generally acknowledged by the Engineering profession that this is the best form for sewers where the quantity of sewage is constantly varying, it is unnecessary for me to dwell on the advantages of adopting it for the Madras sewers.

The formula by which the dimensions and slopes of the sewers have been calculated is the one used by Mr. Beardmore in his work, "Manual of Hydrology;"

$$v = 55 \sqrt{2 h f},$$

in which v is the velocity of the stream in feet per minute— h the hydraulic mean depth in feet—and f the fall in feet per mile.

A single example will best explain how the dimensions of the sewers for the Main Line have been decided on.

It has been assumed that the quantity of water used per head of the population, may ultimately be as high as twenty gallons per diem. Excepting the western portion of the neighbourhood lying to the north of the Railway, the population of which is about 54,000, the whole of Madras will be drained through the Main Sewer. If the population of Madras be taken at 428,000, the total quantity of water flowing into the cesspool in 24 hours through the Main Sewer will be $(428,000 - 54,000) \times 20$ gallons = 7,480,000 gallons, or 1,196,800 cubic feet. Assume that half this quantity, or 598,400 cubic feet, will run off in 8 hours, the period of maximum daily flow, then the quantity to be discharged every minute by the Main Sewer will be $\frac{598,400 \text{ cubic feet}}{8 \text{ hours} \times 60 \text{ minutes}} = (\text{say}) 1,247 \text{ cubic feet}.$

Now, a sewer 6 feet by 4 feet, laid at a slope of 2 feet per mile, will discharge upwards of 1,650 cubic feet per second, assuming the co-efficient of friction to be .75. The velocity of the stream would be about 18 inches per second. Allowing a large margin for prospective population, I think if the Main Sewer at its junction with the cesspool is 6 feet by 4 feet and laid at an inclination of 2 feet per mile, it will be quite large enough. I very much doubt if the Main Sewer will for many years be more than one-third full. But it is safer to make the sewers too large than too small.

As it is not intended that the sewers proposed to be laid down according to this Project shall remove rain water, it is necessary that the principles

on which the general system of drainage have been designed should be explained. In order to utilize to the utmost the natural slopes of the ground for the street drains, I have run the Main and Branch Sewers, as a general rule, along the valley lines of each neighbourhood. To ascertain, however, *at what depth* they should be placed below ground, I commenced laying down the street drains from the highest points in each district, and working down to the Main and Branch Sewers. The slopes given to the street drains, which will be earthenware pipes of 6 and 9 inches in diameter, are such as to admit of the sewage flowing through them at the velocity of at least 3 feet per second. The 6-inch pipes at the highest points in each district will be laid at an inclination of from 1 in 150 to 1 in 100. and, in those streets which are situated nearer the valleys, the slopes of the drains will be much greater than this. The slopes of the 9-inch pipes range from 1 in 250 to 1 in 170. In fact, the levels at which the sewers are put below ground are such as to admit of the pipe-drains in all the streets being laid at such inclinations as will generally enable them to keep themselves clear of deposit.

On the accompanying plan of Black Town, the complete system of sewers and pipes for this district is shown. The general principles of drainage which I have adopted will be better understood by an examination of this plan than by any written explanation on my part.

I have given the greatest consideration to the question of slope. Had the strata on which Madras stands, been favorable to the construction of sewers at a great depth, I should have laid them at a much greater slope than that on which they are placed at present, but these strata consist almost everywhere of sand or clay, and water is found in all parts at about the level of the datum line. The building of the sewers, therefore, if they were put very deep below the surface, would be difficult, and attended with considerable expense. I have preferred to adopt a medium slope, and propose to turn the abundance of water to use in flushing the sewers.

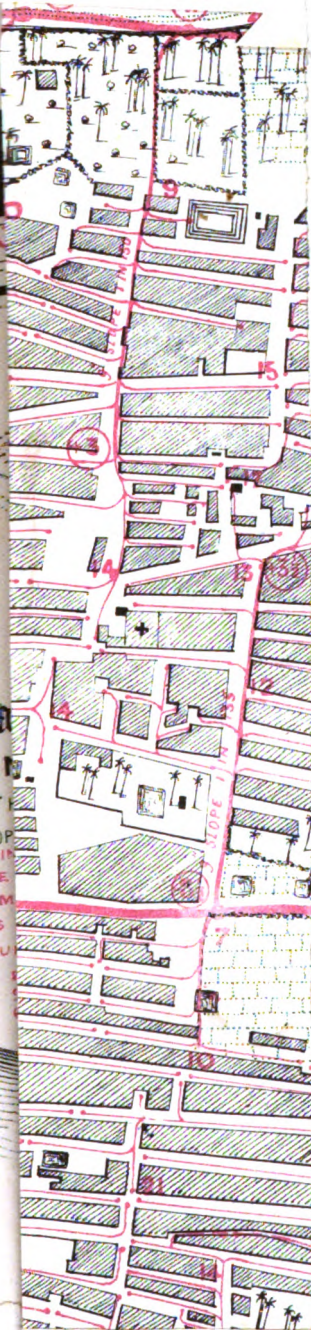
The Main Sewer at its head will be 3 feet by 2 feet, and laid at an inclination of 4 feet per mile, and at its termination it will be 6 feet by 4 feet with an inclination of 2 feet per mile. It will start at about the level of the datum line and will terminate at the level of 16.25 feet below the datum line. Where each Branch Sewer joins the Main, the dimensions of the latter will be increased, and as the Main Sewer becomes larger the slope will be gradually decreased.

General
Hospital

Medical
College

PLAN.

SHOWING THE
PROPOSED
FIGURES ENCLOSED IN
LEVELS AT WHICH THE
REFERENCE TO DATUM
ALL OTHER FIGURES
REFERENCE TO DATUM



ANG No 10
ANG No 2

N P

MBANKME

101
53
OUND

EVISH
63
AND

12 23
SH

1/2 MILE

S.E.



All the Branch Sewers, without exception, are to be 3 feet by 2 feet, and to be laid at an inclination of 4 feet per mile. They are considerably larger than they need be, so far as the quantity of sewage which they will have to convey away is concerned, but it would be difficult to cleanse a sewer of smaller dimensions thoroughly. I had thought at one time of using large earthenware pipe-drains for the branch sewers, but the expense of these would be as great as that of the sewers now proposed.

The entire system of sewers is designed to secure one uniform velocity (about 18 inches per second) for the sewage throughout its flow, from the beginning to the end of each sewer.

All junctions between the sewers will be effected by Bell-mouth Junctions.

As fast as the sewage arrives at the end of the Main Sewer, it will be pumped up by means of steam pumps to a height of 10 feet above the datum line, and it will immediately enter the Outfall Sewer, which will carry it to the sea. The position of this Outfall Sewer is shown in the map of Madras, above given. Its dimensions are the same as those of the Main Sewer at its junction with the cesspool, but while the inclination of the latter is 2 feet per mile, that of the Outfall Sewer is 3 feet per mile. This extra fall has been given with the view to secure a greater velocity for the flow of the sewage, as there will not be those facilities for flushing the Outfall Sewer which exist for the other sewers.

A great portion of the Outfall Sewer will run above the surface of the ground, but the line which has been adopted for it is very favorable, and no impediments to traffic will in any way be caused by this work.

The Outfall into the sea has been designed with great care. It will be built of solid ashlar masonry, standing on a groyne of granite boulders run out 200 feet into the sea. The invert of the sewer will be on a level with low water-mark. I think the Outfall will be found strong enough to resist the action of the surf.

Every sewer will be thoroughly ventilated through charcoal disinfectors. The ventilators will be placed at about 100 yards apart, and will be so arranged that dust or gravel falling through them from the roads will be intercepted and prevented from entering the sewers. The dirt can be removed at stated times without interfering with the action of the ventilator.

In connection with every ventilator there will be either a man-hole or

side entrance leading into the sewer, so that, when necessary, men may easily enter the sewers to clean or inspect them.

The St. Thomè and Outfall Sewers being above the level at which water is found, arrangements cannot be made for collecting water below ground for flushing them; but for all the other sewers there will be a flushing apparatus in connection with every ventilator and man-hole or side entrance, as the case may be. The flushing arrangements will, therefore, occur at intervals of about 100 yards apart, and it is expected that each apparatus will cleanse the sewer thoroughly up to that point in it where the next apparatus occurs.

The accompanying plan represents a flushing reservoir in connection with a man-hole and ventilator. The foul air from the sewer will travel up the man-hole shaft—pass through the charcoal in the box *a*, the bottom and top of which will be made of iron wire netting—and will escape, first through the opening *b*, and then through the ventilator *g*, to the open air. Any gravel or dust falling through the ventilator will be intercepted in the chamber *c*, and when it is necessary to remove the rubbish, the trap door *d* will be opened, the box *a* pushed into the recess *e*, and the chamber *c* will be cleansed through the door *f*, on the opening of which the rubbish will fall out and be received in a basket held at the mouth of the entrance. When the rubbish has been removed, the door *f* will be closed, and the box *a* will be pulled out of the recess and replaced in its original position over the man-hole shaft. Thus, all the foul air that escapes from the sewer will be made to pass through the charcoal which, it is expected, will in a great measure, disinfect it.

At the bottom of the man-hole shaft there will be a masonry reservoir (capable of holding about 350 gallons of water), which will be fed from a filtering well. The reservoir will be connected with the sewer by an iron pipe (6 inches in diameter) furnished at one end with a stop valve and at the other with a sluice gate. The water from the filtering well will pass into the reservoir through a small pipe, and when the reservoir has sufficient water collected in it, the pipe will be closed by a self-acting ball-valve.

In order to flush the sewer, the man employed on the work will first open the trap door at the surface of the ground—he will then descend the ladder, and, pushing the box of charcoal into its recess *e*, pass down to the bottom of the man-hole shaft. A few turns of the handle fixed to the stop valve will open the mouth of the flushing pipe, when the water from the

SCALE .4 FEET TO AN INCH

Digitized by Google



reservoir will rush through it, open the sluice gate *k* by the force of its pressure, and pass into the sewer with considerable velocity. After all the water has escaped, the sluice gate will fall down by its own weight, and the stop valve will be closed by the man, who may then leave the reservoir to fill again, and pass up the ladder to the open air. As soon as the reservoir is emptied, the water from the filtering well will begin to flow into it, and in the course of a few hours the whole apparatus will be again ready for use.

It is expected that a pressure of 2 feet of water in the reservoir will give a sufficient scouring velocity to the water. If, however, this amount of pressure should, in practice, be found insufficient, the reservoir can be filled to the depth of 3 feet by altering the position of the ball-valve.

The Outfall Sewer and the St. Thomè Branch Sewers must be flushed by forming temporary dams across them and removing the dams suddenly. This is practised in England and found to answer.

All the sewers and other works will be constructed with machine-made steam pressed bricks laid in the best hydraulic cement. The inner surface of the sewers and other works will be lined with asphalt half-an-inch thick, and the inverts of the sewers will be formed with earthenware blocks of English manufacture. Round those sewers which run beneath the level of water, there will be a casing of concrete. A general idea of the form of the sewers and the manner in which they will be constructed, may be obtained from the accompanying diagram.

Pumping arrangements.—Assuming that 20 gallons of water will be used, per diem, per head of the population, the total quantity of sewage to be raised by the steam pumps daily would be:—

Population of Madras. Gallons. lbs.

$$428,000 \times 20 \times 10 = 85,600,000 \text{ lbs.}$$

And if half this quantity be supposed to enter the cesspool during the 8 hours of maximum flow, the power of the engines should be sufficient to raise 42,800,000 lbs. in 8 hours. The average lift from the cesspool into the outfall sewer would be $26\frac{1}{2}$ feet. The power of the pumps, therefore, should be—

$$\frac{42,800,000 \text{ lbs.} \times 26\frac{1}{2} \text{ feet}}{33,000 \text{ lbs.} \times 8 \text{ hours} \times 60 \text{ minutes}} = \text{say } 70 \text{ horses.}$$

I consider that two engines, each of 36 horse-power, would be ample for all purposes. I would not recommend the erection of a third engine as a

reserve, for I very much doubt if, for many years, the quantity of water used daily per head of the population, will even approximate to 20 gallons. Indeed, one engine of 36 horse-power would, in my opinion lift all the sewage that might flow into the cesspool during any hour of the day. The second engine, therefore, would be as a reserve. If, at any future period, it were found that these two engines were not sufficient for the work required of them, a third could easily be procured, but it would be very unadvisable to go to the expense of providing more engine power at first than could be utilized afterwards.

By the cesspool, to which I have alluded so often, it must not be supposed that a large reservoir for ponding up the sewage for many hours is intended. This system, which is practised in England, and of which the most notable examples are to be found in the grand London Drainage Works, is obviously not suited to a country like India where decomposition sets in so rapidly. The cesspool for the Madras Drainage Works, will be a small well of, perhaps, 8 or 10 feet in diameter, into which the sewage will be led for conveniences of pumping. During those hours of the day when there is a little or no sewage to be raised, the engines will be stopped and the sewage will be allowed to accumulate in the Main Sewer, which, in fact, will be the ponding reservoir, and take the place of those enormous cisterns which are constructed in Europe.

As so many improvements are yearly made in England in pumping engines, of which the Indian Engineer is not so much as aware, I have thought that it would be useless for me to attempt the designs for the engines for the Madras Drainage Works. Much better designs could be obtained by the Government from some one of the numerous Engineers in England, who devote their entire attention to this class of work. A few remarks as to the requirements of the engines for Madras will not be out of place here. 1st. The boilers must be constructed on the most improved principles, and with the view to the smallest consumption of fuel in proportion to the work performed. Where, as in Madras, coal is sometimes not to be had at less than 50 shillings per ton, the necessity for the careful construction of the boilers, with the object of saving fuel, cannot be exaggerated. 2ndly. The furnaces must be made for the combustion of either coal or wood. 3rdly. In connection with the pumps, arrangements must be made for separating, if necessary, the liquid from the solid portion of the sewage: and a filth-hoist for the purpose of raising the latter must

be erected to be worked by the engines. I would leave it to the Engineer in England to decide what style of engine should be adopted—whether high or low pressure, whether condensing or non-condensing, whether single acting or double acting, &c.

On receipt of the plans of the engines, the buildings at the Pumping Station can be designed. With this report is forwarded a plan and sections of the ground where the sewage is to be raised, and such information is given on the plan as will enable the Engineer in England to understand the special requirements of the case.

Street Drainage.—The street drainage will be effected by means of 9-inch and 6-inch glazed earthenware pipes of English* manufacture. Only in one instance will a pipe of larger dimensions be laid down. I propose to use pipes of these two sizes as the most convenient for the objects in view. Every street will be drained by a 6-inch pipe leading to a 9-inch sub-main, which will run directly to the main or branch sewers. The 6-inch street pipes will usually begin at 3 feet below the surface of the ground, and will slope down uniformly to meet the 9-inch sub-mains. The least slope for the 6-inch pipes will be at the top of the ridges in each District (about 1 in 150), and the greatest slope in those streets which are nearest the main and branch sewers (about 1 in 50). In laying down the street drains, it will be necessary to provide means of access to them at intervals of about three hundred feet apart, so that they may be easily cleansed when obstructed. In connection with these entrances leading to the drains, ventilators and small flushing reservoirs might be formed, similar to those adopted for the sewers. Where the pipes were above the level of the water, some other means of flushing would have to be arranged. A water-cart, with a long hose, would, perhaps, be the simplest plan.

I would strongly urge that the pipes used for the Madras drainage be of the kind known as "saddle and chair" pipes. If they get broken, they can easily be removed, and others can be substituted without shifting more pipes from their position in the line than the number to be replaced.

House Drainage.—The house-drainage will be effected by three and four-inch earthenware pipes laid at as great an inclination in each instance as the internal arrangements of the walls and rooms of the dwelling will admit of. The pipes will start from the back yard of the house and will issue into the street from under the front door of the dwelling. The admirable system

* Why should not these be made in India?—[Ed.]

known as "back drainage" in England cannot be adopted in Madras. The destruction of property would be so great as to put it entirely out of the question. In London, where there is generally an open yard at the back of every house, there is no difficulty in draining the houses to the rear—in fact, it is cheaper to do so, but in Madras the back yard to the house is surrounded by small buildings, the destruction of which would be necessary before a pipe could be laid. Every house, moreover, invariably slopes, and some very considerably, *from the back yard towards the street*. To attempt "back drainage" will be to drain the houses against the natural slope of the ground. Many objections may be found and urged against carrying the pipe through the entire length of each man's dwelling and taking it into the street drain from under his front door, but long attention to this subject, and a careful inspection of numerous dwellings all over the town, have convinced me that this is the only method at our disposal. It is not possible to make use of the present house drains, which are usually channels of about 4 inches square, and run beneath the wall which separates two contiguous buildings, and is common to both. These drains having been built along with the houses, there is no means of getting at them except by pulling down the walls, which cannot be done without causing damage to the dwellings. In many of the streets, the slopes which have been given to these channels are very slight, and they constantly become choked up in consequence.

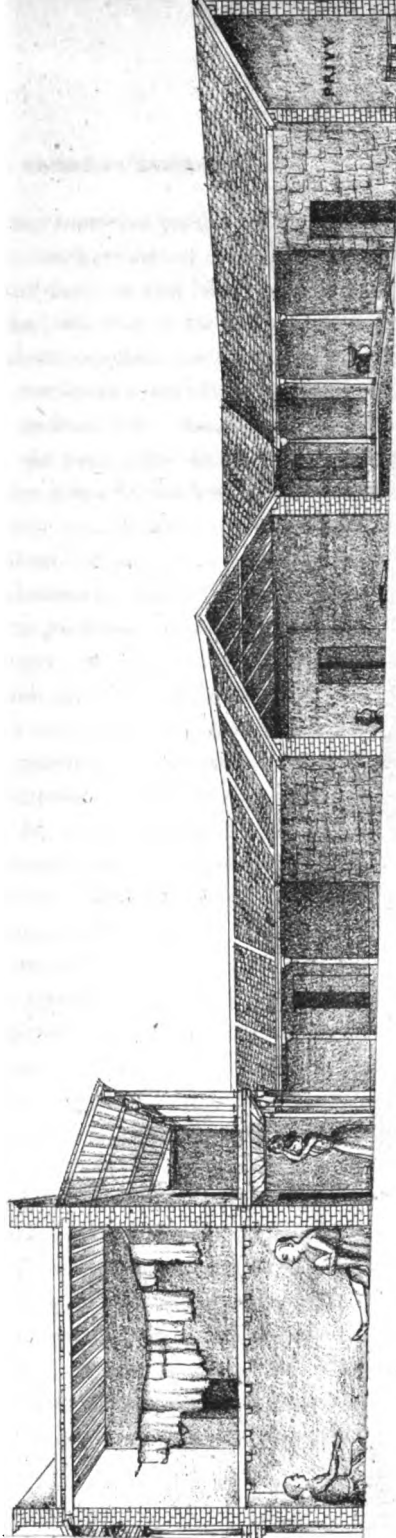
I would, therefore, leave the present house drains as the discharging channels for rain-water, and would lay down three and four-inch earthenware pipes in the manner already proposed for the sewage. In every yard, or wherever water may be used within a native dwelling, there would be a small cistern fitted up with a sink. The earthenware pipe, which would run from the back to the front of the house, would, in most cases, pass directly under these sinks and be connected with them by syphon traps.

To illustrate my meaning, I will take the most ordinary case—a native dwelling with, say, three open yards, one behind the other, and with a well in the back, and another in the front, yard. The earthenware pipe would start from near the well in the back yard, run across the second yard to the well in the first yard, and thence pass through the dwelling and out under the front door. It would join the street drain in the middle of the street. Round each well it would be necessary to put up a brick dam two or three inches high—just sufficiently high to intercept the

Madras Drainage.

PERSPECTIVE SECTION OF A FIRST CLASS NATIVE HOUSE IN MADRAS.

showing the System of drainage proposed.



water, and sufficiently far from the parapet of the well to admit of the inmates of the dwelling bathing and cleaning their pots in the space between the parapet and the dam. A sink would be fixed in this open space so that all the water that was used at the well would escape through the sink and pass at once into the earthenware pipe. In many cases the dam would not be required, for there is already a channel from each well, and the sink might at once be fixed in it. Care should be taken not to lay it at the lowest point in the open yard, as in that case, the rain falling on the roofs of the houses and in the yard would enter the earthenware pipe.

The house drainage should be carried out under the immediate direction of the Municipal Commissioners. Every house-owner should be at liberty to lay down the drains in his house himself, subject to the approval of the work by the Commissioners, or, if he preferred it, the Commissioners should lay down the drains for him at their own cost, and increase the rate charged on the house by such a sum as in 30 years would amount to the value of the work done, with interest thereon.

I must not omit to explain in this place how I intend that the excreta should be disposed of. So far as the urine is concerned the matter will be very simple. The connection at present between the privy drain and the house drain will be stopped, and the former will be joined to the new earthenware pipe through which all the urine will escape to the sewers. For the removal of the ordure I would encourage, as much as possible, the system which obtains at present throughout the town,* but I would, at the same time, try to improve it. The abominable smells in all parts of Madras are not produced, as is generally supposed, by the excreta of the population, but by defective drainage. It is the *refuse water* in the houses and in the streets into which all manner of garbage is thrown to ferment, and generate foul gases, that creates the dreadful nuisances so much complained of. What is chiefly required to prevent excreta producing a nuisance is a constant inspection of the privies in the dwellings. Although the ordure is removed daily, yet the privies themselves are not kept clean. Very often there is a stoppage in the channel which carries away the urine, or the ordure is dropped on the bare floor from which it is impossible to remove it altogether. Now, if the Municipal Commissioners would organize a system of inspection and insist on every householder keeping

* *Vide page 8.*

his privy in a wholesome state, we might soon get rid of the evil. Of course, the use of clay, ashes, &c., should be encouraged as much as possible. This would be nothing more than the dry system applied to dwellings, and would have this advantage, that each householder would be saddled with no more than the expense of removing the nuisance produced in his own house and by his own family. The cost of this plan to the Municipality would really be most trifling. For the first few months it might be necessary to examine each privy once in every two or three days, but after a few men had been punished for the filthy state of their privies, even this amount of inspection would not be called for. A weekly inspection would subsequently answer every purpose. Twenty-five Native Inspectors would suffice for the whole of Madras. In each District there should be one European or East Indian Superintendent, who should keep the Inspectors up to their work, and receive their daily reports. Both the Superintendent and the Inspectors should have no work but that of looking after the privies.

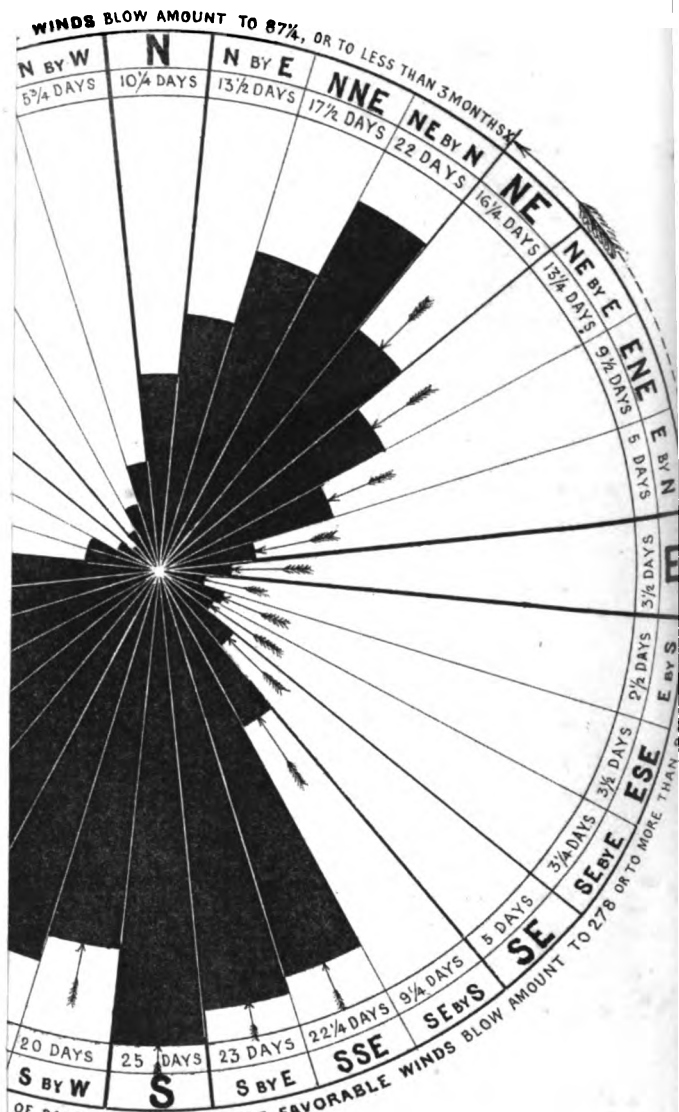
If each Superintendent received 30 rupees, and each Inspector 7 rupees, monthly, the total yearly cost of (say) eight Superintendents and twenty-five Inspectors would not amount to 5,000 rupees. The only objection which may be urged against this scheme, is, perhaps, that the householders would object to the privacy of their dwellings being invaded for the inspection of their privies. But, considering that ultimately the privies would not require to be inspected more than perhaps once a week or so, and that sweepers at present enter each house every day to clear away the ordure, the above objection would really be an absurd one.

The best system for the removal of excreta is the sewer system—provided that plenty of water can be employed to carry away the urine and ordure, and that a liberal use can be made of some deodorizing solution to prevent effluvia. There is nothing to equal the water-closet for cleanliness and wholesomeness. It acts perfectly if deodorizers are used as well as water. Both deodorizing and antiseptic solutions will, before long, be procurable at prices that will admit of their free use even by householders, but many years must elapse before every house in Madras is supplied with water. Until then, I am satisfied that it will be best to continue the present system.

Utilization of Sewage.—Having now explained the Project generally, it is necessary that I should return to a point in connection with it, to which

Madras Drainage.

CHART THE NUMBER OF DAYS IN THE YEAR THE WIND BLOWS IN MADRAS ACH POINT OF THE COMPASS.



convey the smell of the Sewage away from Madras, are marked with arrows.



as shewn above, are averages of 5 Years observations.

Digitized by Google

DRAWN BY H. TULLOCH, CAPTAIN R.C.



I have hitherto only alluded, in order that the description of the works should be as clear and uninterrupted as possible. Under the heading "Objections to Sewers," I have already attempted to prove that sewage is a valuable manure, and that those who are best qualified to speak on the subject are unanimous in their opinion, that it should not be wasted but applied to agricultural purposes. It is unnecessary, therefore, that I should repeat the arguments in this place. The points to which I now wish to draw attention are the very favorable position of Madras for the utilization of its sewage, and the rare opportunity thus afforded to Government of making an experiment on a large scale on this very important question of the day.

The land on which it is proposed to use the sewage, lies to the north-west of Madras. It is a portion of that extensive low-lying tract stretching toward the north, along which the canal runs. The average level of the land is from 2 to 6 feet above datum (mean sea level). It is not possible to say how much land will be required; that will depend on the quantity of sewage available. But if this quantity should be even ten times as much I have allowed for, there is more than sufficient land for the purpose. The only objection which I can conceive will be made to the use of the sewage, is the general one that a nuisance will be created in Madras whenever the wind blows over the sewage-irrigated land towards the town. This objection I shall, therefore, at once attempt to meet.

The accompanying Chart shows the number of days in the year the wind blows in Madras from each point of the compass. All those winds marked with arrows are winds which would convey the smell of the sewage away from Madras. The other winds would blow over the sewage lands to some one or other inhabited quarter of the town. Now, a glance will convince any one by how very much the favorable winds exceed the unfavorable ones. While the latter blow for less than three months, the former blow for more than nine months of the year. It must not be supposed that each wind blows *continuously* during the number of days marked in the Chart. What is meant to be shown is, that the total number of days in the year during which the wind blows from any one point of the compass amounts to that shown in the Chart. The winds N. E. by N. and N. N. E., which I have marked as unfavorable, are really in only a very slight degree so, for they would have to travel nearly two

miles before they reached the nearest inhabited part of Madras, which would be the outskirts of Pursewakum. The nuisance, if there were any, which I altogether doubt, would, at all events, be so very slight as to be scarcely felt.

On the accompanying Map of Madras I have shown the position of the sewage-irrigated lands, and have projected the directions of the winds so that the course taken by each may be at once seen. The only winds, if any, which would be positively unfavorable, are those which blow from between W. by N. to N. by E., but, practically speaking, there are no winds from between W. to N. Only occasionally, for a day or two in each month of the year, does the wind blow from the points between these quarters. It never continues in them. To render this clear I have drawn the accompanying diagram which shows the number of days in every month of the years 1847, 1848, 1849 and 1850,* during which the wind blew in Madras from each point of the compass. It will be noticed how thinly scattered over all the months of the year are the days on which the wind blew from between N. and W.

I think it will now be admitted that no inconvenience will be likely to arise from the use of the sewage on the site I have pointed out. But should the Government have any doubt on the matter, it would be very easy to select a much better site by going further away from Madras. It is a question of expense only, for the farther the land is situated, the longer must be the channel which conveys the sewage to it. I have merely chosen the nearest site on which I consider sewage might be applied without objection being made. My opinion is that the sewage might even be used around the very spot on which it is pumped up from the cesspool, without any nuisance to the inhabitants.

I had partly designed an Irrigation Sewer, but I subsequently decided not to complete it, as it was essential to know first what site the Government might select for the utilization of the sewage. The great advantage of using the sewage will be the saving effected by not having to construct the Outfall Sewer, a work that will cost about three lakhs of rupees. Besides this, the sale of the sewage may be expected to realize a considerable sum.

I beg respectfully to urge on the attention of Government the great im-

* I have not selected these years, but the Government Astronomer (N. R. Pogson, Esq.), gave me the records of them as being those which were in the most convenient form for reference. No records of later years have as yet been published.

Madras Drainage.

MAP OF MADRAS

SHOWING THE COURSE TAKEN BY WINDS
WHICH PASS OVER
THE SEWAGE IRRIGATED LANDS.

Note. a. The figures indicate the number of days in the Year
the Wind blows from each point
b. The favourable Winds are those marked with
arrow-heads and enclosed between the thick lines.

