

portance of this question of utilizing the sewage of Madras. Every town in India has an interest in its decision, and could it be proved that the sewage of towns could be profitably and safely applied to land in India, an incalculable benefit would be conferred on the whole country.

Cost of project.—The following is a list of the quantities of work to be done, and the rates at which they are calculated :—

Quantities.	Description of work and rate.	Amount.
MAIN DRAINAGE.		
Cub. ft.		Rupees.
1,337,751	Brickwork in hydraulic cement, Rs. 0-6 per cubic foot,	5,01,657
1,718,121	Concrete, at Rs. 0-2 per cubic foot,	2,14,765
Sq. ft.		
1,053,100	Asphalting, at Rs. 15 per square of 100 feet, . .	1,57,965
7,000	Plastering, at Rs. 2-8 per square of 100 feet, . .	175
Run. ft.		
104,928	Invert lock, at Rs. 1-8 per running foot,	1,57,392
Cub. ft.		
27,106	Ashlar granite, at Rs. 1-8 per cubic foot,	40,659
Cub. yds.		
529,169	Earthwork, including excavation, re-filling, re-mak- ing road and every expense, at Rs. 1-4 per cubic yard,	6,61,461
991	Tunnelling, at Rs. 7 per cubic yard,	6,937
83,281	Embankment, at Rs. 1 per cubic yard,	38,281
20	Gravel, at Rs. 1-2 per cubic yard,	23
Cub. ft.		
809	Teakwood, at Rs. 3-4 per cubic foot,	2,629
Sq. ft.		
4,203	Galvanized iron netting, at Rs. 0-6 per square foot, .	1,576
Tons.		
81,614	Wrought-iron, at 150 rupees per ton,	2,117
Number.		
1,104	Rivets, at Rs. 0-1-6 each,	104
836	Cast-iron ventilators, at Rs. 30 each,	10,080
336	Trap doors, at Rs. 140 each,	47,040
263	Ball valves, sluice valves, sluice gates with pipes complete for each flushing reservoir, at Rs. 90, }	23,670
Tons.		
6,258	Granite boulders at Rs. 2 per ton,	12,516
	Total Rupees,	18,74,047
STREET DRAINAGE.		
Rnn. ft.		
577,490	Six-inch glazed earthenware pipe drains, including digging, laying down, jointing, filling up, and every expense, at Rs. 1-4 per running foot,	7,21,868
61,400	Nine-inch do. do. do. } at Rs. 1-12 per running foot,	1,07,450
2,800	Twelve-inch do. do. do. } at Rs. 2-4 per running foot,	6,800
Number.		
214	Man-holes and side-entrances for the nine and twelve-inch pipes, at Rs. 500 each,	1,07,000
	Total Rupees,	9,42,613

I have thought it best to show clearly the exact quantities of work and the rates at which they are calculated, so that an opinion may be formed by the Government on the Estimate.

For sewerage works none but the best procurable materials should be used. Admirable steam-pressed bricks have already been made in Madras—sufficiently good for any engineering purpose. I propose to use bricks similar to these for the Madras sewers. Hydraulic cement can be made wherever lime and clay are to be had, and I have no doubt excellent cement will be produced when the time comes to begin the works. In London, brickwork for sewers, when the bricks are picked stocks and laid in Portland cement, costs under a shilling a cubic foot; but such brickwork will not be attainable in Madras. Brickwork with picked stocks in blue lias lime costs under 9*d.* a cubic foot. I have taken 9*d.* or 6 annas, as the rate for the Madras sewers.

In London, concrete, composed of blue lias lime and clean ballast, costs under 3*d.* per cubic foot. I have taken 3*d.* or 2 annas, as the rate for Madras. Hitherto, I believe, concrete has cost somewhat more than this; but it has been made in such small quantities, that it is difficult to say what the cost will be when it is manufactured on a large scale.

I think it will be necessary to coat the interior surface of the sewers with asphalt, and I do not apprehend any difficulty in the work, as the brickwork will all be built in blocks on the surface of the ground before it is laid in the sewers. The cost of the asphalt coating will, I think, be covered by the rate allowed for it, viz., 15 rupees per square of 100 feet.

It is most essential that the inverts of the sewers should be laid with the best material. They are exposed to much more friction than the other parts of the sewers. For smoothness of surface and for durability there is nothing to equal the glazed earthenware blocks which are now manufactured and used in such large quantities in England for the inverts of sewers. They have been laid down in the London sewers at 2*s.* per running foot. I have allowed 3*s.* or Rs. 1-8 per running foot for Madras.

Earthwork, including digging, re-filling, tamping, shoring, pumping, keeping the works clear of water, re-making road-ways, and every expense whatsoever, has been done for the London sewers at 2*s.* 6*d.* per cubic yard. There is no reason why this rate should be exceeded in Madras.

Six-inch glazed earthenware drain pipes have been laid down in London at 2*s.* per running foot, including digging, re-filling, and every expense

whatsoever. Nine-inch pipes have been laid at 2s. 6d., and twelve-inch pipes at 3s. per foot run. The rates I have adopted for the Madras sewerage are,—for the six-inch pipes, including all bends and junctions, Rs. 1-4; for the nine-inch, Rs. 1-12; and for the twelve-inch, Rs. 2-4 per running foot. The use of none but the best earthenware pipes should be contemplated. It would be folly to use country-made pipes as they are manufactured by the potters at present.*

I have assumed that each Man-Hole or Side-Entrance for the street drains will cost 500 rupees. The quantities of materials will differ according to the position of each, but I think the above will be found a near approximation to the cost.

The other items in the preceding estimate are of small amount, and it is not necessary that I should refer to them, as any slight alteration in the rates for them will affect the total cost of the works in only a slight degree.

Some land will have to be bought up for the works, and the value of this has been ascertained, in communication with the Collector's Department, at 25,340 rupees. A few small buildings in the line of the sewers will likewise have to be purchased. The cost of these will be 20,000 rupees. The cost of the engine and pumps (72 horse-power) has been calculated at 1,500 rupees per horse-power, delivered in Madras, or altogether to 1,08,000 rupees. The Pumping Station, and works in connection with it, (including expenses of erecting the machinery) will, it is calculated, cost 70,000 rupees. There are no plans for this work, as I have already explained, but I believe 70,000 rupees will cover all expenses.

The total estimate for all the works is as follows :—

	Rs.
Main drainage,	18,74,047
Street drainage,	9,42,613
Land to be purchased,	25,340
Buildings do.,	20,000
Engines and pumps of 72 horse-power, at 1,500 rupees per horse-power,	1,08,000
Pumping station, including cost of putting up machinery, and other works,	70,000
Total Rupees, ..	30,40,000
Add about 10 per cent. for sundries and contingencies,	3,10,000
Total Rupees, ..	33,50,000

* But there is no reason why they should not be improved. Witness the earthenware pipes now made at Allypore by the Irrigation Department, N. W. P. See No. CXVI. of these Papers.—[Ed.]

If Government decide, as I trust they will, that the sewage shall be utilized for agricultural purposes in the neighbourhood of the Pumping Station, the cost of the Outfall Sewer, about three lakhs of rupees, will be saved. An Irrigation Sewer will, in this case, have to be built, but its length need not be more than one-third that of the Outfall Sewer, and its dimensions need not be so great. The cost of the Irrigation Sewer may be put at about a lakh of rupees. Deducting the cost of the Outfall Sewer (about 3 lakhs of rupees) from the amount of the above estimate (33½ lakhs) and adding the cost of the Irrigation Sewer (say a lakh of rupees), the total of the estimate becomes 31½ lakhs.

It will be seen that I have allowed the large margin of upwards of 3 lakhs (10 per cent. on the estimate) for unforeseen contingencies.

The cost of the establishment for superintendence will probably be as follows:—

	Rs.
1 Mechanical Engineer, specially brought out from England to superintend the working of the engine and to keep the accounts,	400
2 European or East Indian engine-drivers, at Rs. 50 each,	100
4 trained firemen, at Rs. 15 each,	60
4 ordinary firemen, at Rs. 8 each,	32
25 men (mostly sweepers) to look after the sewers and pipe drains, and to be available generally for any work, at Rs. 5 each,	125
1 Storekeeper and accountant,	50
1 Clerk,	25
4 Peons, at Rs. 6 each,	24
	<hr/>
Monthly cost, Rupees, ..	816
	12
	<hr/>
Yearly cost, Rupees, ..	9,792
	<hr/>

If 5 rupees yearly represent a Capital of 100 rupees, the above sum for superintendence would represent a capital of $(9,792 \times 20 =)$ say, 2 lakhs of rupees.

I think it may fairly be assumed that for many years to come, the quantity of sewage will not exceed 10 gallons per diem per head of the population. The total quantity of sewage to be raised by the pumps daily, taking the population of Madras at 430,000, would, therefore, be 4,300,000 gallons. Good engines of the largest size (of about 200 or 300 horse-power) lift from 2 or 3 million gallons of water a hundred feet high with a ton of coal.

Small engines (such as those proposed for the Madras Drainage) would not lift more than half this quantity, or say $1\frac{1}{2}$ million gallons a hundred feet high. This is equivalent to more than $4\frac{1}{2}$ million gallons 27 feet high, which is the height to which the pumps will have to raise the sewage. About a ton of coal or say $1\frac{1}{2}$ tons at the outside, will, therefore, be consumed daily in Madras. The cost of coal, if imported direct from England and not purchased in the local market, may be taken at 20 rupees a ton. The yearly cost for fuel will be $(365 \times 30 =) 10,950$ rupees.

To this sum we should add, say 2,050 rupees for oil, tallow, and other sundries, which would then make the total yearly expenditure about 13,000 rupees. This would represent a capital of $(13,000 \times 20 =)$ say $2\frac{3}{4}$ lakhs of rupees.

If the works are properly executed in the first instance, and a sufficient establishment, such as that proposed, is maintained to look after them, the repairs ought to cost little or nothing. There are sewers at home which have cost nothing for repairs for years after they have been laid down. But I will assume that the repairs every year will amount to $\frac{1}{2}$ per cent. on the cost of the works, i. e., on $31\frac{1}{2}$ lakhs, supposing that the Outfall Sewer is not built. This will be equivalent to, say, 16,000 rupees yearly, or to a capital of about $3\frac{1}{4}$ lakhs.

The total estimate, then, under all heads, will be as follows:—

Cost of works,	81½ lakhs.
Superintendence,	2 "
Fuel and sundries,	2½ "
Repairs,	8½ "
	<hr/>
	89½ lakhs.

We are now in a position to compare the cost of sewerage with that of Dry Conservancy. In my estimate above of $89\frac{1}{2}$ lakhs of rupees, I have included every possible charge. I will even assume now that the works may cost as much as 50 lakhs, or half a million pounds sterling. And what will the rate-payers receive for this sum? All liquid refuse will be removed from the precincts of their dwelling and will be utilized on land. Ultimately, I have no doubt that the value of the sewage for agricultural purposes will repay the cost of maintenance, but I will not assume this now.

The Estimate I prepared of the cost of Dry Conservancy* was 75 lakhs

* *Vide* Page 19, i. e. capitalizing the annual cost of establishment and carriage, and adding it to the first cost of the privies, &c.—[ED.]

of rupees. But I did not include the cost of procuring clay, which amounted to 31 lakhs, and I excluded all cost of repairs and a number of other items. The calculations based on the enquiries made into the cost of Dry Conservancy by the Sanitary Commissioners, brought up the cost of this system to 258 lakhs. Let me suppose, though for argument's sake, that a million pounds sterling will cover all expenses. We then have half a million pounds sterling for a system of sewerage by which all liquid refuse is removed, and a million pounds sterling for Dry Conservancy by which only urine and ordure are removed, which together amount to *one hundredth* part of the sewage. So that it will cost at least twice as much to remove urine and ordure only, according to the Dry Conservancy system, as it will to remove a hundred times their amount of sewage by the Sewer system.

It has been urged that the cost of draining Madras according to this Project will amount to as much as the value of all the house property in it, and that it will be better to remove the town bodily, as the Americans remove their houses, than to attempt to drain it. It is best to meet arguments of this kind by facts. The value of a house is usually considered equal to 30 years' rental. The number and yearly rent of all the houses in the town may be obtained by any one from the Municipal Commissioner's Office, and the value of all the houses will be found to be 850 lakhs of rupees, or $8\frac{1}{2}$ million pounds sterling. Half a million pounds sterling (the assumed cost of this Project) is not 6 per cent. on the value of the houses at present, and a good system of water supply and drainage will raise their value in the course of a few years by at least twenty per cent. Money laid out in water supply and drainage works is merely capital sunk to improve house property. The inhabitants recover the outlay by the enhanced value of their houses.

There is an impression that Madras can be drained for a very small sum of money. -I have no hesitation in saying that the idea is absurd. It is possible to have a cheap system of water supply, but it is utterly impossible to have a cheap system of town drainage. In supplying a town with water, you may carry a few pipes to a few central stations and make the inhabitants fetch their water from them. But in draining a town, you must carry a pipe from *every single house* in the town, without exception, to some one central spot. The length of drains in the latter instance becomes enormous. Whatever scheme of drainage is adopted for a town,

the length of the sewers and pipes must be almost exactly the same. In the case of Madras, there must be about 140 miles of sewers and pipes, or, if not, some parts of the town will be left undrained. For whatever sum of money 140 miles of drains can be laid down, for that sum only, and for no less, can Madras be drained.

It is necessary for me to add only, that the success of this, or of any Project for the drainage of the town, will depend, in a great measure, upon the manner in which the works are executed. Contractors who have had practical experience in sewerage works will have no more than the ordinary difficulties to contend with in the building of the sewers and the laying down of the pipes for Madras, but should any one attempt the work who is unacquainted with town drainage, certain failure will overtake him. In the present day, contractors in England have attained great skill in the execution of sewerage works, and I therefore, venture to recommend that, when the Government shall have come to a decision on the subject, they should invite tenders for the Madras Drainage Works in London and accept not necessarily the lowest tender, but the tender of some well-known builder who has already proved himself competent, and who possesses the requisite amount of capital for the undertaking.

H. T.

No. CXL.

WEDGE BRICKS FOR ARCHES.

Memo. on the designing of Bridges and Culverts; drawn up for use in the 3rd Circle, P. W. Department, N. W. Provinces. BY MAJOR J. G. R. FORLONG, C.E., F.R.S.E., Superintending Engineer.

THE accompanying table has been framed as a general guide in designing Bridges and Culverts of certain dimensions, and with the object of collecting data as to the cost of such, as estimated and as built.

It is necessary to explain the system seen here of using wedge bricks, which the writer has employed in bridges, culverts, relieving arches of doors in buildings, &c., &c., ever since their invention (if it can be called such, by Captain Best of the Madras Engineers) in 1847.

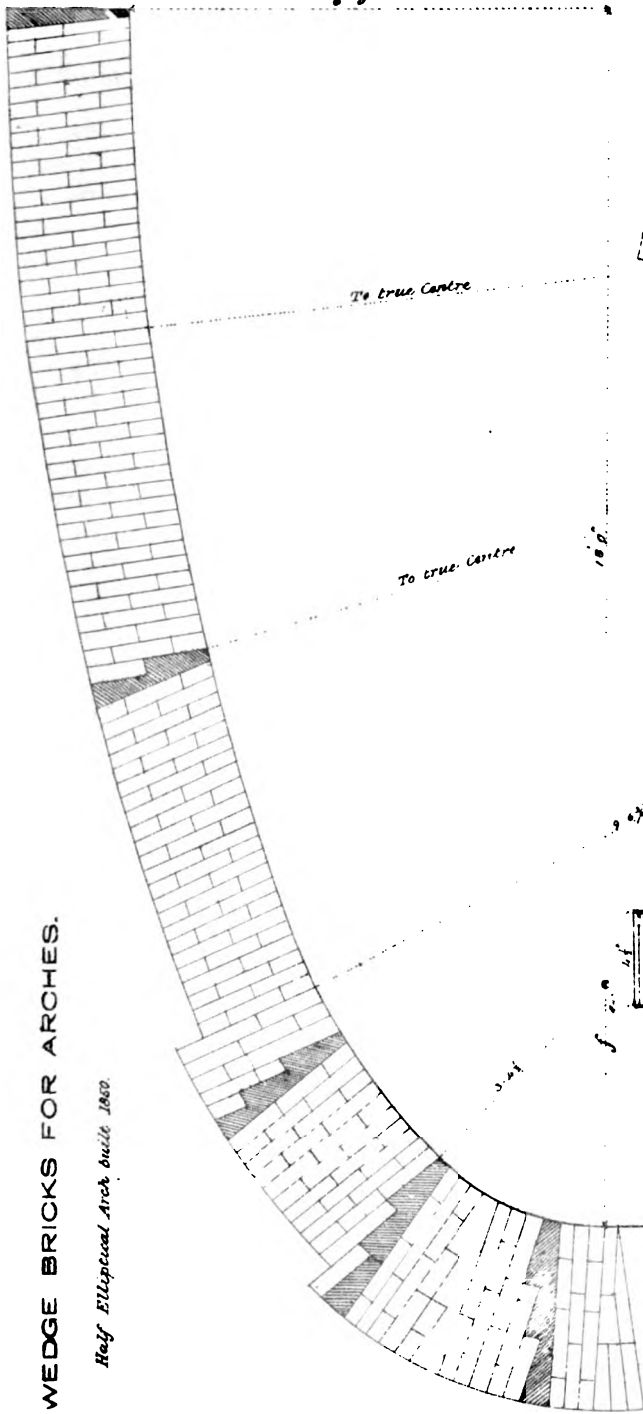
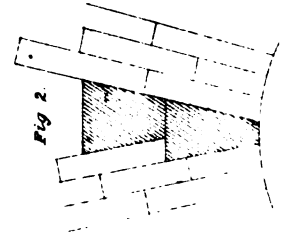
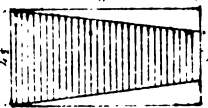
This one form of wedge [*Fig. 1*] can be used in *any* arch and with *any* kind of rectangular brick, and is a complete preventive of bad work, such as mortar dodging towards the extrados, in order to get the curves, the common artifice of all builders.

The wedge course occurs at true calculated distances, and a simple inspection of the face, or of the extrados or intrados of the arch, will at once prove if it is true and good work and according to specification; and this no other system will do, not even if all the bricks were true moulded voussoirs, for amidst such a mass of wedges, an ever increasing or decreasing error will be found in large arches, which will in practice throw out the true calculation of the number of voussoirs. In this system the wedges are so few as not to affect such, even in the largest arches.

A half section of an elliptical arch of 36 feet span, built about 17 years ago

WEDGE BRICKS FOR ARCHES.

Half Elliptical Arch built 1880.



Splice. Every 6" of a yard = thickness of a brick

For focus of true Ellipse, made centering such for simplification

by the writer, accompanies this, to show the occurrence of the wedges in curves of different radii in the same arch.

The wedges here used were $9 \times \frac{4\frac{1}{2}}{2\frac{1}{4}} \times 2\frac{1}{4}$ inches, with rectangular bricks $9 \times 4\frac{1}{2} \times 2\frac{1}{4}$ inches, and such are the best sizes for all arch bricks; common walling bricks in India are usually $12 \times 6 \times 3$ inches, which is a little too long for the wedge. If so long, it is apt to be broken in transit.

If the wedge is not the same length as its rectangular brother, the result will be as shown in *Fig. 2*, according to the thickness of voussoir.

The rule for finding the wedge courses is seen in the case of 9-inch bricks at foot of table; it is generally $\frac{R' \text{ radius}}{\text{length of brick}}$. The quotient is the number of courses *between* each wedge brick, counting from the crown which is itself a wedge.

Example.—Radius of an arc of 24 feet rising $\frac{S}{4} = 15$ feet, which $\times 12 = 180$ inches; $\frac{180}{9} = 20$, which is the number of courses the wedge bricks will be apart, to form this curve. As a course is here $2\frac{1}{4}$ inches, this $\times 20 = 45$ inches length on intrados between wedges, and as* intrados = $333\frac{1}{3}$ inches, half of this on each side of crown = $166\frac{2}{3}$ inches, which divided by $45 = 3$ wedge courses and $31\frac{2}{3}$ inches. This, however, mistries to assure themselves of no mistakes, ascertain practically by laying down the curve with radius and bricks, all full size, on the ground, remembering to allow for the mortar.

The number of wedges required in each wedge course for an arch of which the roadway (R) = 18 feet; will = 18×12 inches = 216 inches, length of arch in inches, which divided by $2\frac{1}{4}$ inches = 96 wedge bricks in each line of wedges. This multiplied by the 7 courses for 9 inches depth of voussoir, gives 672, and for 18 inches gives 1,344 wedge bricks.

It is as easy to make bricks of one size as another, the contractors being merely supplied with the different kind of moulds. These should have rims of hoop iron, and be large enough to admit of the shrinking of the clay.

This opportunity may be taken of stating that in large arches, it is a good plan to use 1 lb. of goor† water (or tolerably strong glutinous water,

* (Chord of $\frac{1}{2}$ segment $\times 8$) - chord of whole segment $\div 3$ = arc of whole segment. In this case $\frac{(12' 5'' \times 8) - 24 \text{ feet}}{3} = 2\frac{1}{4}$

† Sugar.

made by boiling down bullock or dog skin) to every 2 cubic feet of unslacked lime, and the same in plaster, with the addition of the hair of the animal; for the latter, the mortar should be made up, and stand for 15 days, and for the former, it is best made up as required.

Instead of painting or plastering bridges and culverts, the following has been found a far cheaper, and generally as good, a preservative. Rub the whole surface of walls, soffits, &c., with a deep red, but softish brick, dipped in fresh lime (not mortar) and strong goor water, of 1 lb to the gallon to 1 lb. of fresh lime. The rubbing to continue till the surface is quite smooth, and the whole nearly set. The cost of this has been ascertained on a large bridge near Agra not to exceed 8 annas per 100 square feet, and should always be done before removal of scaffolding. The freshly ground soorkhee rapidly and firmly sets, and care should be taken not to rub after it begins to set, but to have the whole surface then level.

AGRA, }
April, 1867.

J. G. R. F.

d Culverts.

		A.	P.	F.	W.	R.	Actual and estimated cost; the latter in black figures.			
4 of ct. ing te.	Top width of	Foundation allowed for below level of bed.		Water- way, square feet.	Road- way, in- cluding parapets.	Remarks.	H.	Esti- mate.	At per	
		Abut- ment.	Pier.						Square foot of W. W. water- way.	Lineal foot of span.
Barrel culver- ing cylind- long,	None. Only a bed for which estimate allows. Masonry.	None. Cylinders merely laid along side each other.	1-6 2-2 2-2 2-2	3 7 12½ 19½	21 ft., which may be increased.	Minimum height for cylinders of these lengths and diameters.	16-0 6-0 7-0 8-0	RS. { 100 110	RS. 24	RS. 36
Arched only	2-0 2-0 2-0 2-6 2-6 3-0	1-1½ .. 1-6 1-6 1-6 2-0	2-0 2-0 2-0 2-6 2-6 3-0	39 20 49 54 108 105	24 feet.	As actually built in 1855-66.	9-0 6-0 9-0 9-0 9-0 12-0			
Bridges, 4th	3-6 4-6 5-0 5-6 5-6 6-0 7-0 7-6 8-0 8-6	2-6 3-0 3-6 4-0 4-0 4-6 5-6 6-0 6-0 6-0	3-6 4-0 4-6 5-0 5-6 6-0 7-0 8-0 8-6 9-0 10-0	169 202½ 288½ 378 492½ 532½ 621 245 990 1,008 1,037½	18 feet.		15-0 18-0 21-0 21-0 24-0 24-0 24-0 30-0 30-0 30-0 30-0			
"	6/2	6/2	Of course this depends on the site. These depths are merely assumed for estimate purposes.	S X height of abutment + (VS/2)						

Notes of road over top of
should be 1-6" be-
Diam. 0.

5th.—The bricks are assumed to be 9" x 4½" x 2½"
and the wedges 9" x 2½" x { Top width, 4½"
Bottom, 2½".

J. G. R. F.



No. CXLI.

IRRIGATION IN MYSORE.

Abridged from a Report by MAJOR R. H. SANKEY, R.E., Chief Engineer, Mysore.

I HAVE the honor to reply to Circular No. 25, of the Government of India, dated 22nd March, 1866, calling for information regarding irrigation projects which, while proving remunerative to the State, should be primarily "calculated to prevent the occurrence or mitigate the severity of drought and famine," and requesting that a "review be made of the projects completed and in progress."

While most desirous of confining my remarks strictly to the points adverted to by Government, the nature of the subject in its bearings on this part of the country, necessitates more general treatment than would elsewhere be requisite. This is owing simply to the vast number of irrigation works, which the physical condition of Mysore, in common with much of the rest of Southern India, has given rise to in past ages.

Excepting in the Mulnád or rainy tracts of the Western Ghats, it is almost needless to say that the first necessity of a fixed society, next to that of providing itself with shelter, must have been the construction of reservoirs for arresting and storing up the rain-fall which, from the peculiar conformation of the ground, and nature of the soil, would otherwise have escaped to the sea, or been lost in other ways.

The storage of water for irrigation, doubtless followed closely on its collection simply for domestic purposes. In all the open country we therefore now find, that population has little or no existence, excepting in con-

nection with works of this description. And hence, to deal with the immediate and pressing wants of a people so situated, attention must of necessity be primarily devoted to the repair, development or reconstruction of existing tanks and channels. As regards entirely new projects, their superior attractiveness to the Engineer will sufficiently ensure their not being forgotten.

It will be sufficiently obvious from these brief remarks that the subject as proposed by Government, has here a widely different signification to what it necessarily would have in Northern India, where, from the presence of other physical characteristics, irrigation is for the most part a late introduction, and modern Engineers have had, so to speak a "tabula rasa," whereon to sketch their projects.

A general view of the existing irrigation works of Mysore, however imperfect, consequently appears to me inseparable from any proper consideration of the matter in hand. But before proceeding to deal specifically, with the two heads into which the subject naturally divides itself, (viz. (I.) Tanks, (II.) Anicuts and Channels), I would invite attention to the accompanying Map, showing the distribution of the two systems of works, with the general conditions under which they have grown up and are at present found to exist.

The unshaded portion of the map is the actual surface of the country, the drainage of which is caught up and stored in tanks. The shaded portions are those whose drainage, on the other hand, though partially used for rice and garden cultivation in the rainy and forest tracts, and partially diverted by anicuts in the lower reaches of the several streams, escapes nevertheless for the most part unutilized beyond the limits of Mysore and Coorg, and eventually, in great measure, to the sea.

The thin colored lines are the watersheds of the several streams, laid down carefully, like the above, from the Indian Atlas; those of similar tint belonging to the same main river systems. It will be thus seen, that Mysore gives birth to all the great rivers of the Southern portion of the Peninsula, and has therefore a primary natural right to the use of their waters, a position, which it will be shown further on, her people have not neglected.

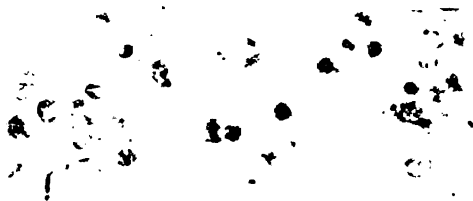
To elucidate this portion of the subject I have drawn up the annexed Table.

MYSORE & COORG RIVER SYSTEM.

Scale, 15 Miles to one inch.

The blue figures show the annual





MYSORE RIVER SYSTEMS.	Total length of the main rivers with their principal affluents within the Province.	Area over which the drainage is unintercepted by Tanks in Mysore.	Area over which the drainage is intercepted by Tanks.	Total area of each catchment basin.	Percentage of whole area under the Tank System.
	Miles.	Square Miles.	Square Miles.	Square Miles.	
I. Kistna river.....	611	4,814	6,217	11,031	56.47
II. Palar.....	47	...	1,036	1,036	100.00
III. Pennair.....	167	334	1,946	2,280	85.35
IV. Pennaur.....	32	222	1,319	1,541	85.60
V. Cauvery.....	646	5,526	5,769	11,295	51.75
VI. Western coast rivers.....	103	1,881	...	1,881	...
Totals for Mysore and Coorg	1,606	12,777	16,287	29,064	56.16
Deduct Coorg.....	...	1,795	...	1,795	...
Remaining for Mysore.....	1,516	10,982	16,287	27,269	59.78

Were the revenue survey complete, it would be an easy matter from this to give the precise area of wet cultivation under each stream, the work done, and rent paid for their waters; but with the present inexact returns, it is useless to do so.

It will be observed that of the 27,269 square miles covered by Mysore, nearly 60 per cent. has, by the patient industry of its inhabitants, been brought under the Tank system. Unless under exceptional circumstances, none of the drainage of these 16,287 square miles is allowed to escape, or rather *should*, with proper attention, be allowed to escape, were all existing works in their normal condition. To such an extent has the principle of storage been followed, that it would now require some ingenuity to discover a site within this great area suitable for a new tank. While restorations are of course feasible, any absolutely new work of this description would, within this area, be almost certainly found to cut off the supply of another lower down the same basin—to interfere in fact with vested interests.

The activity of the nation has, by no means however, been confined to this extent of work, vast as it is. In addition to the river works, which will hereafter be alluded to, there are an enormous number of small tanks, scattered throughout the rainy tracts of Mysore and Coorg, to a great extent buried in forest glens.

The rice lands here are narrow, low lying strips placed between the spurs of the hills, retentive of moisture, and only require a tank or dam large enough to supply water, if necessary, three or four times at the most critical period of the season. These reservoirs are too small to preserve water through the dry season, and are made without sluices or stone facings; so that the water below the *codi* [waste weir] level is let out by cutting the bund. This system also applies to "tota," or garden land.

In two points these small tanks, common alike to the Nuggur Mulnád, Coorg, &c., differ essentially from those which I have classed under the Tank System. *First*, they are all individually small, placed at the head of each minor valley, and meant only for occasional use. *Secondly*, they do not exist in chains, and are consequently not mutually dependent for safety one upon the other. Being in their nature very little open to improvement, they do not affect the immediate question raised by Government, and consequently do not call for further notice.

Physical aspect of the country.—It is almost unnecessary to remark, that of the various physical causes which, while rendering possible, have at the same time fixed the limit of the Tank system, "*cæteris paribus*" the actual quantity of rain-fall is by far the most important, and as this again depends mostly on elevation above sea-level, it may be noted that while points on the same latitude, along the Northern and Southern frontiers, have an elevation of about 2,000 feet above the sea, there is a general rise of from 1,000 to 1,500 to the central watershed line dividing the Northern and Southern river systems. This line in fact fairly divides the country into two nearly equal areas. Though fewer heights along the Western Ghats have been fixed than could be wished, it may be assumed that their general elevation ranges from 4,500 to 6,000 above sea-level, or from 2,000 to 3,000 above the Mysore plateau.

Judging from the actual state of things it would appear that 60 inches of rain per annum has limited the tank system; while with from 30 to 35 inches, every drop that has fallen in the country has been successfully stored. If this latter amount of rain could be counted on, there would be

little cause to fear even a scarcity of food, much less a famine, but this is unfortunately not the case in exceptionally dry years, and is more particularly observable in an almost rainless tract which I shall now advert to.

Over a large sector extending from Cuddoor through Hossdroog, the Mauri Cunawai, Heerioor, Dodary, and Mulkalmooroo, with a great extent of country on either side, the rain-fall ranges only from 10 to 20 inches per annum. And that this is due to the action of the towering mass of the Bababoodin Hills [Culhutti Peak, 6,000 feet ; Moolanghery, 6,350 feet] which stands across the path of the vapour bearing S. W. Monsoon, I have endeavored in a previous report to show.*

Whatever the reason, however, the country is, comparatively to the rest of Mysore, rainless, at times almost absolutely so. Ravaged by no less than eleven Mahratta invasions, between 1760 and 1792, the unfortunate inhabitants, have also, from this physical peculiarity, periodically been subjected to the still more dreadful horrors of famine.

What the people of this District suffered since the early part of the present year, it would be difficult to say. Early in March the tanks began to run dry, and towards the end of April, they were almost completely so, not to be replenished till late in September or early last month. At the best of times in this period, there was little else than liquid mud to be procured for domestic purposes. Cholera broke out again and again, cutting off all communication between each wretched village and its neighbours. There being neither fodder nor water, the cattle, upon which the ploughing for the following years depended, died in vast numbers; and spite of every exertion on the part of the civil officers, and particularly Lient. Pole of this Department, in giving out tank and other work, it is much to be feared that disease and famine have swept away a large proportion of the inhabitants. As it is here chiefly, that the humane intentions of Government may above all find fitting scope, several works of irrigation will, it is hoped, find place in the forthcoming Budget. These will be specially alluded to further on.

To the above imperfect sketch of the chief physical characteristics, which have either favored or limited the tank system, I would add one or two brief remarks on others, which have affected favorably, or otherwise, the construction of irrigation works generally.

* Memorandum on the Mauri Cunawai dated, 29th January, 1863.

The first of these is the generally undulating character of most of the open country. Totally unlike the wide plains of Northern India, there is probably not a square mile in the whole country absolutely flat or level. While in the Carnatic, the slopes of the country are not much more than 4 feet per mile, they here range from 10 to 20 in the flat portions, and as high as 60 and 80 feet elsewhere. The original cost of storage in Mysore, as also the risks, have thus been proportionably enhanced. The channels drawn from the several anicuts, moreover, for the same reason, command relatively but little ground, the rapid side-slopes preventing their drawing away to a sufficient distance from the river margins.

The second point in which there has always been a considerable disadvantage, is the incoherent nature of the soil, which over the greater portion of Mysore, is chiefly red and sandy, resulting from the disintegration of gneiss. Pure clay is mostly to be found in nests of decaying felspar, &c,—and is necessarily rare. Hence good puddle, that essential in all reservoir work, has been wanting. Leakage is therefore common, and water in motion rapidly works its way, soon destroying all before it. West of Seerah, and throughout the catchment basins of the Huggary and Soolikerray, a decaying metamorphic rock of a crystalline ferruginous character prevails, with a great extent of cotton soil, neither of which are of any use for the manufacture of puddle. The tank bunds here have therefore been formed under great disadvantages.

In the matter of stone, Mysore is highly favored, as the prevailing gneissose rock, where the cleavage is horizontal, splits off readily in large sheets from 3 inches to 2 feet in thickness, by the simple application of heat to the upper surface. By punching small holes, these sheets can by wedging be divided with great precision, into fairly even slabs of almost any dimensions, thus affording at once a most valuable material for all such works, as anicuts, codies [tank waste-weirs] sluices, overfalls, &c.* Stone telegraph posts thus prepared and 25 feet high have everywhere been employed. The natives have apparently used this material from time immemorial, though the ordinary pitching of their tank bunds is, for the most part, formed of rough natural blocks, picked up in the neighbour-

* In the High School, Bangalore, columns 35 feet high and not over 15 inches square have been used of this material. It is also employed for architraves, and for bridge girders up to 11 feet span. Extreme hardness has however prevented its use as dressed stone, excepting under very exceptional circumstances.

hood. Sometimes also they have employed round worn or disintegrating stones, which are of course quite unfit.

To the general excellence of the stone and its universal applicability, may, with possibly the scattered nature of the lime deposits, be attributed the practice of making the stability of all anicuts and over-falls to depend solely on the size and position of the individual blocks used in the work, instead of on the homogeneity and cohesiveness of the mass. This serious constructive error, which has caused endless trouble and expense, will be noticed more particularly further on—meanwhile it appears undesirable to defer longer such observations as I have to offer on the number, construction, and repair of the tanks considered individually, with the best method of meeting the objects proposed by Government.

Tanks.—By the returns of 1853-54, there were 26,450 tanks in Mysore classed as municipal or unirrigating, and irrigating. Of this enormous number there were 4,106 large irrigating reservoirs, 13,737 small, and 8,609 unirrigating, giving over all, about 1 tank per square mile in the gross.

In 7 talooks of Colar, where there are moderate conditions of rain-fall, and no reservoir of extraordinary size, there were I find 3,611 tanks, of which 2,950 were irrigating—the proportion being 1 village, and 1·07 irrigating tank to the square mile. The average quantity of wet cultivation was 10 acres under each, but this is of course not wholly to be depended on.

Turning to the rainless tract above mentioned, taking the talooks of Hossdroog, Davengherry, Cancoopah, Moolcalmooroo, Harnhully, and Boodihaul, in all there were 1,009 tanks registered, the proportions being 0·47 villages and 0·31 irrigating tanks per square mile, while under each of the latter, there were only 2·5 acres of wet cultivation on an average. Allowing the returns to be relatively, though not absolutely, correct, it would thus appear that in these barren famine stricken talooks, there was only one quarter of the wet cultivation in equal surfaces of country, as compared with Colar. While moreover the average of population, was by the last Administration report, 151½ per square mile for the whole of Mysore, I find that in these tracts it was only 71.

The classification simply into “large” and “small” is, as affording no clue to capacity or irrigation power, extremely vague; and under the first head especially there are some truly gigantic reservoirs which deserve separation from the rest.

Among these latter, I would specially mention the Nuggur Soolikerray, which has a margin of some 40 miles, a bund 1,000 feet long, 84 feet high, and having a breadth of base of upwards of 600 feet; the Mudduck tank, which is the terminal reservoir at the head waters of the Vedavutty, having a bund 1,220 feet long, 90 feet high, and 660 feet broad at base; also the great Mooteetalau, situated north of Seringapatam, on one of the feeders of the Lokani river, adverted to as follows by Buchanan.* “Two mountain torrents here had united their streams, and forced away through a gap between two rocky hills. *Rama Annuga* stopped up this gap by a mound said to be 78 cubits high, 150 cubits long, and at the base 250 cubits thick. The superfluous water is let off by a channel, which has been cut with great labor through one of the hills, at such a height as to enable it to water a great deal of the subjacent plain, which is three or four miles in extent.”

Works of this kind are however a class “*per se*.” Originally being natural basins, it was only needed that the gap between the two hills guarding the outlet of the valley, should be filled up, and a good position for the waste-weir secured. Precisely such positions are those of the Coombar Cuttay, and Mauri Canwai situated in the line of hills south of Heeroor, both of which works are now being estimated for.

The ordinary Mysore Tank is, however, a much longer and lower description of work; but on this point I think it better to substitute Captain (now Major-General) Green's remarks for my own, and therefore make no apology for making the following extracts from that Officer's Report of the 9th October, 1846, published in the selections from the Records of the Commissioner's Office :—

“*Tanks*.—There are upwards of 20,000 tanks in the returns, the bunds of which are of every variety of length from a quarter of a mile to $1\frac{1}{2}$ miles. They are, with very few exceptions, faced with a rough stone revetment, having a batter of about one horizontal in two vertical; the stone facing averages from a yard, to half a yard in thickness, and is backed with loose rubble stones, which are together of a thickness equal to that of the large stones in front. Occasionally a lighter description of revetment retains the rear slope of the bund. The breadth of the earthwork is proportioned to its height, which is greatest in the centre of its length. An ordinary bund is about 12 feet broad at top, 60 feet at bottom, and 18 feet high; there are many in every Talook, however, which exceed the above section.

“*Sluices*.—Each tank is provided with from one to two, and sometimes three sluices, by which the water can be let out on to the fields at pleasure. Their position is gener-

* Journey through Mysore. Volume II. Page 82.

ally on a level with that of the bed of the tank, but if any portion of the lands to be irrigated be above that level, one or more of the sluices is placed at a corresponding height. A tank sluice is a large, substantial and not unfrequently an expensive work; it consists of a two yard square brick or stone cistern one yard high, to keep off the sand at the front of the bund, with one or more valves, or plug-holes in a stone at the bottom, from 6 inches to a foot in diameter. The valve is attached to a pole so long, that the top shall never be covered with the water in the tank. It is held in an upright position by 2 or 4 vertical stone pillars from 9 inches to half a yard square, to which horizontal stones are attached, one at top and another midway, down through a hole in the centre of which, the valve rod works, having a stout chain and pin to uphold it when necessary, and to regulate the discharge; the pressure of the water upon the top of the valve keeps it sufficiently tight, when lowered into the valve hole, to prevent the escape of the water. At the rear of the bund, another cistern of about the same dimensions and usually of brick in chunam is built, three sides of which are furnished with square openings and shutters, to admit of the water being turned off in the required direction. The two cisterns are connected with a tunnel, the length of which depends upon the cross section of the bund through which it is laid, and is generally from 10 to 30 or 40 yards. The vent throughout the tunnel, for the passage of the water, is about $2\frac{1}{2}$ feet high and 2 feet broad. These dimensions are adopted to permit of a man going in to clear away obstructions, and to examine the state of the tunnel occasionally, should anything appear to have gone wrong. The cross section of a tunnel is like that of a massive barrel-brick-drain, but the vent is generally rectangular and cased with granite slabs about 6 to 9 inches thick.

"Codies.—In addition to the sluices each tank is provided with from 1 to 4 open masonry outlets, called codies, the gorges of which vary from 10 to 100 yards in width, and by which the surplus water of the tank escapes to other tanks below. As the rush of water over the codies would wash away any but a strong description of work, by which it is confined in its passage from the tank, the codies are necessarily made very substantial with the largest sized rough stones procurable in the neighbourhood; those of the large tanks rivalling the smaller anicuts on the rivers in the massiveness with which they are constructed, and the brick retaining walls with which they are frequently protected. Codies are generally of a square figure covering as much ground lengthways, as in their width. The front, which breasts the water, consists of a solid rough stone wall from 1 to 2 or 3 yards deep, according to the quality of the soil, and of proportionate thickness. It is furnished with dam-stones, which project a yard and a half, and are let firmly into the top of the wall at 1 yard intervals. The addition of some sticks, straw, and turf placed in front of these vertical stones makes a temporary dam, by which the ryots are enabled, after the burst of the monsoon is over, to retain the water in the tank at a level about two feet higher than they otherwise could have done, and to secure the water for a so much longer period.

"The sides of a cody are protected by wing walls 1 to 2 yards high, of rough stone or brickwork, which contract or approach one another at the ends of the gorge wall, and widen out above and below, forming, as it were, the sides of the funnel of discharge.

"The stones on the lower side of the gorge wall, are usually laid over suitable foundation in the form of a sloping apron, from its top to the bottom of the nullah below, by which the force of the water is broken; in cases, however, where it is found

difficult to render this (the ancient mode of building codies) permanent, recourse has been had to disposing of the apron stones like a flat pavement at the foot of the gorge wall (whatever be the height of the latter) taking care to have a very solid iron clamped platform of cut stones for the water to cascade upon. Its force is there expended, and it flows gently away from the foot of the gorge wall without having the power to do any mischief; this plan is found most effectual, and has never failed wherever it has been tried.

"The level of the top of the cody, whether of the permanent masonry, or of the low temporary dam now occasionally put above it, is the gauge of the powers of capacity of the tank; above that, the cody is always open and acts as the safety valve of the tank.

"In the nullah, immediately below a cody, is sometimes built another work of rough stone like the cody, and equally large, but which so applied is termed a "cuttay." Taken off, from above the latter, is a channel of irrigation. This is a very good arrangement, when the levels are favorable. The cody retains the water in the tank at its highest safe level; the cuttay below appropriates the surplus water, which the cody has discharged, and which but for such cuttay would be lost. Pouring over the cody in a thin sheet of perhaps a few inches only in depth, the sectional area of the water is fully sufficient to supply an ordinary tank channel of irrigation, and when it ceases, recourse is had to the sluices in the bund which are then opened. The Coonghul great tank, the tank at Heerashay, the Kickary tank, and the Hullaypoor tank at Nunjingode, all first class tanks, have cuttays below the codies of this description; and there are many others in different places. As the surplus water for 10 or 15 days annually is discharged in a great volume over the codies, the cuttays below are then exposed to a great shock from the impulse thereof, and require to be substantially constructed like the river Anicuts.

"As the alluvial deposit, year after year accumulating, gradually raises the beds of tanks, they would in process of time become useless, were not the alternative adopted from time to time of adding to the height of the bunds, which of course involves an enlargement of the cross section generally, as well as the raising of the codies and the construction of new sluices at higher levels than the former ones occupied, when the sand has eventually choked them up.

"Thus, even if no breaches occur, there is a constant yearly increased demand for tank work, and several of the bunds have attained an immense height in the effort to keep them sufficiently above the surface of the water. The upper part or roadways of several bunds in each of the four Divisions, are on a level with the tops of the cocoanut, and even of the more lofty areca, trees in the gardens immediately below them.

The same resource is had recourse to, in discharging the sand from the tank beds, that is adopted for the ejection of that carried into the channels of irrigation from the rivers. But a different season is selected; instead of the close of the monsoon, its commencement is taken, and no sooner is it seen that the monsoon has set in, than the ryots range themselves about the sluice head in the tank, which is at this time shallow, and stir up and agitate the bed, till, reduced to a semi-liquid state, it runs off through the sluice with the water. This, like the opening of the nullah under-sluice, is however but a partial remedy. It is less expensive to raise the bund than to carry away the sand by hand.

"Most tanks receive their supply from the high ground in the neighbourhood, and irrigate paddy fields or gardens immediately below them; but there are exceptions to

this, as numerous tanks are partly supplied by channels winding round more remote hills, and which catch all the rain water flowing down their sides and convey it into the tank. Water-courses or nullahs which are called into existence during a local fall of rain, are also dammed up, and their contents in like manner appropriated to the benefit of tanks. A single tank may possess several feeders of this kind, all of which require to be kept in repair.

"In like manner the fields to be irrigated are occasionally at a distance from the tank, and have channels of irrigation therefrom, including their windings, of from 2 to 30 miles long, and upon the preservation of all of which in proper order, depends the success of the crops. The water of the Soolikerray lake irrigates land at a distance of 30 miles. Other reservoirs of water, not connected with the irrigation, but such as public wells, bowries, cuttays and so forth, which are required for the use of the inhabitants and their cattle, have been extensively restored in every Talook in the country; and the consideration of the Government in directing these improvements of works so essential to the health and comfort of the community, is rightly appreciated and gratefully acknowledged.

"Many of the tanks, aqueducts, anicuts, and channels of irrigation, which had failed during the Rajah's Government, previous to the year 1835, as well as the village reservoirs, have been restored. Others, which were decayed have been efficiently repaired, and the few which were tolerable have been put into perfect order. It may be confidently affirmed that none of the works of irrigation have deteriorated since the transfer, but that their condition has been very greatly improved."

So far as can be judged, in regard to the condition of the tanks in 1846, the description should probably be held to apply, rather to their then state, as compared with what they had been under the previous Native Government, than to their actual condition as tested by that high and efficient standard, which alone could be accepted with the present views of Government, and under scientific direction.

It will I think be conceded, that the area at any time actually under wet cultivation, is the best test of the efficient state or otherwise of the reservoirs, from which the supply of water requisite for that cultivation is derived. At least I know of no other, and have inserted on the next page the following quinquennial return, for the 25 years between 1837-38 and 1861-62, obligingly supplied from the Commissioner's office.

Judging from this, the works are probably now in a more prosperous condition, than at any other time of which we have record, and the increase in efficiency has apparently fairly kept pace with the increased liberality in the expenditure, taking into account the great rise in labor rates of late years.

But when we come to examine accurately their real condition, we find that while admitting fully the progressive advance that has been made, the tanks are in anything but a satisfactory state. Further, that while indivi-

Years.		Acres under wet and garden cultivation.	Expenditure on agricultural repairs other than the Astagram channels.	Average yearly outlay.
From	To		Rupees.	Rupees.
1837-38	1841-42	17,05,150	4,70,178	94,036
1842-43	1846-47	18,49,759	4,32,254	86,451
1847-48	1851-52	20,87,929	5,86,443	1,17,289
1852-53	1856-57	21,60,309	7,00,205	1,40,041
1857-58	1861-62	21,69,040	8,07,619	1,61,524
Total outlay in 25 years, ..			29,96,699	1,19,868

dual repairs have been dealt with energetically and effectually, there has been a clear want of a general plan of action under scientific direction. As a rule, breaches of tanks and anicuts have on their occurrence, been vigorously taken up. But with all these cases, there has not been apparently that thorough sifting of causes, and reference to general scientific principles, which there can be little doubt is equally essential with energetic treatment.

The Executive Engineer of the Bangalore Division reports, that fully half the tanks under him are either breached, or in need of thorough repair. In Chittledroog 285 tanks, or one-third of the registered number, are similarly out of order. In Toomkoo, 530 out of 1,124; in Shemogah, 2,496 out of 4,520; and in Mysore, 705 out of 1,409. Captain Johnson, the most experienced Executive Officer in the Province, states, with reference to the latter district, that three-fourths of the tanks require absolutely necessary improvement, and that one-half are positively unsafe. It is this real condition of matters, with which we have to deal, if, as now determined by Government, the people are to be preserved by all human means from the effects of drought.

Without a much more complete examination of existing works, and in the absence of detailed estimates, it would of course be quite impossible

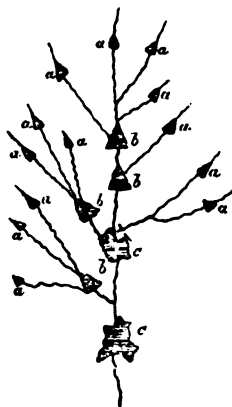
to say what would be the cost of the requisite renewals, &c, to the tanks now out of order; but assuming roughly that, in all, 1,500 first class tanks and 4,500 second class require the ordinary outlay now made in dealing with special cases [*i. e.*, about 3,000 rupees for each 1st class, and rupees 1,500 for each 2nd class tank], the total outlay would probably not fall far short of Rs. 90,00,000.

Looking at the vast amount of patient industry, and even drudgery, devoted by the native cultivators to the preparation of the ground under the tanks for rice cultivation, it must, to ordinary observers, be a strange matter that they never once dream, of giving even an hour's work, to the preservation of the bunds upon which the fruits of their labors entirely depend. Not only however is such actually the case, but with stranger fatuity still, they appear to do all in their power to render the bunds insecure. They cultivate against orders close under the foot of the embankment, they dig roots, cut firewood, make foot-paths in every direction, drive over their cattle and carts when possible, and in a hundred other ways loosen the soil and weaken the work. Not satisfied with this they, against the most positive orders, temporarily build up the waste-weirs between the dam stones, with a view to increase the capacity of the tank, and thus almost insure the work breaching in case of flood. This is no imaginary picture, as I have reason to believe that several of the late breaches to tanks have occurred from this reckless inattention to orders. But beyond all this, there are criminal acts, such as cutting bunds, &c., to cause breaches, with the apparent object of reaping the advantage; *First*, of the expenditure which will probably take place in repairing the work; and *Second*, in the abundant yield of the dry crops, sown in the rich loamy bed, while the work is out of action.

It is, of course, beyond my province to suggest what direction legislation should take in order to deal effectually with such offences; but I may be permitted to observe among other matters, that the universal safety of the bunds over which our high roads have been carried, points to the desirability of making the top of each tank bund, into a well formed level village path-way, with the preservation of which the village authorities should be specially charged, as also with the absolute prevention, under specified penalties, of all acts like those I have described, directly tending to the injuring of the work.

Regarding the general plan of action for bringing all the works up to

standard, there are so many points of constructive detail involved, that I must limit myself here to one of prime importance.



The side sketch shows an ordinary stream under the tank system. Population taking possession of the high grounds, constructed the small tanks *a, a, a, a*, and after these minor feeders had been thus brought under regulation, they then throw bunds up lower down forming other and larger tanks *b, b, b, b*, and eventually first class tanks *c, c*, further down still in the main stream. The tanks *a, a, a*, are of course individually of small importance and indeed so are the tanks *b, b*. The villages connected with them are also small, and unable

to make themselves heard. As sometimes occurs, with excessive floods, the whole chain of tanks goes together (many of the smaller, and earlier constructed tanks, having no provision for discharging surplus water) and sweeps with it the terminal tanks *c, c*. These latter, as relatively very important in a revenue sense, and usually connected with large communities, have their repairs attended to immediately, while those higher up the valley (*b, b* and *a, a, a*) are left in the breached condition. The slightest reflection will show that this is the reverse of a really scientific management; and that as the safety of *c, c*, depends on the working condition of those higher up, these latter should be seen to first. An accurate scientific determination of the capacity of the waste weirs, height of the bunds, &c., of each and all of these, is consequently a prime essential of safety, for the greater and more important works below.

In concluding this notice about tanks, I shall state briefly what works it is proposed to bring forward in the next Budget, not so much as forming the commencement of the systematized work which I have ventured to recommend, but as an endeavor to meet the most urgent requirements of the rainless and barren tract of country which has suffered lately the horrors of famine as before adverted to.

I hope to be able to bring forward definitely the long discussed project [amounting say to Rs. 9,00,000] for the Mauri Cunawai tank, and Estimates are, it is understood, nearly ready for the Coombar Cuttay [Rs. 1,00,000] with 9 restorations of reservoirs in the Chittledroog Division,

amounting perhaps in the aggregate to Rs. 70,000. This, in addition to the ordinary tank repairs by Civil Officers, would afford, for the time being, great relief to the sufferers, while proving very remunerative to the State. The latter point will of course be fully stated in sending up the detailed Estimates.*

The only other project of large dimensions is that of the Mysore Soolikerray or Cundly tank, a great terminal reservoir on one of the feeders of the Shimsha river, which, though commenced centuries ago by the natives was never finished. The Estimate may be 1 lakh, or Rs. 1,20,000, and is understood to be well advanced.

[*To be continued.*]

* The remunerative returns promised on the usual tank repair Estimates, passing through this Office, vary from 30 to 40 and even 50 per cent. on outlay, but there is no absolute proof that these percentages are realised, and as in the *first* place the cost of maintenance and risk is left out of the calculation, and in the *second* a general scheme, embracing all the tanks of the country, must of necessity take the bad with the good, the profits though undoubtedly very remunerative, must be struck at a lower figure, and probably on the average would not much exceed net 10 per cent. all round.

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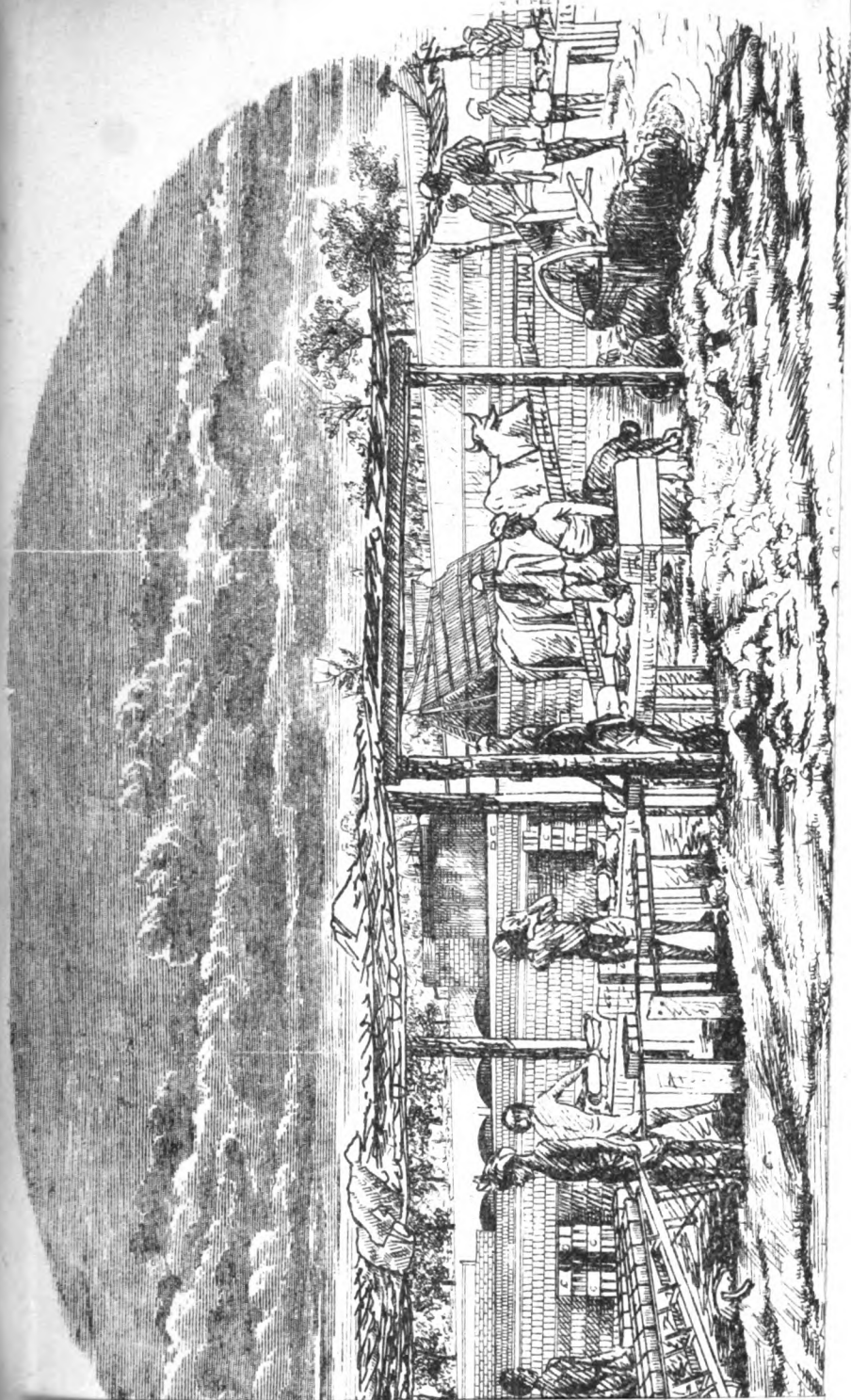
BRICK-MAKING—NEAR ROORKEE.

Notes on the Brick Kilns at Mahewah, on the Ganges Canal. By
CAPTAIN F. D. M. BROWN, V.C., *Assistant Principal, Thomason
College.*

THE village of Mahewah is three miles from Roorkee, at the upper end of the great Solanee embankment, by which the Ganges Canal is carried over the valley of that river. A large brick yard was here formed for the supply of bricks to the canal works, and as this has lately been remodelled on the English system of moulding and burning, it is thought that some details of the working and cost may be acceptable. I am indebted to T. Marten, Esq., Superintendent of Materials, Ganges Canal, for the ample information he has given me of the details, and of the results of his experience in brick-making.

The earth, for making the bricks, is prepared from the spoil bank of an old cutting; down the middle of this bank a deep trench has been dug, which fills with water in the rains, and is supposed partially to temper the clay.

The *Pug-mill* [Fig. 1] is sunk $2\frac{3}{4}$ feet, so that the clay may be tilted in, by an easy ramp leading to the top, and at the same time the men below may be able to lift the prepared clay to the level of the ground. The casing of the mill is made of $\frac{1}{4}$ -inch sheet-iron, 4 feet high and 3 feet diameter at top and bottom. The casing is raised 12 inches from the bottom of the pit, and half the mill is bricked up; the clay oozing out of the opening thus formed on the unbricked side. The shaft is made of $2\frac{1}{2}$ -inch square bar iron, having 7 iron blades, 4 inches $\times$ $\frac{1}{2}$ -inch, and supported at the top on three sides by T iron struts, the fourth being open to leave room for



tilting in the earth. The uppermost blade is $1\frac{1}{2}$ feet from top of iron sheeting, and inclined at about 25° , the angle increasing with each blade, the lowest one being 70° . The *levér* is 15 feet long, and worked by a pair of bullocks. This mill is sufficient to supply six tables.

The *Moulding tables* are $6\frac{1}{2} \times 2\frac{3}{4} \times 2\frac{1}{2}$ feet; to each is fixed the lower part of the mould [Fig. 2], and an iron basin holding water in which the wooden strike is kept. The *strike* should be made of deodar or some fir wood, and a new one issued daily to each table. At right angles to the table and to the left of the mould is the *page* [Fig. 3], consisting of two parallel $\frac{1}{2}$ -inch rod iron bars about 7 inches apart, bolted at one extremity to the frame of the table, and at the other to an upright plank, and supported at the centre by another upright plank. Under the table is a strut, immediately below the centre of the mould, to prevent any "kick" or spring from the table. This should be looked to and be wedged up every day.

The *Brick mould* [Fig. 4] is of $\frac{3}{8}$ -inch iron, $10 \times 4\frac{1}{2} \times 8\frac{1}{2}$ inches, inside measurements; when put on the table it rests on the four adjusting screws A, A, &c. [Fig. 2], which are so regulated that the bricks turned out are the required thickness, $3\frac{1}{8}$ inches. The tops of these screws, as also the parts where the mould rests, become indented from the constant blows on them and might, with advantage, be steeled. The bottom of the mould, which is also iron, has a die upon it, $8 \times 2\frac{1}{2}$ inches, raised $\frac{1}{8}$ -inch, this makes an indentation in the brick which is intended to hold the mortar, and enables the mason in building to draw the joints very fine. To mark the brick, the letters G. C. (Ganges Canal) are raised $\frac{1}{8}$ -inch on the die. A wet brick, as turned out of the mould, weighed 4 seers 12 chittacks; the sun dried, 3 seers 12 chittacks.

Moulding and Stacking.—The man who prepares the clay into suitable lumps for the moulder, must be careful to make each lump solid, without cracks, by repeatedly thumping and pressing it on the table, as these cracks form blemishes in the moulded brick. At the same time he must be careful in keeping his part of the table well sanded.

The mould is cleaned first with water and then sanded, the die being cleaned when necessary with a country made horse-brush. The moulder takes one of these prepared lumps in both hands and, raising it above his head, throws it into the mould; he then clears off the superfluous clay with his hand (taking care to leave the full amount required) and pressing the remainder into the mould, strikes it with a small wooden straight edge;

the strike is cleaned, as it is put back into the water, against the sharp edge of the iron bowl.

Having moulded the brick, he places the mould sideways, with a smart blow, on the bars of the page, which, by their spring shake the brick loose; he then places a board $12 \times 6 \times \frac{1}{2}$ inches against the lower side of the mould, and putting the board flat on the bars of the page, with the brick and mould resting on it, removes the mould and slips the board, with brick upon it, along the bars of the page to make room for the next.

The bricks are sanded and carried away on the boards in hack-barrows [Fig. 5] which hold 26 (viz., 13 on each side). The hacks are on terraces, raised 9 inches from the ground, and covered with a layer of flat bricks laid dry; they are three bricks broad, so as to hold two rows, and long enough to hold the day's work of a moulder, as putting on a second course the same day spoils the shape of the bricks. A moulder can make 1,000 bricks per day; and when working by contract, 1,500.

In hacking the bricks they are lifted from the hack-barrow between two pallets, viz., the original one below the brick and another put on the top, by this means the shape of the brick is not injured, they are placed at once on edge, with the distance equal to the thickness of a pallet between them, and each brick to break joint with the one below; the top of each row must be sanded before the next is put on.

The number of hands employed at six tables are:—

3 men to dig, prepare earth and pump water.

3 „ to wheel prepared earth into the pug-mill.

2 „ to take the earth as it comes out of the pug-mill and place it in lumps on the level of the ground.

2 „ to carry the lumps from pug-mill to moulding tables.

6 „ (one standing opposite each moulder) to prepare the earth in suitable and compact lumps for moulder.

6 „ moulders.

6 „ (one to each table) to carry the bricks away and hack them.

One pair of bullocks to work pug-mill.

2 boys to turn the bricks on their backs while drying.

Total, $\left\{ \begin{array}{l} 28 \text{ men,} \\ 2 \text{ boys,} \end{array} \right\}$ and one pair of bullocks.

The moulders are paid Rs. 6 per mensem, the other laborers from 4 to 5; boys, from Rs. 2 to 3.



Fig. 11.
Iron Mould.

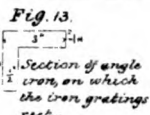


Fig. 13.

Section of angle iron, on which the iron gratings rest.

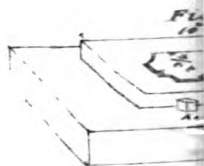


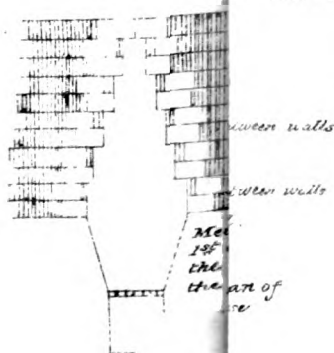
Fig. 12.



Fig. 14.



Fig. 15.



inner walls

outer walls

Max 18" the air of

Section on ABCD.

Fig. 9.

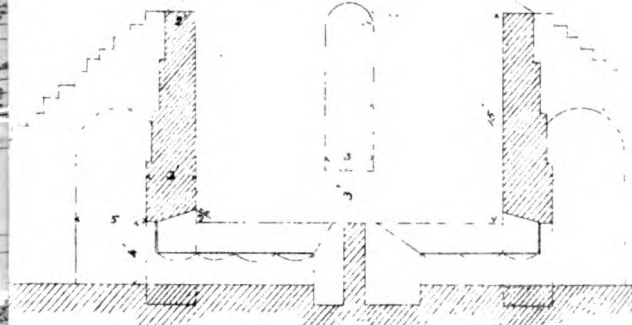


Fig. 7.

Plan of Kiln.



Kilns.—The floors of the kilns are level with the ground, the flues and ash-pit are sunk 4 feet. The flues face N. and S., that is, at right angles to the direction of the prevailing wind.

The fuel is thrown on to the iron bars of the flues through an iron door [Fig. 6], which must be always kept shut, except when supplying the fuel, as an immense amount of heat is lost if left open; and this the stokers are very apt to do, unless closely watched as the doors are difficult to open. By putting an iron ring on the door instead of the knob handle, as at present, and opening with a detached hook, this difficulty might be obviated.

The sill of the doors is raised 6 inches above the top of the grating.

There are two sizes of kilns in use at Mahewah. *Figs. 6, 7, 8, 9, 10, 11, 12, 13*, give all the dimensions of the larger size as built at present; but only one or two kilns of this size have as yet been fired. From the experience gained in burning these, it is proposed to make the following alterations in the next ones built.

The two flying buttresses on each side will be removed, as they make the stoke-hole so hot towards the end of the burning that the stokers can hardly remain there; at the same time the walls, which are already too thin, are to be made 4 feet 6 inches at bottom and 3 feet at top, and buttresses left only at the four corners. The flues are to have only three sets of bars each (with 9 bars in each set), the remainder of the flue being sloped up (shown in every second one, *Fig. 7*), as with four sets of bars the flue is too long to stoke properly.

This kiln holds 1,65,000 bricks. The walls are built of peela bricks set in mud and well "leped," both inside and out. The kilns now burning are converted from Sindh kilns, which were already standing, and several dimensions had to be adapted to circumstances; one chief point being that the end flues are put too far in from the side walls.

The small kiln, built on Mr.* Hickmott's plan (measuring 30 × 18 feet and 14 feet high inside) has the walls 4 feet thick up to the level of the ground, and 3½ feet thick to the top: the two long walls have a slope of 1 to 12 inwards, which appears to be a capital construction, not only in strengthening the walls but by keeping in the heat. There are only four flues, 5½ feet apart, the two end ones being 2½ feet from the side walls. Below the door of the flue is an iron damper to regulate the draft; it has been found that when these are shut, the heat becomes so great

* In charge of the large Government Brick-yard at Akra, near Calcutta.

in the flues that the bars of the grating are bent and rendered useless, and the arch bricks fuse; they have therefore been discontinued in the new kilns. The same effect is produced if the ashes are allowed to accumulate in the ash-pit, which must be kept constantly raked out.

This kiln holds 65,000 bricks.

The price of the iron-work at the Roorkee Workshops is as follows :—

- 1 Fire-door, at Rs. 15 each.
- 1 Fire bar, 7 seers 6 chittacks, at Rs. 9 a maund.
- 1 Angle iron support, 12 seers 8 chittacks, at Rs. 9 a maund.
- 1 Iron brick mould, at Rs. 1-8 each.
- 1 Table complete (including table, die for brick mould and page), at Rs. 102.
- 1 Pug-mill (iron work), at Rs. 175.
- 1 Hack barrow, at Rs. 28.
- 1 Earth barrow, at Rs. 12.

In *loading the kiln*, the bricks for the first 11 courses are laid on edge close together in parallel walls [*Fig. 14*], with 5 inches interval between each wall and 5 inches between the inside long wall of kiln and the first wall of bricks. Where these parallel walls cross the flues, the bricks are corbelled out [*Fig. 15*] meeting in the 11th course. As it is most important that these openings should be properly built (as their falling in smothers the fires and causes every conceivable damage), a triangular wooden centering is used to insure regularity and proper bond. Another important point is that, the parallel walls should be built perfectly plumb and straight, as any unequal pressure coming on them when the bricks are soft, from the intense heat, causes the wall to give in that direction, and the bricks above of course fall in. The centre wall is one or two bricks thick (according to the room left) with no opening for flues; the bricks, however, are placed on edge not quite touching, so that the communication between the sets of flues on each side is not entirely cut off.

In the 12th course [*Fig. 16*] the bricks are laid on edge, on the parallel walls, with the interval of a brick between each, and the openings between the walls are bridged over by bricks on edge, alternating with those on the wall.

The 13th course is laid on edge at an angle of 45° to the walls of the kiln, with the interval of about an inch between each brick.

The 14th course is laid on edge, parallel to the side of the kiln, leaving intervals of 1 inch; the upper courses are built each at right angles to the one below, the intervals getting smaller till the last 5 courses, in which the

bricks are placed close together, and a top course of bricks laid flat; over all this is put two layers of oopla.

If whilst loading there is any chance of rain, light king-post trusses, made of angle iron, are thrown across the top of the kiln, these are connected together by stout ropes and bamboos and small choppas (12 × 10 feet) placed on them.

Soft woods and dāk (which is generally more or less decayed) are a bad description for burning, as they smoulder and do not give a brisk fire; of keekur, sissoo, or any hard wood, less than three-fourths the quantity as compared with the soft wood is required.

In firing the kiln, the arrangements are as follows:—

Commence firing in the evening with chips, just enough to warm the kiln (1 man to 3 doors). On the second evening, this small fire should be pushed back to the end of the flues. Third evening, the fire (still kept very low) is brought to the front again. Fourth evening, the firing is forced on vigorously; 2 men are now put on to every 3 doors, and the firemen are relieved every 12 hours. During the night, go to the top of the kiln, and should the fire be breaking out at any place, it must be immediately stifled by throwing a few baskets of ashes over the place where it is doing so. This must also be done on the next two nights, as that is the only time you can see how the kiln is burning.

The fires are kept up as strong as they can be till all the wood is burnt, the quantity, under ordinary circumstances for the small kiln, being about 10,000 cubic feet or 2,000 maunds of dāk wood, or three-fourths of the same weight of sissoo, keekur, babool, or any hard wood; taking the latter at 4 cubic feet to the maund. This, if fired properly, will take 3 days and 3 nights of slow, and 3 days and 3 nights, of vigorous, firing. When the kiln is burnt it looks at night from the top, like a molten mass, and appears almost transparent.

When the firing is stopped, the top of the kiln should be covered at once with 6 inches of ashes. The doors are left ajar for 12 hours, after which they are opened, and the whole of the openings carefully bricked up.

In the first kiln burnt, the openings were bricked up at once, and the bars and supports of the grating were found doubled up and rendered useless; whereas four kilns have now been closed in the manner recommended, and the grating bars are still good. Mr. Marten says that the bricks are not injured in the slightest by not bricking up at once; I think that the grating might be so arranged that it could be pulled out, like a drawer, on

to a travelling truck, and removed to a flat platform to cool; or some other arrangement might be made for removing the grating, as the air, though slightly heated by the remains of the fire, yet striking on the bricks when at such a high temperature, must make them more brittle than they otherwise would be.

The kiln should on no consideration be opened under 15 days, and the longer they are left, of course the better the bricks will anneal.

The average weight of 4 pukka bricks after exposure to the cold weather rains, was 3 seers 10½ chittacks each; and after soaking for 24 hours in water, 3 seers 14½ chittacks; average of absorption, 4 chittacks, or little more than $\frac{1}{4}$ of its weight. I then placed the bricks in the sun, tilted up on a zinc roof for seven perfectly dry and cloudless days in April, and found that their weight averaged exactly the same, 3 seers 10½ chittacks, showing that they had not absorbed more than a normal amount of moisture at the time of first weighing.

Another pukka brick straight from the kiln, weighed 3 seers 9½ chittacks, after soaking it in water for 15 minutes, it weighed 3 seers (all bubbling having ceased after about 13 minutes). After 6 days' immersion, it weighed 3 seers 0½ chittacks, showing that a brick has absorbed nearly all the water it is capable of doing as soon as it ceases to give off bubbles, and that a quarter of an hour is ample time for soaking bricks before using. On soaking pukka bricks straight from the kiln, they absorbed on an average 6½ chittacks; while those which have been exposed to the weather absorbed only 4 chittacks of water, showing that these bricks naturally absorb about 2½ chittacks from the atmosphere in ordinary weather.

Out-turn.—As these are the first kilns of the kind that have been burnt at Mahewah, the results must be considered only as experimental:—

RETURNS OF SMALL KILN AT MAHEWAH.

Number of firing.	1st class brick.	2nd class brick.	Half brick.	Peela.	Jhama brick.	Pukka. roora.	Roora for soorkee.	No. of maunds of wood.	Description of wood.
1	21,600	11,000	...	13,000	3,300	c. ft. 300	c. ft. 200	950	Sissoo and babool.
2	18,200	12,600	500	28,860	...	500	45	1,200	Dak.
3*	4,500	7,000	...	55,000	...	...	100	1,400	Do.
4	45,800	8,500	...	5,400	2,700	...	...	2,500	Do.
LARGE KILN.									
	92,000	2,800	...	86,000	8,000	60	...	...	

* This kiln spoiled by rain.

There is no doubt when these kilns are once fairly started, that the out-turn will be far in excess of that here given.

Cost.—The bricks turned out from these kilns are of excellent quality, being well burnt and well shaped. It is impossible to estimate their exact cost without further experience; but the following, taken from the data above given, may be considered an approximation; though, doubtless, the cost will be reduced when the brick-yard is in full working order.

Approximate Estimate of the cost of a small Hickmott's kiln, to hold 65,000 bricks.

c. ft.				Rs.
7,900	Peela brick in mnd, at Rs. 5 per 100 cubic feet,	..	..	395
6,400	Excavation, at Rs. 2-8 per 1,000 cubic feet,	..	..	16
No.				
8	Iron doors, at Rs. 15 each,	..	..	120
32	Angle iron rests, 10 maunds, at Rs. 9 a maund,	..	..	90
216	Grating bars, 40 maunds, at Rs. 9 a maund,	..	..	360
Total Rupees,				981
Contingencies, at Rs. 5 per cent.				49
Grand Total, Rupees,				1,030

Moulding.

6	Moulders, at Rs. 6,	..	..	36	} per month.
15	Men, at Rs. 5,	..	..	75	
7	" at Rs. 4,	..	..	28	
2	Boys, at Rs. 3,	..	..	6	
2	Bullocks, at Rs. 15,	..	..	15	

160 = cost of moulding

1,56,000 bricks, i. e., 1,000 bricks per moulder per day of 26 working days—or about 1 rupee per 1,000.

Approximate cost of one kiln of bricks.

	R.	A.	P.
Moulding 65,000 bricks, ..	66	0	0
1/2 cost of kiln for each burning, ..	103	0	0
Loading and unloading kiln, ..	15	0	0
2,500 maunds of wood, at Rs. 12 per 100 maunds, ..	300	0	0
Wages of firemen, ..	9	0	0
Plant, supervision, &c., ..	50	0	0
Total Rupees, ..	548	0	0

Taking No. 4, or the last firing (in table of results), as the least out-turn that may fairly be expected from the small kiln (the other three being experimental only) and 2nd class bricks as equal to half, and peela and jhama to one-fifth, the value of 1st class bricks, then the whole out-turn will be equal in value to $45,800 + \frac{8,500}{2} + \frac{5,400 + 2,700}{5} = 51,670$ 1st class bricks.

Hence the approximate cost of the bricks may be put down as—

10·5	rupees per 1,000 for 1st class bricks.
5·25	" " 2nd "
2·1	" " Peela and jhama.

F. D. M. B.

No. CXLIII.

THE TELEGRAPH TO INDIA.

Abridged from the Minutes of Proceedings of the Institution of Civil Engineers for 1865-66. BY SIR CHARLES T. BRIGHT, M.P., M. Inst. C.E.

The junction of the European and Indian telegraph systems, and the extension of a line from Rangoon to China and to Australia, by way of Java and Timor, have engaged the attention of telegraphic Engineers for some time past. The line between Europe and India has now been completed, and a large number of messages are daily sent to, and received from, the chief cities of the Indian Empire.

In considering the best mode of constructing a telegraph to India, two routes present themselves for selection, each possessing certain merits and disadvantages. By laying a submarine cable from Malta to Alexandria, and thence by way of the Red Sea and the Arabian coast to Kurrachee, nearly the whole of the line would be submerged, and would thus be free from the risk of interference at the hands of the natives, to which a land line, passing through Asia Minor, Mesopotamia, and Persia, would be subject.

In 1858, a company was formed, under a guarantee from the Government, and a submarine cable was laid from Suez to Aden and Kurrachee; and there is little doubt, that had the route been carefully surveyed, and had the cable been more substantial and better insulated, the line might have worked well for many years. It should, however, be borne in mind, that at the date when the cable referred to was designed and manufactured, the conditions requisite for carrying out works of the kind had not been so

clearly established as they are now, nor had the coating of the conducting wires with insulating materials, attained the high degree of excellence which it has since reached.

While the Red Sea line was in course of construction, the Turkish Government was engaged in erecting a line of telegraph, between Constantinople and Bagdad, passing from Scutari, through Angora, Diarbekir, and Mosul. This line, and its extension to the head of the Persian Gulf had been urged for a long time by Her Majesty's Government, who appreciated the importance of two distinct telegraphs to India. On the failure of the Red Sea line, steps were taken, after a survey by Colonel Goldsmid, to extend the Indian land telegraph in a westerly direction, along the Mekran coast, and for ascertaining the feasibility of erecting land lines through Mesopotamia and Persia, to meet the Mekran telegraph, at Gwadar or Churber. With the latter objects in view, the late Colonel Patrick Stewart, R.E., was sent from India on a special mission to Persia. He arrived in England in the summer of 1862, at the same time that Mr. Latimer Clark, M. Inst. C.E., returned from a careful examination into the state of the cable between Suez, Aden, and Kurrachee. The result of Mr. Clark's investigation showed the impossibility of restoring the Red Sea and Arabian line, and Colonel Stewart reported against the reliability of a land line along the coast of the Persian Gulf.

A submarine cable from the head of the Persian Gulf to Gwadar, the most westerly point to which it was then found practicable to extend the Indian land telegraphs, was therefore determined upon by the Indian Government, in connection with a land line to be erected, with their assistance, by the Turkish Government between Bagdad, Bussorah, and the mouth of the Shat-el-Arab, and with lines to be constructed by the Persians, from the Russian frontier to Ispahan, Teheran, Shiraz, and Bushire, with a cross connecting line, between Bagdad, Khanakain, and Teheran. It was afterwards resolved, in consequence of the workmen on the Mekran land telegraph being molested by the natives, to continue the submarine line, from Gwadar to Kurrachee. Colonel Stewart was appointed to direct the carrying out of this great length of line; the engineering and electrical superintendence of the submarine portion of the work, and the submersion of the cable, being intrusted to the Author and Mr. Latimer Clark.

To allow of a high speed of working, without any excessive expenditure upon the conductor and insulator, it was determined to divide the line into

sections, with a station at Gwador on the Mekran coast, another near Cape Mussendom on the Arabian coast, at the entrance to the gulf, and a third at Bushire, on the coast of Persia. The soundings and "bottom" in the Persian Gulf are well known, through the careful surveys of the officers of the Indian navy. The character of the bottom is, however, of so much importance in regard to the permanence of a submarine cable, that a special survey was made by Lieut. A. W. Stiffe, Assoc. Inst. C.E., formerly of the India navy. The soundings between Gwador and Fao are exceedingly favorable for the deposition of a cable, being such as to allow of the cable being laid at a general depth of from 35 fathoms to 60 fathoms, and the bottom being principally composed of sand and soft mud. Between Gwador and Kurrachee, the bottom is less favorable, being in some places rocky and irregular.

Such being the conditions to be provided for, the core, composed of 225 lbs. of copper, and 275 lbs. of gutta percha per nautical mile applied in four coatings, with alternate layers of Mr. Chatterton's compound between the coatings and next to the copper wire, was ordered in November 1862, from the Gutta Percha Company. In the following month, a contract was entered into with Mr. Henley, of North Woolwich, for applying the outer covering, consisting of a serving of hemp surrounded by twelve galvanized iron wires, each .180 inch in diameter. The cable, thus covered with iron, was then coated with two layers of a bituminous compound, composed of mineral pitch and silica, with a small proportion of Stockholm tar, applied alternately with two servings of hemp laid in opposite directions; the whole being passed under heavy rollers while in a plastic state, the outer covering being thus pressed between the iron wires, and into a solid mass. By the proper application of such a coating, the outer iron wires of a submarine cable are preserved from oxidation for a long period, and the cost of the materials employed and of their application, is very trifling compared with the total value of the cable, and its increased durability. For the shore ends, a larger cable was constructed, the outer iron wires being .300 inch in diameter. A special length of extra heavy shore end, with outer wires .380 inch in diameter, was made also for use at Bushire.

In the early construction of submarine cables, the conductor was formed of solid wire; but since 1856, when a strand of seven wires was adopted, in the cable laid between Cape Breton Island and Newfoundland, the latter form has been generally used, as there is much less danger of the conductor

being broken. There is, however, the disadvantage attaching to the strand form, that the amount of surface, compared with area, being increased, the retardative effects of induction are proportionately experienced. To obviate this defect, Mr. L. Clark devised, in 1858, a conductor built up of segmental copper wire, and an outer tube was afterwards suggested by Mr. Wilkes. The result of experiments upon this form of conductor, compared with a strand made of the same copper and of the same gauge, showed that the segmental conductor preserved equal mechanical properties, coupled with the best form for electrical requirements.

The respective merits of gutta percha, and of its various combinations and modes of application, as compared with india rubber, whether pure, masticated, or vulcanized, have been so warmly discussed at the Institution and elsewhere, that the propriety of adopting gutta percha for use in a warm climate, may be considered, by some, to be questionable. The examination of the Red Sea line, however, demonstrated most distinctly, that there is nothing to prevent the use of gutta percha in a warm climate, if proper precautions are taken; while on the other hand, there is, as yet, no experience of any other insulator which has been shown to be successful on a practical scale and for a sufficient length of time, to induce confidence in its durability.

The joints made in the insulating material during manufacture, and in the finished core, have always been the subject of considerable anxiety to those engaged in the supervision of submarine telegraphs; as although the loss on a single joint may be so small as hardly to affect the tests obtained upon a considerable length, yet dearly-bought experience has shown, that the defect may contain within it the seeds of a serious fault hereafter. To insure the highest attainable perfection in this important part of the manufacture, a plan was adopted, at the suggestion of Mr. Latimer Clark, which will be readily understood by reference to [Fig. 1] of the Plate. A gutta percha trough, about 18 inches long, and 1 foot deep, containing water, is insulated from the ground by four legs of vulcanized india rubber, or preferably, by suspending it from the ceiling by gutta percha cords. The joint under examination is immersed in the water, and a battery of high tension (A) is connected to the copper conducting wire for five minutes, and all the electricity that escapes through the immersed joint during this time, passes into the insulated tank of water. To increase the capacity of the tank for storing up electricity, it is connected with an electrical condenser

(B), consisting of a great number of talc plates, coated on both sides with tinfoil, and having the same electro-static capacity as 1 mile of the cable. The escaping electricity accumulates in the condenser for the given time, and is then suddenly discharged through a delicate suspended needle galvanometer (C), and the number of degrees of the deflection furnishes an exact measure of the quantity of electricity passed through the insulator at the joint. In testing the joints in the Persian Gulf cable by this system, every joint was rejected and cut out whenever it gave less resistance than 40 feet of the core. Newly-made joints were found, almost invariably, to test perfectly, and it was only after at least twenty-four hours' immersion, that a reliable test could be taken. The advantage of this system (which was employed at the Gutta Percha Company's works, and at Mr. Henley's factory) will be apparent from the fact that thirty defective joints were rejected and replaced.

In testing the conductivity of the conductor, its resistance was taken by means of a Wheatstone's electrical balance. The lowest limit of specific conductivity allowed for the copper was 76, that of pure galvanoplastic copper being taken at 100. An electrician was employed at the copper wire manufactories to see that none below that standard was supplied, and an extra price per pound was paid, *pro rata*, for all copper having a higher specific conductivity than 81. The mean conductivity of the whole cable was thus raised to 89.14. In many of the older submarine cables, which were laid before this point had received attention, the conductivity was as low as 30 and 40.

Previous to any tests being applied to the core at the Gutta Percha Company's works, the coils were immersed in water at a temperature of 24° centigrade, and the water was steadily maintained at that temperature for at least twenty-four hours. The resistances of the coils, which were in lengths of about 3,000 yards, were carefully recorded and tabulated, and formed an important check to the temperatures shown by the thermometers in the cable tanks, during the sheathing of the core. The coils were then removed to Mr. Reid's pressure cylinder, being still maintained at the temperature of 24° centigrade. The insulation of the coils was next taken with a battery of five hundred Daniell's elements. They were afterwards subjected to a pressure of 600 lbs. to the square inch, and the insulation test was repeated. The lowest standard of insulation admitted was specified to be such, that each nautical mile of cable should give a resistance of

THE TELEGRAPH TO INDIA.

Fig. 1.

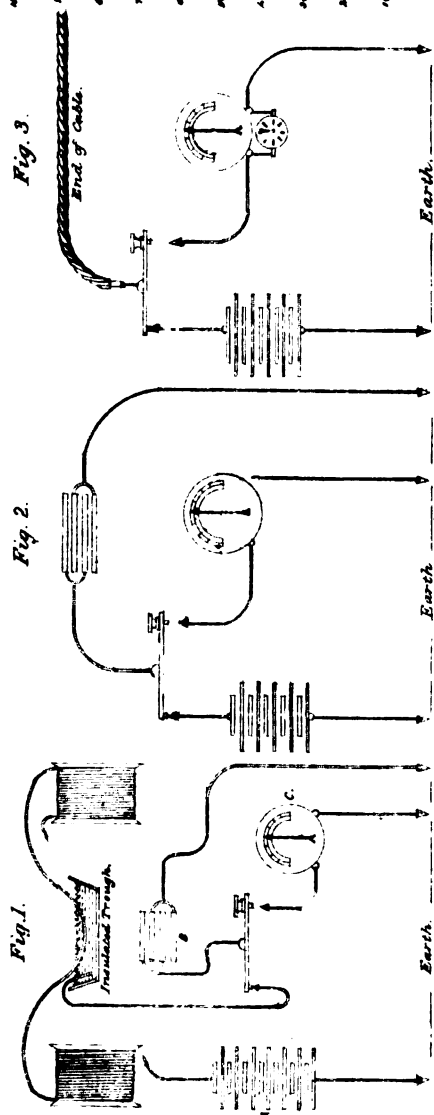


Fig. 2.

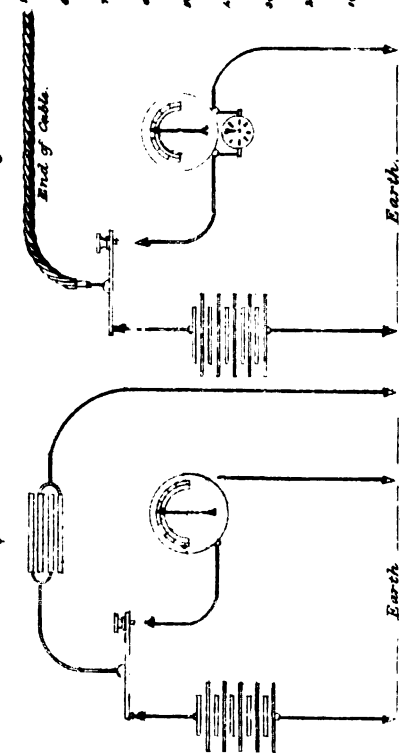


Fig. 3.

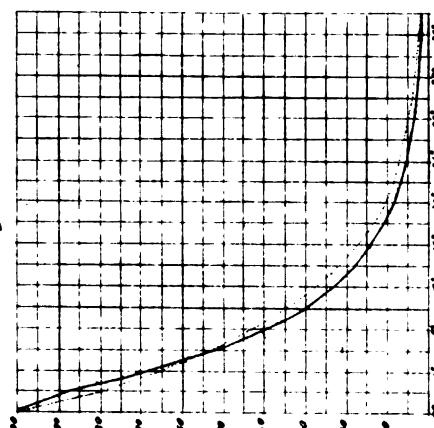


Diagram of the resistance of the Gutta Percha core of the Persian Gulf Cable, between the temperature of 0° and 38° Centigrade.

115 millions of Siemens' mercury units, or 109.9 millions of British absolute units. The average resistance of the whole core, at 24° centigrade, was 192.8 millions of British absolute units. The insulation, of course, improved under pressure, the gain being generally about 16 per cent. It was observed also, that irrespective of temperature, all the coils improved greatly by time. Coils, which when first tested gave a certain resistance, would, after six or seven months, give an increased resistance of 100 per cent. and upwards; so that unless the age of a coil be specified, the mere resistance test is, to some extent, fallacious. Each coil was subjected to a time test, by charging the core with a battery of about forty-eight cells, leaving it disconnected for one minute, and then measuring the amount of loss which had been sustained during that time by leakage; the amount of charge remaining was usually from 50 to 60 per cent. of the original charge. The absolute inductive capacity of each coil was also taken and recorded.

In the absence of a determinate unit of inductive capacity, or quantity of electricity, condensers were employed, formed of plates of mica, coated on each side with tinfoil, and having a standard capacity equal to that of 1 mile of the Persian Gulf core; these have been found in practice very permanent and extremely convenient for use. The measurements were taken after one minute's electrification, by observing the swing of the suspended needle of a galvanometer; and the extreme variations in the several coils did not exceed 8 per cent. above or below the average capacity. From these data, when tabulated, it was easy to ascertain the inductive capacity of any portion of the cable, with such accuracy, that in one interruption which occurred during the laying of the cable, from the copper wire having broken within the gutta percha, the distance of the fault which was calculated at 92.33 miles, proved to be actually at the distance of 92.4 miles. [Figs. 2 and 3] illustrate this system of testing.

During the manufacture of the core, advantage was taken of the facilities offered at the Gutta Percha Company's works, for trying a series of experiments, as to the effect of temperature upon the conducting power of gutta percha and india rubber. It had long been known, that the resistance of these substances varied greatly with changes of temperature; but the exact law had not been hitherto satisfactorily determined. To endeavor to ascertain this, four coils of the core manufactured for the Persian Gulf cable were lent by the Indian Government. These were immersed in an iron

tank, containing about 1,200 gallons of water. The tank was thickly felted on the exterior, and facilities were provided for heating the water uniformly, by steam pipes. The coils were each 1 mile in length, and were first reduced to the temperature of 0° centigrade, by the admixture of ice, and were maintained at this temperature for three days, the water being kept incessantly agitated. The resistances of the copper and gutta percha, and the inductive capacity of the core were then taken. The temperature of the water was next raised gradually, and the measurements were repeated at every 2° up to 38° centigrade. The time occupied in the experiments was thirty-three days, during which nineteen series of observations were taken, the water being kept in constant agitation during the whole period.

From the mean results of these experiments, the following formula has been obtained :—

$$R \times \cdot 8944^t = r$$

where R is the resistance at any given temperature, t the increase in degrees centigrade, $\cdot 8944$ a constant deduced from experiment, and r the resistance at the higher temperature.

The resistances, when plotted, from a logarithmic curve, are shown in [Fig. 4]; and for the purpose of comparison, a curve calculated from the above formula is shown in juxtaposition.

The numerical values, as found by experiment, and calculated from the above formula, are given in the following table :—

Temperature (Centigrade).	Resistances obtained by Experiment.	Resistances calculated by Formula.	Temperature (Centigrade).	Resistances obtained by Experiment.	Resistances calculated by Formula.
0°	100.00	100.00	20°	8.43	10.74
2	84.14	80.00	22	6.82	8.59
4	64.66	64.00	24	5.51	6.87
6	47.65	51.20	26	4.47	5.50
8	37.15	40.96	28	3.51	4.40
10	28.97	32.77	30	2.99	3.52
12	23.18	26.22	32	2.48	2.82
14	16.89	20.97	34	1.92	2.26
16	14.37	16.78	36	1.68	1.80
18	11.05	13.42	38	1.43	1.44

It is probable that the coefficient $\cdot 8944$ will vary slightly with different samples of gutta percha; and from some tests of the core of the Atlantic cable now under construction, kindly furnished by Mr. Willoughby Smith, it would appear that the formula $R \times \cdot 9029 = r$ would apply more nearly to the Atlantic core.

The experiments on temperature were extended to cores of vulcanized

india rubber manufactured by Mr. William Hooper. The absolute resistance of this material is well known to be much greater than that of ordinary gutta percha; but its variations of resistance under changes of temperature, are similar in character to those of gutta percha. Between 0° and 38° centigrade, the resistance of gutta percha decreases seventy times, and that of several samples of vulcanized india rubber, from sixty-three to thirty times, depending on the purity of the material. The curve of variations appears to be a logarithmic one, like that of gutta percha, and a similar formula is applicable.

The coils, after being accepted at the Gutta Percha Company's works were forwarded to Mr. Henley's factory, where they were deposited in a tank of water, and again tested for insulation. The hempen serving over the core, and the outer galvanized iron wires, were applied in the usual manner without any novelty in the machinery calling for special remark.

The external protecting coatings of the bituminous compound were laid on by means of an elevator, driven from the closing machine, so that when the machine stopped, the supply of the hot compound ceased. The completed cable was immediately coiled into tanks filled with water, which were under cover, and where it was continually tested.

The manufacture of the core, by the Gutta Percha Company, was commenced on the 3rd February, 1868, and was finished by the 23rd October following: that of the outer covering by Mr. Henley, was commenced on the 20th February, and was completed on the 10th November, in the same year.

The following are the lengths and weights of the several forms of cable made:—

	Lengths in Nautical Miles.	Weight in Tons.
Main cable,	1,172	4,386
Shore cable,	50	500
Extra size shore cable, . .	12	192
Total,	1,234	5,028

This quantity of cable was coiled on board the following vessels, between the months of July and November, 1868, each ship taking her departure for Bombay as soon as loaded.

Names of Ships.	Ships' Tonnage.	Miles of Cable on Board.	Weight of Cable.
Assaye,	1,598½	367-98	1,399-34
Tweed,	1,608	349-39	1,328-26
Marian Moore,	1,036	174-92	647-20
Kirkham,	1,061	187-61	734-20
Cospatrick,	1,199	142-10	799-00
Amberwitch,	441	12-00	120-00
Total	6,943½	1,234-00	5,028-00

The above-named ships, with the exception of the "Amberwitch," were sailing vessels, the Government of India being possessed of steamers (formerly belonging to the India navy) suitable for towing the sailing vessels during the laying of the cable. Each ship was provided with three iron tanks, a small engine, and a Gwynne's pump for filling and emptying the tanks. Paying-out machinery, consisting of a drum and breaks with the usual stern and leading sheaves, was also fitted. These appliances were similar to those employed on previous occasions, and did not embrace any new, or noteworthy feature.

The "Amberwitch," a screw steamer of 441 tons burden and 70 horse-power, was purchased for permanent service on the line, for repairing the cable in case of need, and for carrying stores and changing the staff between the stations. She was fitted with iron tanks for receiving the cable, with paying-out machinery, with an engine and machinery for raising the cable, and with an ample stock of testing apparatus, buoys, chains, grapnels, and all other requirements for repairing submarine cables. The ships were furnished with testing apparatus, and tests were regularly taken on the voyage out, by competent electricians. They arrived in Bombay in the following order:—

Names of Ships.	Electrician in charge.	Date of Arrival.
Marian Moore,	Mr. E. Donovan,	21st December, 1863.
Kirkham,	Mr. E. D. Walker,	19th January, 1864.
Tweed,	Mr. T. B. Mosely,	5th February, 1864.
Assaye,	Mr. J. E. Woods,	10th February, 1864.
Cospatrick,	Mr. P. Crookes,	15th April, 1864.

The "Assaye" met with bad weather, and it was necessary to lighten her by emptying the tanks. It is satisfactory to record that, although the tanks in one ship were thus emptied for eleven weeks during the voyage out, not the slightest elevation of temperature occurred, owing to the protection from oxidation afforded by the outer bituminous covering. In the case of the Malta and Alexandria cable, it was stated by Mr. H. C. Forde, M. Inst., C.E., that the dangerous increase of temperature which took place, when a cable without such protection was left uncovered by water, was the source of considerable anxiety.

During the passage of the cable to Bombay, constant tests were made on board the several vessels, and some interesting records were taken of the currents produced by the action of the earth's magnetism on the coils of cable, at each roll of the vessel. These were most evident in the higher latitudes, became invisible at the equator, and were in the reverse direction in the southern hemisphere. In rough weather, they were sufficiently powerful to interfere seriously with the measurements of the conductivity of the copper wire; but this evil might be at any time obviated, by coiling one half the cable in a reverse direction to the other half.

Sufficient cable for the section between Gwadur and Mussendom having arrived at Bombay in the "Marian Moore" and the "Kirkham," these vessels were towed to Gwadur by the "Zenobia" and "Semiramis," two powerful paddle-wheel steamers of the Bombay marine, commanded respectively by Lieuts. Carpendale and Crockett, formerly of the Indian navy. On the 3rd February the end of the cable was landed from the "Kirkham," with the aid of the gun-boat "Clyde" (Lieut. Hewett), and of the paddle-box boats of the "Zenobia." At 8.0 p.m. on the following day the Author commenced laying the cable from the "Kirkham," in tow of the "Zenobia," towards Mussendom; the screw steamer "Coromandel," commanded by Lieut. Carew, with Colonel Stewart on board, piloting the course. On the morning of the 6th, having laid all the cable from the "Kirkham," she was anchored in lat. $25^{\circ} 19'$, long. $59^{\circ} 9'$, Ras Munday bearing N.W. $\frac{3}{4}$ W. In the afternoon the "Marian Moore," in tow of the "Semiramis," was brought to anchor, in a convenient position for passing over the end of the cable for splicing, and for transferring the stores from the "Kirkham." On the following day, the laying of the cable was commenced at 4.0 p.m. from the "Marian Moore," the "Kirkham" being sent back to Bombay for discharge in tow of the "Semiramis."

On the morning of the 8th the ships anchored off Ras Jask until the evening, in order to make the Arabian coast the next morning, by daylight. The following day, at noon, the "Marian Moore" came to anchor in Malcolm's Inlet, a quarter of a mile from the landing place. The end of the cable was not landed until the 13th, a short land line having been constructed, in the mean time, to a temporary station on the other side of the peninsula. Mr. Newall's cones and rings were employed in each vessel, and everything worked well and smoothly during the laying of the cable, no incident having occurred worthy of special remark.

Except in the cases of an unsuccessful attempt to connect Cagliari with the coast of Africa, in 1855, and of a cable which was lost, between Newfoundland and Prince Edward's Island, in the same year, submarine cables have hitherto been laid from steam vessels. But, although it is convenient to have steam power immediately under control, on board the ship in which the cable is coiled, the Author considers that in some cases, such as the work now described, where the cable is to be laid in a sea rarely subject to disturbance during the seasons for submergence, and where the depth of water is not great, sailing ships, towed by steam vessels, may be employed with safety, and it will be found that the economy in so doing, when the cable has to be conveyed a great distance to its destination, is very considerable. In this instance no difficulty of any kind was experienced. The steamer towed the cable-ship with two hawsers, and the ships were in constant communication, by a complete system of signalling. During the day, an apparatus, consisting of a lever carrying a white disc in front of a black board, was placed at the stern of the steamer, and on the forecastle of the cable-ship. By night, a signal lantern, with an obscuring disc, was used. Telegraph signallers on board each vessel were always on duty, using the dot and dash telegraphic alphabet with the apparatus. By this means, every requisite message was rapidly sent to the towing steamer, and the instructions conveyed were so promptly despatched and acted upon, that no inconvenience whatever was felt from the separation of the vessels.

The electrical observations made on board ship during the paying-out of the cable, were numerous, and required thirty-four columns of figures at each set of measurements. They comprised a test for conductivity and insulation, and the power of communication with the main land for five minutes, every quarter of an hour. The admirable marine galvanometer of Professor William Thomson, F.R.S., was used. This consisted of a doubly

suspended needle and coil, with a small mirror and reflecting apparatus. The instrument was enclosed in a massive case of wrought iron, to reduce the effect of the earth's magnetism.

After the completion of the Gwadur and Mussendom section, some delay arose, owing to the other ships not having arrived. The time was occupied in establishing a station upon an island in Elphinstone Inlet, and in coaling the steamers at Bassadore and Muscat, where supplies of coal had been provided by the Government of Bombay, to meet the requirements of the expedition.

The "Tweed" and "Assaye" arrived in Elphinstone Inlet on the 12th and 13th March respectively; and on the afternoon of the 18th of the same month, the laying of the cable towards Bushire was commenced. Nothing that requires special remark occurred during the laying of this section, nor in the completion of the other portions of the line. The distance run, the length of cable laid, and the depths of the several sections, are given in the following table:—

Section.	Distance Run in Nautical Miles.	Cable Laid in Nautical Miles.	Mean Depth in Fathoms.	Greatest Depth in Fathoms.	Date of Completion.
Gwadur-Mussendom, .	345.50	357.34	47	122	Feb. 14, 1864.
Mussendom-Bushire, .	379.25	392.65	35	58	March 25, 1864.
Bushire-Fao,	149.00	152.20	20	26	April 5, 1864.
Gwadur-Kurrachee, .	241.00	246.00	20	64	May 15, 1864.
Total . .	1,114.75	1,148.19	...	...	...

An additional length of 18 miles of cable was added to the Gwadur-Kurrachee section, to bring the line to Minora point near Kurrachee, in place of Cape Möaree (the original landing place), making the length of that section 264 miles, and the total length of cable laid 1,176 miles.

The line in the Gulf and across its entrance, is laid upon an exceedingly regular bottom; upon a portion of the Mekran coast, and especially between Gwadur and Kurrachee, the bottom is by no means so good, being in some places rocky and very irregular. To have laid the line more to the south, would have imperilled the successful accomplishment of repairs, in case of need hereafter; but the cable is no doubt subject to risk upon this section, and has already required repair in shallow water, from chafing on the rocks during the S.W. monsoon in the year 1864.

The temperature of the sea, at the upper end of the Persian Gulf, was, when the cable was laid, 21° centigrade at the surface, and 17° at the bottom; at the entrance to the Gulf, it was 23° at the surface, and 21.5° at the bottom; and near Kurrachee, 26° at the surface, and 24.2° at the bottom.

The following are the insulation tests taken after immersion :—

Section.	Temperature at the Bottom.	Resistance per Nautical Mile.	
		Siemens' Units.	British Absolute Units.
Gwadur-Mussendom, . . .	22° centigrade	358 millions	342 millions
Mussendom-Bushire, . . .	21 "	390 "	373 "
Bushire-Fao,	17 "	601 "	575 "
Gwadur-Kurrachee, . . .	24 "	280 "	268 "

It will be observed that, there is apparently a great difference between the insulation of the several sections. By reducing the resistances, however, to the same temperature, they will be found to be remarkably uniform. Thus the comparative resistances at 24° centigrade, the temperature of the Gwadur-Kurrachee section, and also that at which the tests were taken during the manufacture of the core, are—

Section.	Resistance per Nautical Mile.	
	Siemens' Units.	British Absolute Units.
Gwadur-Mussendom, . . .	286 millions	274 millions
Mussendom-Bushire, . . .	279 "	267 "
Bushire-Fao,	276 "	264 "
Gwadur-Kurrachee, . . .	280 "	268 "

If the cable, offering a mean resistance of 280 millions of Siemens' units per nautical mile, had been laid in sufficiently deep water to reach the unvarying temperature of 39.5° Fahrenheit, or about 4° centigrade, which is met with at a depth of 1,500 fathoms, the resistance would have increased, by the difference of temperature, to about 2,600 millions of units per nautical mile, with the additional increase due to pressure, which is about 16 per cent., for every 200 fathoms.

From the date of the completion of the submarine line in April 1864, it has been regularly worked by an efficient staff of station superintendents and signallers, selected from the service of the telegraph companies in this country. Mr. Walton, who had charge previously of the Mekran Coast Telegraph, is the chief superintendent. Instruments of the most modern construction are employed at each station, supplied by Messrs. Siemens and Halske, who also provided the iron posts and insulators, used over part of the Turkish and Persian land lines.

It was expected that the Turkish land line, between Bagdad and the head of the Gulf, would have been completed simultaneously with the submersion of the Persian Gulf cable. In this, however, much disappointment was experienced, notwithstanding the indefatigable exertions of Colonel Kemball, C.B., H.M.'s Resident at Bagdad. The line was completed with the aid of Mr. T. H. Greener, southwards, from Bagdad to Hillah, and thence to Diwanyeh, and northwards, from Fao to Korneh, where the Tigris and Euphrates meeting, form the Shat-el-Arab: but the Montefic tribe of Arabs being in revolt against the Turkish Government, the completion of the line was delayed until the commencement of the year 1865. It was not until the end of February, that arrangements had been so far organized, as to allow of the line to India being opened for the transmission of public messages, when a telegram was received in London from Kurra-chee, in eight hours and a half. This was speedily followed by numerous commercial messages to and fro; and the line is now in daily operation, carrying a large traffic between India and Europe.

In the working of the Turkish line, there is, however, much room for improvement, which it is hoped the importance of the traffic will induce. Before long, the opening of the Persian line of telegraph from Teheran to Ispahan, Shiraz, and Bushire, with the connecting line from Bagdad, by Khanakain, to Teheran, will afford an additional route by which the Persian Gulf cable may be reached, passing through Russia by way of Tiflis and Erivan, and the competition of the two lines will no doubt materially improve the service.

These extensive lines have been finished under the superintendence of Major J. U. Champain, R.E., assisted by Lieutenants Pearson and St. John, R.E., and a few selected non-commissioned officers and men. The energy and perseverance with which this arduous duty has been performed, can be best appreciated by those who have worked in an Oriental country, with all

the difficulties of absence of land carriage and labor, coupled with every form of official apathy and obstructiveness.

The extension of the telegraph to Australia must speedily follow the successful establishment of electrical communication between India and Europe. At present, the Indian telegraphs are constructed as far to the eastward as Rangoon; the distance thence to Singapore is about the same as that of the Persian Gulf line, and a route with a favorable bottom can be selected for a cable. Between Penang and Singapore it would be desirable to lay a heavier cable than in the northern portions of the line.

The feasibility of establishing a land line down the Malay Peninsula demands consideration, before determining upon the adoption of the sea route. There are no insurmountable physical difficulties, as regards either the country or its inhabitants, to prevent the erection and maintenance of a land line. There are, however, no roads, except mere bridle-paths, to the south of Tavoy, and a large expense must be incurred in clearing the jungle.

The cost of a submarine cable in Europe compared with a land line, is very great; but the cost of a land line in uncivilized countries, without facilities for the conveyance of stores and workmen, is considerably increased; while the cost of maintenance, and the chances of interruption and delay, in re-establishing communication, are also greater. The regularity of the working of a properly-constructed cable would, in the Author's opinion, soon compensate for the additional outlay involved in the adoption of the sea route, by which also the communication could be more speedily effected.

Between Singapore and Hong Kong, a cable can be readily carried in shallow water, touching at Saigon; or the connection with China may be made by crossing the peninsula with a land line at Mergui, and carrying a cable across the Gulf of Siam. A further portion of the route might be carried by land, by way of Bangkok, and Cochin China; but the Author is of opinion that although a branch, or a loop line, might be taken by land in this direction, the main line, upon which the regularity of the Chinese traffic would depend, should be submarine.

It has been proposed to take a land line of telegraph from Rangoon, through Burmah and Western China; and the arguments urged in favor of this route by its projector, Captain Sprye, are very strong. The Russian Government is also gradually extending the telegraphs to the Chinese

frontier, with the intention of ultimately connecting Pekin with the Russian system.

To discuss the relative geographical and commercial features of these projects would exceed the limits of this Paper; but the Author considers, that at present the best, most reliable, and most speedy plan for connecting China to India by telegraph, is by a submarine cable.

Proceeding southwards from Singapore towards Australia, the first section, from Singapore to Banca Island and Java, can be taken in shallow water. A cable laid in 1858 from Singapore to Batavia failed soon after being laid; but the cable was a very light one, and unsuited to the bottom. By selecting the route to be followed, and laying a properly-constructed cable, there would be no difficulty in maintaining permanent communication between these points. A land line of telegraph has already been constructed by the Dutch Government, throughout Java, and a cable may be taken from the south-eastern extremity of that island to Timor, terminating at a station to be established at Coupang. From Timor to the north coast of Australia, a submarine line can also be laid in shallow water, with the exception of a short distance to the south of this island, where the depth is not known, no positive soundings having been yet taken. The telegraph is rapidly extending northwards, from Brisbane towards the Gulf of Carpentaria, and the whole of the intermediate country is being quickly occupied by settlers.

The Author cannot conclude without expressing his deep regret, that Colonel Stewart did not survive to witness the completion of his labors, the opening of the Indo-European line, to the accomplishment of which he so largely contributed by his energy and perseverance. By his death the country has lost an accomplished and fearless officer, unsurpassed in zealous devotion to his duties, and rarely equalled in administrative capacity.

No. CXLIV.

ECONOMY OF STEAM POWER IN INDIA.

Notes on the Economy of the Steam Flour Mill, lately erected at the Commissariat Bakery, at Bareilly. By CAPT. C. S. THOMASON, R.E.

BAZAR wheat, 230 maunds 9 seers 9 chittacks (230·24 maunds), at the rate of 13 seers 11 chittacks per rupee, is purchased for Rs. 663·516.

The above wheat is first passed through the winnowing machine, and the out-turn is found to be—

	mds.	s.	c.	maunds.
1st class wheat,	192	10	0	(192·25)
2nd „ „	29	37	4	(29·981)
Foreign grain and waste,	8	2	5	

After passing through the mill (excepting the foreign grain, which is valued unground) the out-turn is classified and valued as follows, at bazar rates:—

From	Out-turn.				Remarks.
	Classification.	Quantity in maunds.	Rate per maund.	Value.	
1st class wheat, 192 mds. 10 ars.,	{ Flour, ..	64·734	Rs. 8·614	Rs. 363·42	} Actually ground from Oct. 1st to Oct. 8th, in 62·25 hours.
	{ Soojee, ..	65·635	8·000	525·08	
	{ Atta, ..	30·640	8·265	100·04	
	{ Bran, ..	31·241	1·684	52·61	
		192·250			
2nd class wheat, 29 mds. 37 ars. 4 cks.,	{ Atta, ..	29·981	3·265	97·72	} Cost of grinding assumed same as for 1st class wheat.
Foreign grain,	Foreign grain,	8·056	3·000	24·17	
Total value of out-turn from 230 maunds 9 seers 9 chittacks bazar wheat, Rupees				1,163·04	

In obtaining the above result, the following machinery was employed :—

1st. Winnowing machine (for $2\frac{1}{2}$ days), cost Rs. 300 in Bareilly—estimated to last 5 years—wear and tear, Rs. .17 per day.

2nd. Ransome's 36 inch Flour Mill and Dresser, cost Rs. 1,500 in Bareilly—to last 7 years—wear and tear, at Rs. .59 per day.

3rd. Clayton and Shuttleworth's 10 horse-power Traction Engine, cost Rs. 7,400 in Bareilly—3 horse-power is used and estimated at cost of Rs. 2,220; and engine is estimated to last 10 years—wear and tear on 3 horse-power, at Rs. .61 per day.

The total amount of capital represented is therefore Rs. 4,020; interest on which is Rs. .58 per day.

The difference between value of wheat purchased (Rs. 663.52) and out-turn (Rs. 1,163.04) is Rs. 499.52; to obtain which the following expenditure is incurred :—

Particulars.	Ra.	Remarks.
Winnowing machine, labor of, 230.24 maunds, at Rs. 0.8 per 100 maunds,	1.15	2 men and a boy can winnow 100 maunds per day.
Wear and tear of winnowing machine, $2\frac{1}{2}$ days, at Rs. .17,	.43	
Grinding and dressing, 192.25 maunds 1st class wheat, in 6.25 days.		} <i>Vide</i> journal of actual expenditure from Oct. 1st to 8th, actually paid. Estimated.
Engine wages, at Rs. 20 per mensem, ..	4.17	
128 maunds fuel, at Rs. 20 per 100 maunds,	25.60	
Mill wages, 2 coolies, Rs. 5 per mensem, for 6.25 days,	2.08	
Wear and tear 3 horse-power engine for 6.25 days, at Rs. .61 per day,	3.81	
Ditto of mill, at Rs. .59 per day,	3.69	Do. Founded on experience. Estimated.
Oil, grease and waste, $6\frac{1}{2}$ days,	6.25	
Repairs of machinery, $6\frac{1}{2}$ days, at Rs. 1 per day,	6.25	Do.
Interest on capital, engine and mill, $6\frac{1}{2}$ days, at Rs. 5 per cent. per annum,	3.18	
Establishment, supervision, accounts, weighmen, &c., $6\frac{1}{2}$ days, at Rs. 4 per day, ..	25.00	Do.
Grinding 29.931 maunds of 2nd class wheat, at same rate,	12.46	Do.
Cleaning soojee from 1st class wheat, $6\frac{1}{2}$ days, at Rs. 1,	6.25	Do.
Total cost of obtaining out-turn, ..	100.32	

Leaving a profit of Rs. 899.20 in $6\frac{1}{2}$ days, which recovers the whole outlay in 63 days.

Notes on preceding calculations.—The out-turn of the mill and engine (3 horse-power) may be taken at 30 maunds a day.

The working cost of engine and mill is about Rs. 13 per day.

If the Commissariat were to work for themselves, their profits would be much greater even than here shown; for the following reason, viz., 1st, They would require at least two mills, which might be worked by one 6 horse-power horizontal stationary engine, cost of which per horse-power would be less than here shown; the engine wages would remain the same, as also would the item of Rs. 25 per day for establishment, almost the heaviest item in the costs.

2nd. It is more than probable that the heaviest item of all (Rs. 25·60 for fuel) might be almost, if not entirely, saved, by the Commissariat burning the refuse of their cattle-yards, an experiment still to be tried here, but a measure frequently resorted to in England.

The winnowing machine was purchased in Calcutta, and its cost is very much in excess (perhaps double) of what it would have cost if purchased in England and imported here. It ought to be worked by the same engine that turns the mill.

The cost of the building has not been included in the calculation as there was one already available in the Commissariat yard: if required, one might certainly be built at a cost of Rs. 2,500.

The building should be two-storied, and if a lift to the upper story, worked by steam, were attached, it would prove economical. An English weighing machine would save labor, and might be attached at a small cost. One for weighing up to 2 tons cost me £20 fixed in Scotland; it would probably cost Rs. 270 here.

The Commissariat should use none but the best neat's foot oil, which they might make for themselves; it would be not only a saving in first cost, but would also save much wear and tear due to the wretched castor oil at present procurable in Bareilly.

The soojee cleaning, an expensive item as done by hand, if considered necessary, might I think without very great difficulty be done by machine worked by the engine.

It might perhaps be as well to lift the mill a little higher off the ground and have the out-turn shot direct into bags.

BAREILLY, }
December 19th, 1866.

C. S. T.

No. CXLV.

CARROLL'S PATENT CANAL MODULE.

It has long been a desideratum amongst Canal Engineers in India, to have some practicable means of measuring the quantity of water actually delivered through the irrigation outlets of the distributary channels, so that the present objectionable and expensive system of charging according to area irrigated may be done away with. The conditions required for such a contrivance are briefly :—

That there must be a constant and uniform discharge through the outlet (Kolaba) under the varying heads of pressure that practically occur in a rajbuha or distributary water-course. That the contrivance for securing such a discharge must be inexpensive (or it would be out of the reach of the agriculturist), simple (or it would be constantly getting out of order), not easily tampered with (or it would lead to fraud), and not liable to be choked by silt.

Several contrivances have been proposed by ingenious inventors at different times, but none of them have been practically successful. The following, however, which has been invented and patented by Lieutenant Carroll, R.E., so far as it has hitherto been tried on the Ganges Canal, bids fair to answer the purpose effectually; and like many other inventions of equal or greater importance, its construction and method of working are exceedingly simple. Unhappily the clever inventor has been compelled by ill health to quit the country, and to leave to others the carrying out of his idea.—[Ed.]

Description of the Module.

To the mouth of the kolaba a valve is attached of the form and dimensions shown in the Plate, and which may be made of brass or iron.

Its mode of action is very simple. When the plate which hangs in

front of the tube is down, the quadrant which is attached to it, is at its highest point, and it will be seen that a free water-way exist through the tube and between its under lip and the plate in front. If the plate be raised, the quadrant sinks into the tube, and reduces the water-way in proportion to the angle the plate is raised through.

Now, if it be desired to obtain an equal discharge while the head of water in the canal varies from 3 feet down to 1 foot, the plate is weighted so that the force of the issuing stream at a 1 foot head shall be just unable to move the plate outwards. As the head rises above this, the velocity of the stream becomes greater and drives out the plate, thus reducing the water-way till, at a 3 feet head, the plate will remain at a very high angle, and the quadrant will close a great part of the water-way of the tube. The curve of the plate is so adjusted that it shall rest at such an angle as to give the same discharge as at a 1 foot head; when this is done, it is found that at all intermediate heads the discharge remains almost the same. Experiment gives 1 per cent. as the ordinary deviation from exact equality. This module can be equally well applied to regulate under lower heads such as from 1 foot to 3 inches, but requires lighter weights and some other simple adjustments.

The merits claimed for this module are simplicity, cheapness, non-liability to derangement or choking, and the ease with which it can be protected from injury by enclosing it in a small masonry or iron chamber.

The following table shows the result of a series of experiments made with the Module, as lately erected at Tooghulpore on the Ganges Canal, to ascertain the actual deviation from the normal discharge under varying heads of pressure.

The mode of measuring was as follows :—

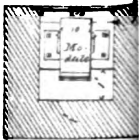
The Reservoir connected with the Canal was filled and allowed then to empty itself through the module, which discharged into the measuring tank. The outlets from this consisted of two sluices cut in a sal wood plank: one below the other, hence the different heads shown on the Abstract (while the water level remained the same), according as the upper or lower one was used.

As the water in the Reservoir fell slowly, the head in the measuring tank was recorded at each decimal of a foot of that fall, and the table here given merely records the extreme of its variation. These variations being very small, the level of the water in this tank is noted as $\cdot 1$ foot above sill

TA

CARROLL'S PATENT MODULE.

Section through Tank



Scale 1/2"

Goal

End view of tank showing gauging rod

Weld Plate

Module and Colubak Head of Cast Iron

Scale 1/2"

Abstract of Experiments made on a Module at Tooghulpore, Ganges Canal, in January and February, 1867.

Variation of head in canal over sill of lock-label.	Variation of head over centre of outlet from measuring tank.	Variations of last number or numbers proportional to extreme discharge.	Mean of the variations of heads or number proportional to mean discharge.	Greatest deviation from mean discharge, measured as a percentage of mean discharge.	Angular traverse of the valve plate between extreme heads, measured from the	ADJUSTMENTS.		REMARKS.
						Height on valve plate.	Level of water surface in measuring tank.	
ft.	ft.	ft.	ft.			lbs. oz.		
3-0 to 1-1	·465 to ·450	·6819 to ·6708	·6768	·6819, or 0·7 p.c.	56° to 27°	7 2	·1 ft. above sill of module	Mean discharge = ·688 c. ft. per second.
3-1 to 1-1	2-205 to 2-040	1-485 to 1-428	1-443	1-428, " 1-0 "	57° to 27°	7 2	·1 ft. ditto,	
3-0 to 1-1	2-145 to 2-010	1-465 to 1-418	1-438	1-465, " 1-5 "	57° to 27° 30'	7 2	·1 ft. ditto,	
2-0 to 0-9	·620 to ·560	·7874 to ·7483	·7629	·7848, " 1-8 "	62° to 34° 30'	3 11	·1 ft. ditto,	Mean discharge = ·5017 c. ft. per second.
2-0 to 0-9	·625 to ·555	·7906 to ·7450	·7594	·7450, " 1-8 "	62° to 34° 30'	3 11	·1 ft. ditto,	
4-5 to 1-3	·572 to ·527	·7563 to ·7259	·7363	·7563, " 2-7 "	60° to 26°	8 5	·1 ft. ditto,	
4-0 to 1-3	·547 to ·527	·7396 to ·7259	·7340	·7259, " 1-0 "	56° to 26°	8 5	·1 ft. ditto,	Calculated discharge from (·7363) as head over centre of rectangular orifice ·6365 ft. X ·335 ft.
4-0 to 1-3	·597 to ·617	·7727 to ·7855	·7787	·7855, " 1-5 "	56° to 26°	8 5	·1 ft. ditto,	

In these last experiments the height of the mouth of the module is reduced a little.

The above are selected from more than 60 experiments made on the valve with different heights, and with its adjustable plate set at different angles: when results as good as these had been obtained, the experiment was repeated four or five times till it was certain that accident had nothing to do with the result. It is necessary to state this to show that these results are not such as might be obtained with a bad valve out of so many experiments.

This table gives only the extreme heads in each experiment; not in the observations themselves, all the heads at each decimal of a foot were entered, and the corresponding heads in the measuring tank. The means given are the means of all of these, and not of the extreme only.

of module, which is about the mean level, and it is desirable that this should be the ordinary level of the run off from a valve in practice.

The angles given are those of the upper part of the valve plate with the vertical thus—

By observing this angle a new valve can be weighted to the proper extent.

It will be observed that the only alterations required to adapt the valve to different ranges of variation of heads, is the alteration of the weights and orifice. The first three experiments are on the most useful form; the cast-iron valve to give 1 cubic foot a second has been designed from this form.



No. CXLVI.

ARTIFICIAL HYDRAULIC LIME.

Description of method used in preparing Hydraulic Lime in Sind, and particularly at Kurrackee. BY W. H. PRICE, Esq., M. Inst., C.E.,
Superintendent Kurrackee Harbor Works.

THE following memorandum is the result of experience in the manufacture and use of artificial hydraulic lime, both in fresh and sea water, during nearly nine years, in the province of Sind; and, as such, may possibly be useful to members of the profession who may have hydraulic works to carry out, at places where natural hydraulic limestone, or reliable puzzuolanas (either natural or artificial) are not procurable, or are at a distance from a market where European cements of suitable quality can be had at reasonable rates.

The process in question was originated I believe by M. Vicat, as described in his "Treatise on Calcareous Mortars and Cements,"* and in the Treatise of Major Gillmore, U. S. Engineers,† as well as in other works.

The method presented therefore no novelty in principle, but was untried in this province, so that it was not without anxiety that I entered on its use for important hydraulic works.

* Treatise on "Calcareous Mortars and Cements." By L. J. Vicat, Engineer in Chief of Bridges and Roads, &c., &c., translated by Captain J. T. Smith, Madras Engineers, F.R.S., &c., &c. London, John Weale, 1837.

† "Practical Treatise on Limes, Hydraulic Cements and Mortars." By Q. A. Gillmore, A.M., Brigadier General of U. S. Volunteers, and Major U. S. Corps of Engineers. New York, D. Van Nostrand, 1863.

My first trial of the material was in 1858, in the building of a regulating bridge across the "Narra supply channel," opening from the Indus, at Roree; and my experience of the lime in that work led me afterwards to employ it on the Kurrachee Harbor Works, commenced in 1860. Here, at first, I used the lime with caution, fearing that though it had proved good in fresh water, it might not prove equally strong or durable in salt; but finding it to answer well in the latter also, the lime was used largely by me; and during my absence in Europe, by Lieut. Merewether, R.E.

Since February 1862, about 50,000 cubic feet, equal to about 800 tons in weight, of the lime, have been used on the Harbor Works, and in no case has it been found to fail.

The material was especially found most valuable in concrete foundations for considerable lengths of wharf walls, in soft mud and quicksand, thus superseding the use of timber platforms or piling, or other expensive methods.

The process of manufacture described in the annexed memorandum is that employed on the Harbor Works since the mortar mills driven by steam power were brought into use; previous to which, the mixture of the lime and clay was made in the ordinary country mill, consisting of a stone roller running in a circular trough, and worked by bullocks. The latter method was also used at Roree, and is still I believe employed on the works of the Sukkur and Shadadpoor Canal, now in progress in Upper Sind. The mill worked by steam power is of course more effective, and at Kurrachee, at least, has been found to do the work more cheaply than the country mill.

The kiln, of which a drawing is appended, is one of the "alternating" kind used on the Harbor Works; it differs little from the kiln suggested in M. Vicat's work, pages 159-160.

At Roree, and at first on the Harbor Works, the ordinary small single country kiln was used, but the three chamber "alternating" kiln is far more economical of fuel, and burns the lime more uniformly.

The appended table, showing the cost of manufacture at Kurrachee (amounting to ten annas = 1s. 3d. per cubic foot) may prove useful. The "per centage" column will afford the means of framing an estimate in other localities, according to the rates of the different items of labor or materials there prevailing.

This lime follows the law of hydraulic limes in general, in admitting

but a small proportion of sand (as compared with rich or fat limes) in the composition of the mortar.

The proportions used on the Harbor Works have usually been:—

For mortar, for concrete,* and footings, 1 lime to 3 sand, parts by measure.

For superstructure, 1 „ to 2 „ „

Though fresh water is indispensable in the mixing of the rich lime and clay, before reburning, yet in the making of the mortar, salt water has been generally used on the Harbor Works, and has been found to answer as well as (if not better than) fresh water.

Attention has latterly been turned to the comparison of Portland cement (imported from England) with the hydraulic lime, and Lieut. Merewether, R.E., has undertaken a series of experiments on the two materials with the view to determine which ought to be recommended for the preparation of blocks of artificial stone, for the projected Manora break-water. There is no doubt that either material will make good work, so that the question resolves itself mainly into one of comparative cost.

The lime is (as might be supposed), bulk for bulk, very much cheaper than the cement; but the latter takes the larger proportion of sand, and the main object of the experiments now in hand is to determine up to what limit the admixture of sand with the cement may be carried, while producing a mortar equal in strength and durability to that made with the hydraulic lime.

To determine this satisfactorily will require some time and numerous trials of different kinds. An important element in the question is of course the lowest rate at which Portland cement of suitable quality can be supplied at Kurrachee. The sample from which the experiments are being made, sold at about four times the cost of the hydraulic lime per cubic foot. At such a rate there could be no inducement to adopt the cement; but judging from English prices, there is reason to believe a steady demand here would induce a supply at a much lower rate than the above. This point, however, remains to be exactly determined.

In connection with the subject of hydraulic cements, it might be suggested as interesting to the profession, that some officers should give their experience in the use of puzzuolanas, natural or artificial; and among the latter particularly of “soorkhee,” or pounded brick, a material so much em-

* The concrete is made by mixing with the mortar twice its bulk of stone, broken to pass through a 2-inch ring.

played in the North West Provinces, and other parts of India, in the composition of mortar for hydraulic works.

Experiments on the latter material made in Sind, caused me to abandon the idea of its use, as the mixture of pounded brick with rich lime, formed a cement, either not at all, or but feebly, hydraulic.

The use of (even the best natural) puzzuolanas with rich limes, would seem at best doubtful, particularly for sea works, serious failures having been reported by eminent French Engineers. See Gillmore on Limes, &c., pages 99 to 109, Arts. 150 to 162. There seems, indeed, reason to believe that Portland cement is coming much into use on the Continent as well as in England, in supersession of puzzuolana, especially for sea works.

Process of manufacture of artificial hydraulic lime on the Kurrachee Harbor Works.—Ordinary rich (fat) lime slaked to powder, is mixed with clay, in the proportions of $5\frac{1}{2}$ parts, by measure, of lime, to 1 part of clay.

The rich lime used on the Harbor Works has been generally made from the hard crystalline limestone procured from the "Gizree" hills, near Kurrachee.*

The clay is procured *in situ* from the bed of the Lyaree river, and is of the description that might be used for bricks or coarse pottery.

The mixture of the lime and clay is made in a mortar pan worked by steam power,† a sufficient quantity of water being added to bring it to the consistency of moderately stiff mortar. The amalgamation should be very thoroughly effected, as upon this greatly depends the quality of the lime.‡

The mixture is then made by hand into balls of about the size of a large orange, which are laid out on the ground in the sun to dry. When thoroughly dried, which takes from two to six days according to the weather, the balls are burned in a kiln; or if the lime is not likely to be soon required, they are stored in a shed. It is most important that the balls should be thoroughly fired before burning.

* Shell lime would probably be found a tolerable substitute where limestone is not easily available.

† At the Roree regulating bridge, the mixture was made by a stone roller, running in a circular trough of brickwork, and worked by bullocks.

‡ If the mixture is properly made, the balls after drying should show a uniform gray color when broken, the white specks of lime not being easily distinguishable.

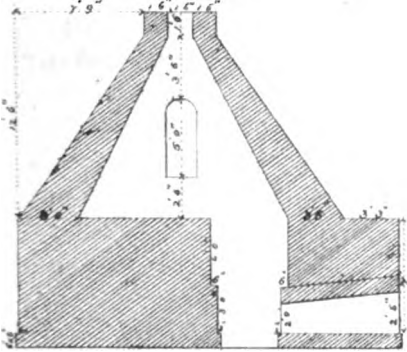
KILN FOR BURNING ARTIFICIAL HYDRAULIC LIME

CONSTRUCTION.

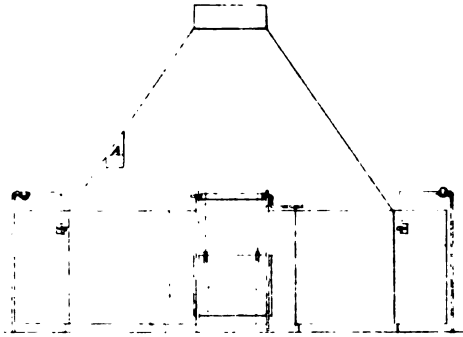
*Sundried bricks set in mud with arches
of fireburned bricks also set in mud
Sliding doors of iron.*

Cost at Barrachee in 1860 Rs 234

Section on A.B.

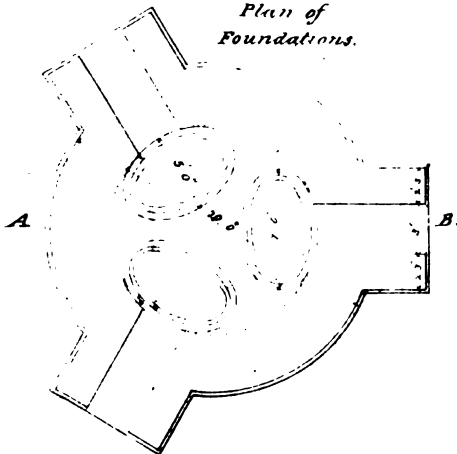


Elevation.

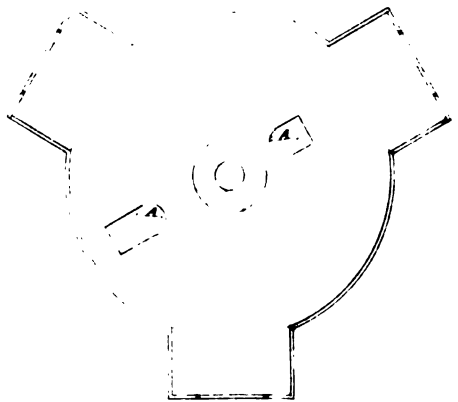


*Note These doors were added after the
construction of the Kiln and proved
very useful and economical in re-
gulating the draught. -*

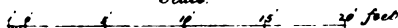
Plan of
Foundations.



Top Plan.



Scale.



The method of burning the lime is as follows:—

The kiln used (*vide* drawing) is constructed on the principle of “alternately foies” (suggested by M. Vicat for the burning of hydraulic lime), the base being in three compartments or chambers, and the chimney in one, common to the three chambers.

Each chamber has an opening for firing, to which a sliding door of iron is attached for regulating the draught.

The lower portion of the charge is formed of limestone hand rubble, laid in the form of a vault, 8 to 10 inches thick, over each chamber.

Above the vaults the kiln is to be filled in with the balls, pieces of firewood being placed vertically at intervals of about 2 feet, to facilitate the draught.

The top of the kiln is left open, but the openings for drawing the lime are closed with sun-dried brick, plastered over.

The chambers are lighted in rotation, each for 20 hours at a time, until the burning has continued for the usual period of 120 hours, being the time required if babool (*Acacia*) wood be used for firing; if jhow (*Tamarisk*) wood be used, 144 hours are required, to be divided proportionately.

The doors of the chambers not in action are closed, the chinks being plastered over with clay.

After the burning, one day is allowed for cooling the kiln, after which the doors may be opened and the lime drawn.

The kiln requires for burning from 400 to 450 maunds (maund equal 82 lbs.) of firewood, if jhow, be used; if babool, 360 to 400 maunds.

The return is from 700 to 730 cubic feet of hydraulic lime, and 160 to 180 maunds (maund equal $2\frac{1}{4}$ cubic feet, measured after slaking) of rich lime.

The quantity of limestone required for the vaulting is from 260 to 290 cubic feet, measured as stacked in heap.

After the burning, the hydraulic lime may be slaked for use in the same manner as ordinary lime. If kept a little time, however, the balls fall to powder, more or less from exposure to the air, but the lime will keep good in this way for some weeks or even months. It is necessary, however, to store the lime under shelter in a closed shed.

The lime prepared under the foregoing process, set under water in from 24 to 48 hours, and appears in every way to fulfil the conditions of an eminently hydraulic lime, as defined by M. Vicat.

Details of cost of manufacture of one kiln yielding about 700 cubic feet:—

NOTE—The lime measures about the same in cubic content whether in balls or after having fallen into powder.

Particulars.	Description.	No.	Rate.	Per	Amount.	Total.	Per centage.
MATERIALS.					R. A. P.	R. A. P.	
Rich lime, - - - {	Maunds, 862 {		1 0 0	mds. 2½	144 12 9		
Limestone for base of charge, - - - {	Cubic ft. 815 {			c. ft. 100	18 2 0		
Water (fresh) for slaking lime, obtained from base of charge,	Gallons, 900		0 5 0	100	2 13 0		
Labor for slaking and measuring lime obtained from base,	Laborers, 21		0 6 0	diem,	7 14 0		
	" 1		0 7 0	"	0 7 0		
	Boys, 6		0 3 6	"	1 5 0		
	" 4		0 3 0	"	0 12 0		
					176 1 9		
Deduct value of rich lime obtained from base of charge, -	Maunds, 170		1 0 0	mds. 2½	68 0 0	108 1 9	24.70
Clay, - - - -	Cubic ft. 148		6 0 0	c. ft. 100	8 14 0	8 14 0	2.08
Water (fresh) for mixing lime and clay, -	Gallons, 1,600		0 5 0	galls. 100	5 0 0	5 0 0	1.14
Firewood (babool), - {	Maunds, 380 {		1 0 0	mds. 2½	152 0 0	152 0 0	34.74
	Lbs., 31160 {						
LABOR, MIXING LIME AND CLAY.							
Manual labor, - {	Laborer, 10		0 7 0	diem,	4 6 0		
	" 32		0 6 0	"	12 0 0		
	Boys, 7		0 3 0	"	1 5 0	17 11 0	4.05
Machinery charges for mixing by steam mortar mill, -			..	..	40 11 0	40 11 0	9.30
Dividing the paste into balls, - - - -	Women, 39½		0 4 0	diem,	9 14 0	9 14 0	2.26
Carried over, -			..	..	..	342 8 9	78.22

Particulars.	Description.	No.	Rate.	Per	Amount.	Total.	Per centage.
					R. A. P.	R. A. P.	
Brought over, -	..	..	..	..	..	842 3 9	78.22
Loading kiln, -	Laborers,	3	0 7 0	diem,	1 5 0		
	"	24	0 6 0	"	9 0 0		
	Women,	3	0 4 0	"	0 12 0		
	Boys,	5	0 3 6	"	1 1 6		
	"	6	0 3 0	"	1 2 0	13 4 6	3.04
Firing kiln including- removal of firewood,	Laborers,	8	0 7 0	"	3 8 0		
	"	12½	0 6 0	"	4 9 6	8 1 6	1.85
Drawing kiln and storing lime, -	Laborer,	12	0 7 0	"	5 4 0		
	"	23	0 6 0	"	8 10 0		
	Women,	1	0 4 0	"	0 4 0	14 2 0	3.23
Foreman lime burner,-	..	Days. 20	1 0 0	"	0 0 0	20 0 0	4.57
						397 11 9	90.91
Add for depreciation of, and repairs to, kiln, lime sheds, tools, and charge for service ground occupied in drying balls, - -	..	..	10 0 0	per c.	..	89 12 4	9.09
Total cost of 700 cubic feet of lime, - -	..	..	..	..	..	487 8 1	100.00
Cost of one cubic foot,	..	..	..	..	..	0 10 0	..

NOTE.—The cost of the hydraulic lime at Roree in 1858 was about 2 annas per cubic foot, but there, labor was only about one-third and firewood one-fourth Kurrachee rates; also stone clay and water were procured on the spot at nominal cost, while all these materials have to be brought from a considerable distance at Kurrachee. Such lime now costs at Roree about 3 annas 7 pies per cubic foot, or 1 rupee for 2 maunds.

W. H. P.

NOTE BY EDITOR.

The following extract is from the Thomason College Manual on Limes and Cements.

Major H. A. Brownlow, R.E., Superintendent Eastern Jumna Canal, made a

most excellent cement from the stone lime and brown alluvial clay procured near the head of his canal, following the directions given by General Pasley,* and it very well repaid the trouble and expense laid out on it.

Hydraulic cement has also been made with considerable success in Madras and at Singapore. Lieut. Morgan on the Eastern Coast Canal, six miles north of Madras, made cement of 7 measures of shell lime to 5 measures of clay, following closely Pasley's rules for mixing and burning it. If applied under water this cement hardened in 24 hours; if applied dry and water let on it in half an hour, it hardened in 8 or 10 hours. The same cement mixed with an equal quantity of soorkhee hardened in 48 hours under water, or in 12 to 24 hours if allowed half an hour before the water was let on it.

The cost of this cement was not more than 4 annas per "parah," of 4,000 cubic inches.

Captain Man, at Singapore, found he could make a similar hydraulic cement of excellent quality using 5 measures of slaked lime to 2 of fresh blue clay.

In some experiments made at Roorkee to discover the best composition for a hydraulic cement, the bricks, the day after being joined were placed at the bottom of the Ganges Canal, and exposed to a stream of nearly 3 miles an hour. The cements were made of old fat stone lime, which had been lying under a dry arch for 6 years

* General Pasley's experiments were made principally with chalk lime, and the blue alluvial clay of the river Medway, near Chatham. The result he arrived at was, that a mixture of 4 parts by weight of pure chalk, perfectly dry, with 5.5 parts, also by weight of alluvial clay, fresh from the Medway, or of 10 parts of the former with 18½ of the latter, would produce the strongest artificial cement that could be made by any combination of these two ingredients.

The weight of the blue clay he found to be ninety pounds, and of the dry chalk powder forty pounds per cubic foot.

His method of proceeding was as follows:—The clay was weighed when fresh from the river (taken from about eighteen inches below the surface), and was never dug unless required at once; it being found that even twenty-four hours exposure to the atmosphere injured it. The chalk was not weighed until well dried and pounded, owing to its extraordinary retentiveness of moisture. The chalk was then mixed with water into a thick paste. The chalk and clay were then each separately divided into portions or lumps as nearly as possible equal, and put alternately into a pug mill of the ordinary description where they were most thoroughly and intimately mixed. The raw cement thus formed was then made up into balls of about two and a half inches in diameter, and placed in the kiln alternately with about equal layers of fuel—a layer of fuel always being at the top and bottom. The fuel used was coke, in preference to coal; and, in the small furnace or kiln used by Sir C. Pasley, three hours was found to be about the average time required for burning the cement. As the calcined cement was drawn from the bottom of the kiln, fresh cement could be put in at the top. The balls, on being raked out, could be tested by applying to them diluted hydrochloric acid. If sufficiently burned, no effervescence ensued; but if they effervesced, they were put into the top of the kiln again to be reburnt. The calcined cement balls, since they would not slake like ordinary lime were then ground to impalpable powder, and stored for use, so that they should not be exposed to the atmosphere. The average out-turn was about nine and a half measures of calcined out of ten measures of raw cement.

Where only hard limestone is to be obtained, General Pasley suggests that instead of grinding it which would be often a difficult and expensive operation, it is better to burn the limestone and slake it before mixing it with the clay.

The above proportions formed the best artificial cements; but he has also recorded as follows:—
"After due investigation, we found that any given weight of well burned chalk lime, and consequently of any other pure quick lime, fresh from the kiln, combined with *twice* its own weight of blue clay, fresh from the river, will form an excellent water cement; observing, however that the quick lime, after being weighed, must be slaked with excess of water into a thinish paste, and allowed to remain in that state about twenty-four hours before it is mixed with the clay."

since being burnt; this was slaked, mixed with $1\frac{1}{2}$, 2, and $2\frac{1}{2}$ times its own weight of ordinary brown clay, following Pasley's directions. The composition of 1 lime to 2 clay, was found the best, and 1 lime to $2\frac{1}{2}$ clay the worst. At the same time some fresh stone lime was ground and mixed up carefully with an equal bulk of ground soorkhee; and the result of a number of experiments proved that although the mortar made of the lime and soorkhee set in the air as hard as that made of the lime and clay burnt together, yet it would in no case set when exposed to the force of the canal stream; while the cement after 14 days under water required a breaking weight of 10 lbs. per square inch to separate the bricks. Some very hard blue clay was afterwards obtained from Hurdwar, and mixed with fresh stone lime, very slightly if at all hydraulic, in the proportion of 1 lime to 2 clay; and balls were calcined, and ground as before; of this cement four prisms were made $6" \times 2\frac{1}{2}" \times 2\frac{1}{2}"$, and after 26 days immersed in water were subjected to a transverse strain, the bearing being 4 inches. The average breaking weight of the prisms was 598.5 lbs.; the greatest being 675.5. This gives the value of C the constant of strength for this cement = 158; while for prisms of Roman cement 11 days old it was only 150.

The lime used in this part of India is derived from three sources; 1, Boulder limestones found in the beds of hill torrents; 2, Marl, or earth lime, as it is usually called; 3, Kunkur lime.

The following is an analysis lately made at Roorkee of the first two varieties:—

Nature of lime.	Moisture expelled at 212°.	Organic matter and moisture.	Siliceous matter and clay.	Carbonate of lime.	Carbonate of magnesia.	Oxide of iron and alumina.	Total.
Marl lime,	1.44	1.27	49.80	37.01	2.79	7.69	100
Stone lime,	0.40	2.43	11.18	50.43	23.73	11.83	100

The kunkur lime is similar to No. 2, both differing widely from the stone lime. All make excellent mortars for hydraulic works; the ordinary mixture with No. 1 lime being 1 part stone lime to 2 of soorkhee, or 140 lbs. lime to 400 lbs. soorkhee (if the mortar is to be used for ordinary buildings 1 lime, 1 soorkhee, 1 sand may be used). With the marl lime, 1 of lime to 1 of sand, without any soorkhee, is used.—[Ed].

No. CXLVII.

IRON MILE POSTS.

Memo. on Iron Mile Posts used in the Burdwan Local Road Division, Bengal. BY LEONARD ROBERTS, Esq., A.I.C.E., *Executive Engineer.*

THE standards are of $1\frac{1}{2}$ -inch angle iron, and cross braces of $1\frac{1}{2} \times \frac{1}{2}$ -inch flat bar iron.

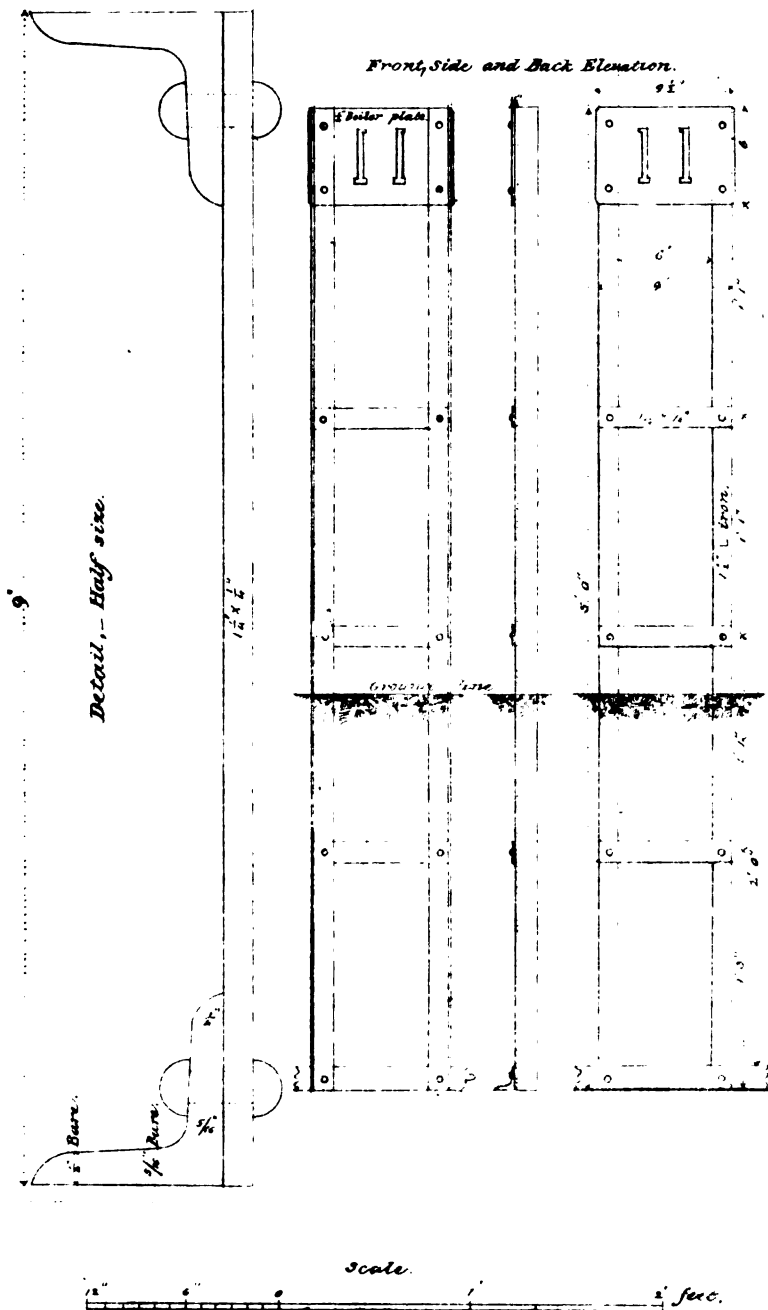
The figure plate is of $\frac{1}{4}$ -inch boiler plate, the figures are $\frac{1}{4}$ -inch in width, $3\frac{1}{4}$ -inches high, and are cut through the plate with a half inch drill, and then filed to shape; their outline being previously scribed from tin templates. The plan answers very well, and the figures show very distinctly when the posts are in position.

The rivets are all $\frac{1}{4}$ -inch, and the posts being well cleaned from any rust, were twice payed over with coal tar and grease, applied hot.

The Iron was supplied through the Department; and, including cost of same, carriage to Burdwan and labor in manufacturing, the cost of each was Rs. 4-4-3.

L. R.

IRON MILE POSTS.



No. CXLVIII.

PENDULUM OPERATIONS OF THE G. T. SURVEY.

(2nd Paper.)

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.

IN 1825, M. Bessel made his experiments for determining the length of the seconds pendulum at Königsberg, with an apparatus constructed and partly designed by Repsold the celebrated artist of Hamburg. The apparatus was contrived so as to avoid any uncertainty in the centre of oscillation of the pendulum, as well as any error in the measure of its length, by observing the times of vibration of a pendulum ball suspended alternately by two wires, whose difference in length was known.

A toise was set upright on a narrow horizontal plane firmly fixed to a perpendicular iron bar, and the contrivance by which the pendulums were suspended, could be placed either on the horizontal plane, or on the top of the toise itself, so that the effective lengths of the wires differed in the two cases by an amount exactly equal to the length of the toise. The wires, which were of steel, were attached to a thin strip of brass which unwound itself over a small cylinder. The pendulum, thus suspended, described the curve called the evolute of the circle. At the lower end of the iron bar, there was a micrometer screw for measuring small differences in the height of the ball.

The system of observation was as follows:—At the commencement of a series of coincidences with the longer pendulum, the thermometers attached

to the toise were recorded, and the reading of the lower surface of the ball was taken with the micrometer screw; the pendulum was then set in motion, and after a sufficient number of coincidences had been observed, the readings of the ball and thermometers were again taken. Exactly the same process was then gone through with the shorter pendulum: then from the times of vibration of the two pendulums whose absolute lengths were unknown, but whose difference in length was accurately known, the length of the seconds pendulum was easily computed.* There were a great many minute details to be attended to, all of which were carried out with the greatest ingenuity and nicety, and all conceivable sources of error were considered and their effects computed and allowed for.

The coincidences were observed in a slightly different way from any preceding method. The pendulum was enclosed in a wooden case, faced with glass to keep out currents of air, as well as to preserve as constant a temperature as possible; the clock was placed about $8\frac{1}{2}$ feet in front of the pendulum, and between the two, the object glass of a telescope was adjusted to form an image of the detached pendulum in the plane of the clock pendulum, to enable them both to be seen simultaneously through the observing telescope, which was set up at a distance of about 15 feet. On the wire of the detached pendulum was fixed a small brass cylinder, painted black, and called the coincidence cylinder; it weighed something under 4 grains, and could be brought exactly opposite the scale for measuring the arc of vibration.

On this scale a black streak was painted, in the middle of which a space was left white, equal to the diameter of the coincidence cylinder, so that when the pendulum was at rest, the cylinder exactly covered it. Again, to the bottom of the clock pendulum a piece of blackened paper was attached, in which a hole had been cut of such a size that when both pendulums were at rest, it exactly coincided with the image of the white space

* Let t_1 and l_1 be times of vibration and length of longer pendulum.

$$\begin{array}{ccccccc} t_2 & l_2 & & & & & \text{shorter} \\ l_1 - l_2 & = & \text{difference in length} & = & a & & \\ L & = & \text{length of seconds' pendulum.} & & & & \end{array}$$

$$\text{Then } t_1^2 = \pi^2 \frac{l_1}{g}, t_2^2 = \pi^2 \frac{l_2}{g}, 1 = \pi^2 \frac{L}{g}$$

$$\therefore \frac{t_1^2}{t_2^2} = \frac{l_1}{l_2}, \frac{t_1^2 - t_2^2}{t_1^2} = \frac{l_1 - l_2}{l_1} \text{ or } \frac{l_1}{t_1^2} = \frac{a}{t_1^2 - t_2^2}$$

$$\text{Again, } \frac{1}{t_1^2} = \frac{L}{l_1} \text{ or } L = \frac{l_1}{t_1^2} = \frac{a}{t_1^2 - t_2^2}$$

on the black streak : hence when the pendulums were moving in coincidence, the coincidence cylinder was visible through the hole, and completely eclipsed the white space. Bessel's result was expressed in lines of the toise of Peru, the standard used in the measurement of the Peruvian arc.

In publishing these experiments, M. Bessel pointed out the true correction for buoyancy, which he had investigated by swinging in air two spheres of equal diameters, but of different densities, one being of brass and the other of ivory, suspended by a fine steel wire ; and again by swinging the same brass sphere first in air and then in water. These experiments showed that the old formula for reducing observations in air to a vacuum gave too small a correction, and that it should be multiplied by a factor.

Mr. Francis Baily made a long series of experiments on the correction for buoyancy, which were published in the Philosophical Transactions for 1832. He used about 80 pendulums, all differing in form, weight, and mode of suspension. From these experiments he deduced factors for pendulums of almost every description that have ever been used, and computed also the weight of the air adhering to each, in other words deduced the *vibrating specific** gravity of the pendulum. He concluded from all his results, that even if a pendulum is formed of materials having the same specific gravity, yet if it be not of an uniform shape throughout, each distinct portion must be made the subject of a separate computation, in order to determine the correct vibrating specific gravity of the whole body, since each part will be differently affected by the surrounding air.

The last extensive series of experiments were those taken in 1828-31 by Captain Henry Foster, who was sent out on a scientific mission by the Board of Admiralty. He took out with him four invariable pendulums of different metals, two of Captain Kater's pattern, and two of Baily's convertible pattern. These last consisted of a plain straight bar, 2 inches wide, $\frac{1}{2}$ -inch thick, and 5 feet $2\frac{1}{2}$ inches long, having two knife edges 39.4 inches apart, but no heavy bob or sliding weights, as in Captain Kater's

* "The vibrating specific gravity of a compound pendulum is *ordinarily* found as follows: Let d', d'', d''' ... denote the distance of the centre of gravity of each body respectively from the axis of suspension : w', w'', w''' ... the weight (in air) of each body : s', s'', s''' ... the specific gravity of each body determined in the usual manner. Then will the required *vibrating specific gravity* of the pendulum be

$$S = \frac{w' d' + w'' d'' + w''' d''' + \dots}{\frac{w' d'}{s'} + \frac{w'' d''}{s''} + \frac{w''' d'''}{s'''} + \dots}$$

(Philosophical Transactions, 1832.)

pattern; the synchronism was adjusted by filing away at one end of the bar; Baily's intention was, that the pendulum should either be used as two different invariable pendulums, or applied as a single convertible one for absolute determinations, at any station. The objection to the form is, that both the knife edges must be exactly perpendicular to the bar, or error is entailed, as the bar is not flexible like Kater's. Captain Foster swung pendulums at all his stations, 14 in number, which were chiefly in the southern hemisphere. He made a set of observations, at Mr. Brown's house before the voyage; on the return of the pendulums to England, they were again swung at the same place, but by Mr. Baily, Captain Foster having been most unfortunately drowned in the River Chagres, in February 1831, just as his mission was completed. His observations were reduced by Mr. Baily, who obtained from them an ellipticity of $\frac{1}{333.7}$.

About this time the Russian government sent out an expedition under Captain Lütke, who used an invariable pendulum, formerly used by Captain Basil Hall. He swung it first at Greenwich, and afterwards at Ulan, in the Caroline islands, Guam, Bonin island (to the south-east of Japan), at Sitka in Russian North America, at Petropaulowski, Valparaiso, St. Helena, and St. Petersburg. He deduced an ellipticity of $\frac{1}{347}$ from his observations.

Shumacher, the celebrated astronomer of Altona, conducted in 1829-30 a series of experiments with Bessel's apparatus, at the castle of Guldenstein, in order to determine the Danish standard, which was to be a certain fractional part of the length of the seconds pendulum, at the level of the sea, in latitude 45° . In order to estimate the influence of the air, he used, instead of a ball, a hollow cylinder of platinum, made by Repsold, inside which a second solid cylinder, also of platinum, fitted perfectly true. The outer cylinder was closed by covers of the same diameter screwing on to it, which were both perforated; the clamp holding the wire was fastened on to the top, and into the bottom was screwed a point with which the contact was made in measuring the height of the cylinder by the micrometer screw.

The pendulum was swung under four different circumstances, viz., the long pendulum, with and without the inner cylinder, and the short pendulum, also with and without it; and as exactly the same surface was exposed to the air in each case, the influence of it could be computed, which was done

by a formula deduced by Bessel. The reduction of the observations was made by Professor Peters. One novelty was introduced, viz., that of computing out the attraction of the ground on which the observations were taken. A square space having a side of 600 toises (1279 yards), in the middle of which the observatory was situated, was subdivided again into 36 squares of 100 toises (213 yards) a side; in each of these borings were made, and specimens of the earth removed and their specific gravities determined; as these were very nearly the same, a mean of the whole was taken. The height of the floor of the pendulum room was $34\frac{1}{2}$ toises (220.6 feet) above the mean sea level, and the attraction of this plateau of the earth's crust introduced a change in the length of the second's pendulum of 0.000215 English inches.

Carlini, whilst measuring the Piedmontese arc in 1821-23, took a series of pendulum experiments at the Hospice on Mount Cenis, with the view of determining the density of the earth. His pendulum was formed of a heavy sphere suspended by a wire, which was attached to a kind of inverted stirrup; in the part corresponding to the foot plate there was fixed a wheel with a sharp edge turning on its axis. This wheel was placed on a grooved plate and formed the knife edge for suspension; the arrangements for observing were similar to Bessel's. Corresponding observations, though not with the same apparatus, were taken by Biot and Mathien at Bordeaux. The result was a density of 4.95.

One more attempt to determine the density of the earth by means of the pendulum was made in 1854 by the Astronomer Royal, Professor Airy, at the Harton Colliery pit. Two invariable pendulums were set up in the same vertical line, one at the top, the other at the bottom of the pit, and their coincidences with the pendulums of two clocks were simultaneously observed, the relative rates of the clocks being determined by a galvanic apparatus. After each series of coincidences the pendulums were interchanged. The distance between the upper and lower pendulums was 1256 feet; a careful description of the intervening strata was prepared, and specimens submitted to Professor W. H. Miller, who determined their specific gravities. The acceleration of the seconds' pendulum below was 2.24 seconds per diem, and the resulting mean density of the earth was 6.565.

The best value of the earth's ellipticity as yet deduced from pendulum observations is undoubtedly that of Mr. Baily's. He combined all the

observations taken with invariable pendulums, and after applying to them all corrections, obtained a mean ellipticity of $\frac{1}{251.5}$. The latest value of the same, from geodetic observations, is Captain Clarke's, R.E., which includes the new Russian arc, and is $\frac{1}{251.35}$. The ellipticity obtained from observations of precession and nutation is $\frac{1}{251.5}$ (Airy's tracts).

The apparatus for the Indian experiments, consists of two invariable pendulums on Kater's principle, a vacuum apparatus with air pump for exhausting, an astronomical clock by Shelton, a good battery of thermometers and a transit instrument. Both pendulums have already done good service; one having been used by General Sabine in his extensive range of experiments, the other by Professor Airy in his Harton pit experiments; they cannot be considered, however, to have retained their original length, as their knife edges have been reground. Each is composed of a bar of plate brass, 1.6 inches wide and rather less than an $\frac{1}{8}$ th of an inch thick; a strong cross piece of brass is rivetted and soldered to the top to hold the knife edge, which consists of a prism of very hard steel, passing through the bar and adjusted at right angles to its surface. The prism is equilateral in section, but the edge on which it vibrates is ground to an angle of about 120° ; the length of the bar from knife edge to the extremity is about 5 feet $1\frac{1}{2}$ inches. At $3' 2\frac{1}{4}"$ from the knife edge, a flat circular bob, also of brass nicely turned and pierced in the direction of its diameter, is firmly soldered on; the part of the bar beneath the weight, called the tail-piece, which is about 17" in length, is reduced to a breadth of 1.7 of an inch and is varnished black, in order to contrast better with the white disc on the clock pendulum, in the observation of the coincidences.

The knife edges rest on agate planes set in a solid brass frame, which is provided with three levelling screws. On the outer side of each plane are Y's, which are moveable in a vertical direction by means of an eccentric; the knife edges rest in them when the pendulum is not in use, and by their means the observer is enabled to lower the pendulum down gently so as to bear always on the same parts of the agate planes. Each pendulum has its own set of planes, and will give different results if swung on any others.

It has been decided to swing the Indian pendulums in vacuo, in order to secure the following advantages. When the pendulum has been set in motion, it will vibrate for a whole day; its temperature will be more equable; it

will not be disturbed by currents of air; and errors in the formula for the correction for buoyancy are unimportant. The vacuum apparatus consists of a cylinder of sheet copper about 1 foot in diameter and rather more than 5 feet long, with hemispherical caps, the upper one of glass and moveable, the lower one of sheet copper and soldered to the cylinder. The upper end of the cylinder carries a strong brass plate, to which are attached the frames containing the agate planes and a bar of the same metal and shape as the pendulums; placed side by side with a pendulum inside the apparatus, the bar and pendulum will be of the same temperature, and it is evident that thermometers attached to the former will give the required temperature of the latter. Two delicate thermometers are attached to the bar, their bulbs being sunk in the metal at points equidistant from each other and the ends of the bar. The stem of the upper thermometer is inverted, and placed side by side with that of the lower thermometer, in order that they may both be viewed through a moderate sized glass plate let into the cylinder. In the lower part of the cylinder there are four other windows, two on the line of the pendulums, to enable their coincidences to be observed; the other two at right angles to these, to give additional light and enable the observer to ascertain whether the detached pendulum is vibrating truly without wobble. There are two scales fixed at right angles to each other, inside the cylinder, on a level with these windows, one of which is used for measuring the arc of vibration of the pendulum, and the other to measure the distance of the pendulum from the former scale, which is necessary to furnish the correction for parallax in the readings of the arc of vibration: it is useful also in placing the pendulum at a constant distance from the clock, which is found convenient in practice.

The upper 4" of the cylinder is made of greater thickness than the rest, and at top is a strong projecting flange which is intended to rest on a strong cast-iron frame made in two pieces; so as to grip the cylinder round the thicker part just below the flange; the halves of the frame are then firmly bolted together with nuts and screws. The upper surface of the flange is ground perfectly true to receive a bell glass, the cap already mentioned, which is like the receiver of an ordinary air pump. The eccentric for raising and lowering the pendulum on to the agate planes passes through a stuffing box in the upper part of the cylinder. Motion is imparted to the pendulums by means of a fork and crutch turned by a spindle which passes through another stuffing box.

The clock with which the vibrations are compared is firmly secured to a wall, and the vacuum apparatus is erected in front, at a distance of about 2 feet from it. The diaphragm for limiting the view of the disc is fitted inside the clock case.

The telescope for observing the coincidences is placed on a small masonry pier at a distance of about 8 feet from the vacuum apparatus and is mounted so as to slide laterally on a graduated horizontal bar; it has also a slight vertical motion. The thermometers and barometers are read from alongside of this pillar by means of a cathetometer, viz., a telescope sliding up and down on a vertical rod. The object of this is to obviate the ill effects of any defect in the isolation of the apparatus, as well as the influence of the observer's person on the thermometers.

As the disc on the bob of the clock and the tail-piece of the detached pendulum are too far apart to be viewed simultaneously by the telescope, a lens is placed between them, so as to throw the image of the white disc upon the tail-piece of the pendulum. The vacuum cylinder and all its adjuncts, air pump, &c., were made by Adie, and are the only new portions of the apparatus.

The method of operation is as follows:—After setting up the clock, the vacuum apparatus is inserted in the iron frame and suspended either on wooden trestles or masonry piers; the frame is roughly levelled; the temperature bar is fixed in position; the agate planes are screwed on firmly to their bed plate, and are very carefully levelled by means of delicate spirit levels provided for the purpose. A pendulum is now inserted and let down upon its planes, but the clock must not yet be set in motion. The telescope is next set up on the prolongation of the line which passes through the two pendulums, when both are at rest. For this purpose it is moved laterally on its graduated support, until a very small portion of the paper disc, on the bob of the clock pendulum, is visible on one side of the tail-piece of the detached pendulum. The reading is noted, and the telescope is then moved in the opposite direction, until an equal portion of the disc is visible on the other side of the tail-piece; the reading is again noted, and the telescope is set to the mean position. The pendulum is then removed, and the diaphragm in the clock case adjusted, until its cheeks are tangents to the disc. The pendulum may now be replaced, and nothing remains to be done but to exhaust the air out of the apparatus and to set the pendulums in motion.

The observations are made in exactly the same way as already described in the account of Captain Kater's apparatus; the times of the disappearance and reappearance are both noted, and the mean taken as the true time of coincidence. The arc of vibration is then determined by noting the reading of the arc, when it is cut by the same edge of the tail-piece on each side of the vertical line. The thermometers and barometer are read by means of the cathetometer. It is usual to observe not every coincidence, but the first three consecutive coincidences, and then the 11th, 12th, 13th, then the 21st, 22nd, 23rd, and so on; after observing the first two or three, the times of the after coincidences can be easily computed with sufficient accuracy to intimate when the observer should be ready to note them.

It is intended to have observations made generally along the Great Arc at stations 2" apart in latitude, and at other points where it may be desirable to obtain data regarding local variations in the intensity of gravity.

The pendulum experiments in this country will afford an independent value of the ellipticity of the Indian arc. It is also hoped that they will throw some light on the existing discordances between the astronomical and geodetic latitudes of the Indian survey.

The amount of the deflections of the plumb line, due to the Himalayas and elevated table lands to the north of India, have been computed by Archdeacon Pratt for the different terminal stations of the Indian arcs; but these determinations are so much in excess of the results of the survey, that it is evident that the effects of the mountain attraction must be in a considerable degree compensated, either by a deficiency of density in the strata to the north, or by an excess of density in the strata to the south, of the survey stations.

Now the pendulum can undoubtedly be made the means of showing whether the compensation is to be attributed to either of these causes; for, whilst the effect of a distant range of mountains on the vibrations would be quite inappreciable, any local variation in the density of the underlying strata would show itself most unmistakably; so that by taking observations both at a normal station, and at a few points in its vicinity symmetrically situated around it, should there be any considerable excess or defect in the density of the strata to counteract the disturbance due to the mountain mass, the pendulum observations would not fail to point it out.*

* Professor Stokes remarks in his letter on these operations: "The pendulum no doubt indicates

The Indian operations will eventually be combined with those taken previously with similar instruments in other parts of the world, to deduce the ellipticity of the earth's mean figure. Both Sir John Herschel and Professor Stokes have remarked, in their letters on the proposed Indian operations, that almost all observations hitherto made have been taken at stations either on islands or coasts, so that a series along the centre of a continent is very much needed. A complete set of observations has been already taken at the Kew observatory by Mr. B. Loewy, with the Indian apparatus; and on the completion of the experiments in this country it will be returned to Kew, in order that final observations may be taken, to show whether the pendulums have undergone any change in the interim.

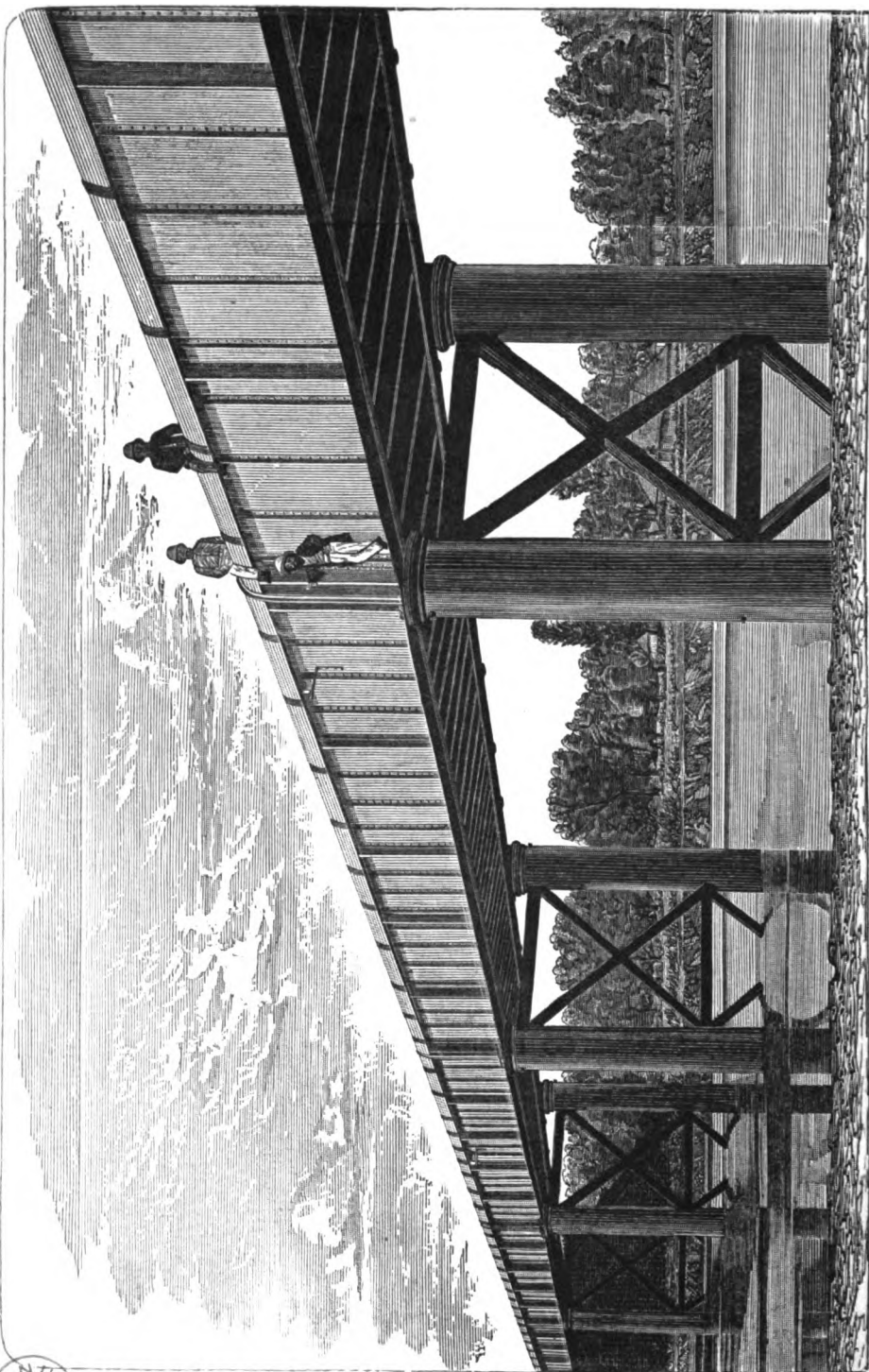
It is to be hoped, however, that so good an opportunity will not be lost of extending these observations to stations easily accessible from India, though not included within its limits. On this head Professor Miller's opinion may be quoted at length. "Much would be added to the value of the observations made at the stations of the Indian survey, if, before the pendulums were brought back to England, observations could be made with them at some other points, especially points nearer to the equator, such, for instance, as the south coast of Ceylon, Singapore, or on the coast of Borneo. Another accessible point, interesting from being in a long line of depression, where a large gravitation might be expected, is Aden."

The intention of the Russian government, to have similar observations made along the Russian arc, has already been alluded to. If, after the return of the pendulums to England, they were to be swung at one of the Russian stations, it will be possible to combine the Russian with the Indian operations, and deduce a value of the earth's ellipticity from exclusively Continental observations, extending from Cape Comorin to the northernmost part of Finmark.

G. B.

only the vertical component of the disturbing force, whereas it is the *horizontal component in the plane of the meridian* that affects the measures of arcs; at any one station, of course, a horizontal disturbance may exist without a vertical disturbance, and *vice versa*; but in a *system* of stations disturbances of the one kind must necessarily be accompanied by disturbances of the other kind. Indeed it is theoretically possible, from the vertical disturbances, supposed to be known *actually* to calculate the horizontal disturbances, and that without assuming anything beyond the law of universal gravitation. Actually to carry this out, would probably require observation to be made at stations more numerous than can be thought of, but the fact of its possibility shows how severe a check pendulum observations are capable of exercising on the results of geodetic observations."

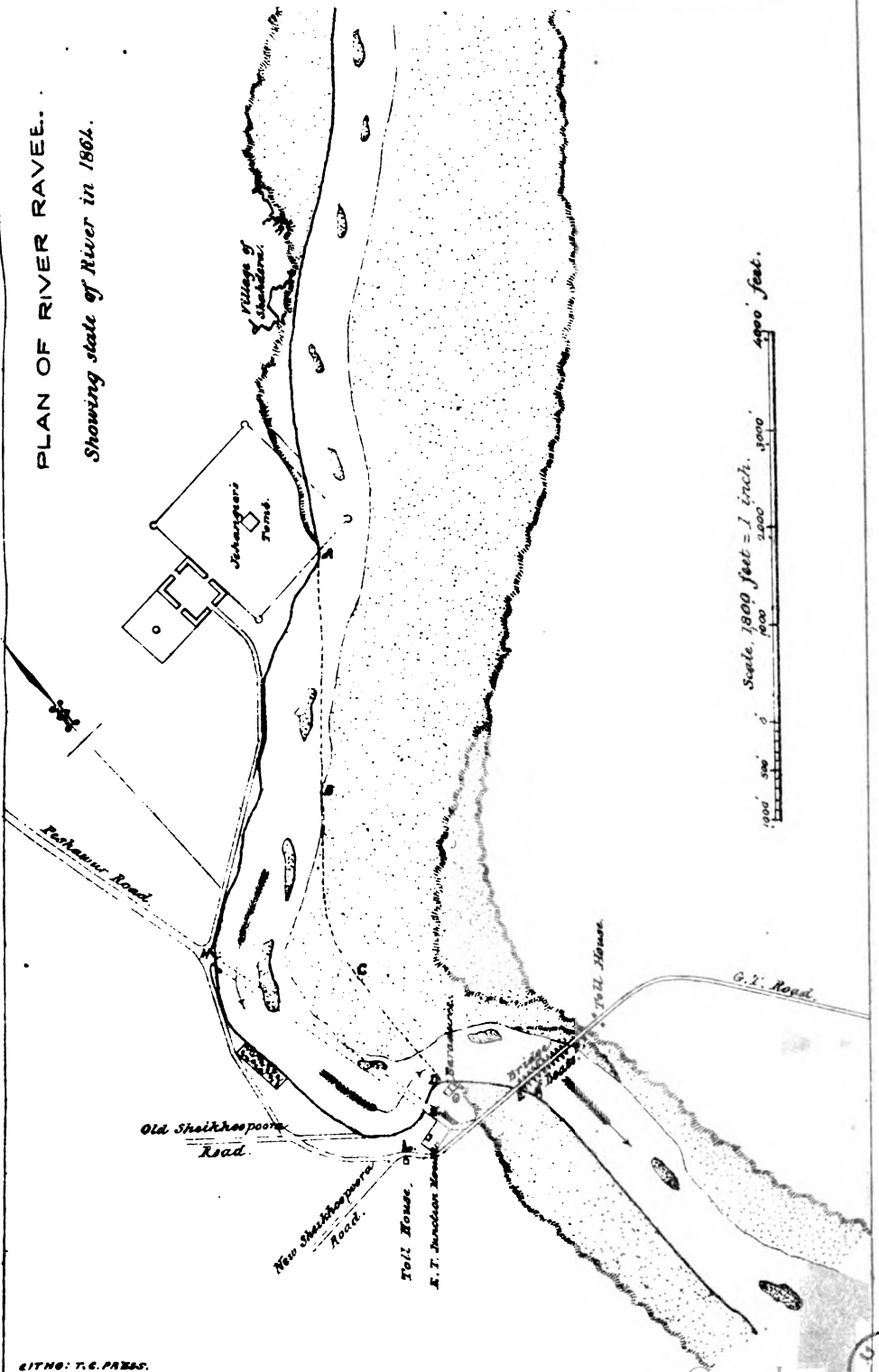
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ECHAMUTTEE BRIDGE.

PLAN OF RIVER RAVEE.

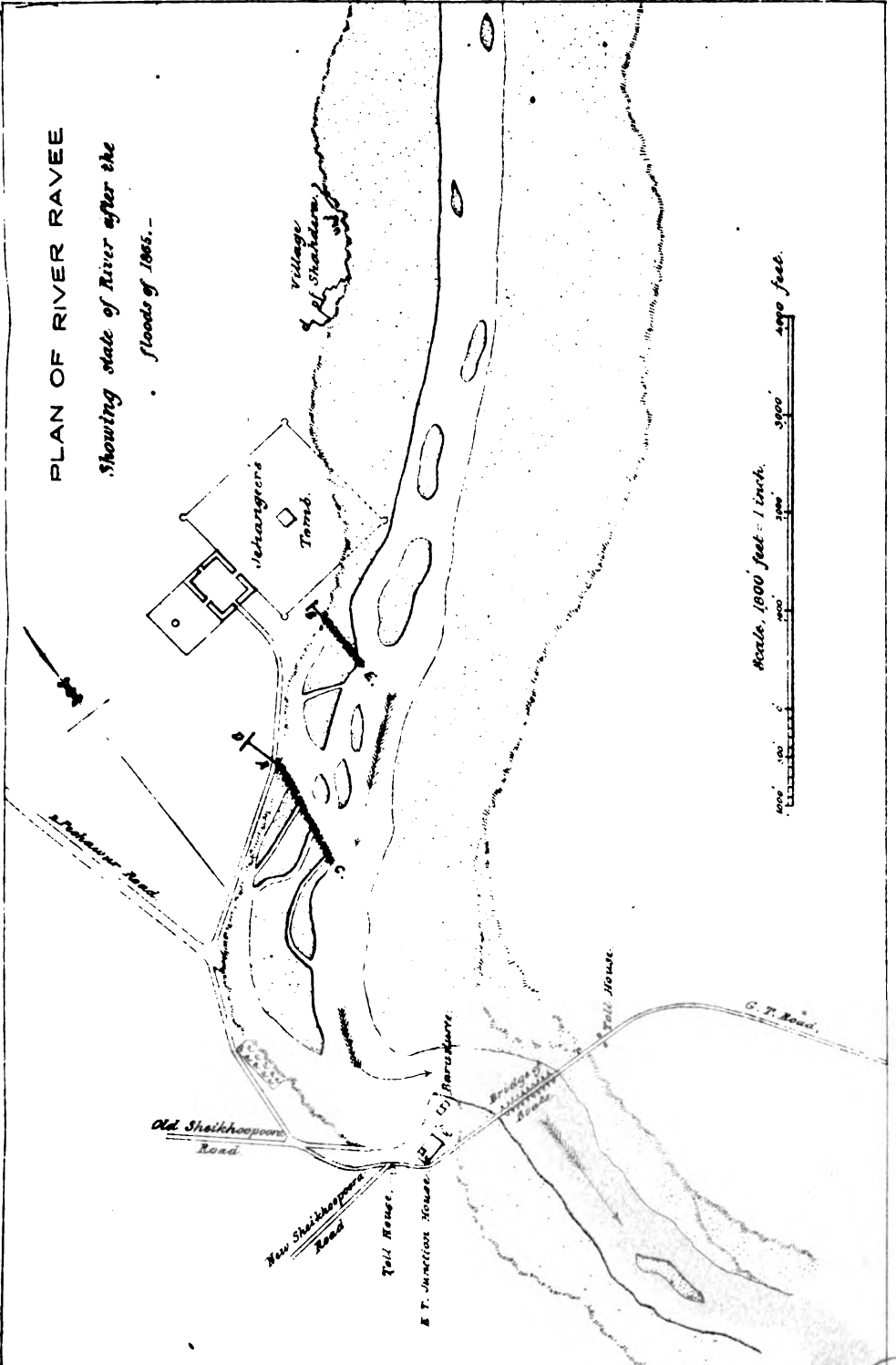
Showing state of River in 1864.



PLAN OF RIVER RAVEE

Showing state of River after the

Floods of 1865.



No. CXLIX.

ECHAMUTTEE IRON BRIDGE—EASTERN BENGAL RAILWAY.

THIS bridge, of which an Engraving is given in the Frontispiece, crosses the Echamuttee river, just below its separation from the Matabangah river. It has five spans of 80 feet each, being about 16 feet above the highest flood-level, and 42 feet above the water in the dry season. The girders are of wrought-iron, 8 feet deep, resting on cast-iron cylinders, which are sunk 33 feet below the bed of the river, by the pneumatic apparatus, invented by Mr. J. Hughes. The total height of each cylinder pier is 75 feet.

It may not be uninteresting to those unacquainted with the mode of sinking cast-iron cylinders by the pneumatic apparatus, to give a brief account of the method that was adopted in the construction of the bridge.

In the first place, a substantial timber stage is formed across the river, on piles driven securely into the bed. A road-way is then formed to carry two powerful travelling or Wellington cranes; and when these are erected, the lowermost cylinders, which are 7 feet in diameter and 6 feet long, weighing each three tons, are carried to their respective places. The bottom cylinder, having a knife-edge, readily cuts its way into the clayey ground. One or more cylinders are then placed and bolted on to the lower one, precaution being taken that the joints are made quite air-tight. Large boxes of iron weights, amounting in the aggregate, occasionally, to thirty tons, are then put on the top, which by shear dead weight force the cylinder down. This weight however, will not cause them to sink more than a few feet. The pneumatic apparatus then comes into action.

An air-tight cylinder, or "bell," as it is technically called, of wrought-iron, 7 feet in diameter, 9 feet long, and weighing upwards of nine tons, is fixed on to a length of the cast-iron cylinder pier to be sunk.

The "bell" is a cylinder fitted with a wrought-iron cover securely bolted to it. Through this cover two cast-iron chambers, called "air-locks," project $2\frac{1}{2}$ feet above the top of the cylinder, and 3 feet 9 inches below the cover: they are D shaped, in plan, with a sectional area of about 6 square feet.

The top of each air-lock is provided with a circular opening, 2 feet in diameter, and with a flap, working on a horizontal hinge, that serves to close it air-tight when the chamber is filled with compressed air.

The communication from the chamber to the inside of the cylinder is made through a rectangular opening, 2 feet by 3 feet 4 inches on the flat side of the chamber, and has an iron door, working on vertical hinges, to close it air-tight, when required.

The flap is analogous in its use to the lower gate of a canal lock, and the door answers a purpose corresponding to that of the upper gate.

These air-locks are placed upon opposite ends of the same diameter of the cylinder, and the lock doors open so as to communicate with opposite semi-cylinders.

Two light wrought-iron cranes are fixed inside the cylinder, the jibs of which sweep over the space between the air-locks, and extend into the chambers when the doors are open; so that a loaded bucket suspended from the crane may be deposited in the chamber, with the least amount of labor.

A chain passes over the sheaves of these cranes, and round the barrel of a windlass, worked by two handles in the ordinary way; and carries a loaded and empty bucket at opposite ends.

The air-locks are furnished with cocks, communicating from the interior of the cylinder to the chamber, and from the chamber to the atmosphere.

Of these, each air-lock has two sets; one set, accessible from the inside of the chamber, is designed for the use of the men passing into or out of the cylinder, with the view of giving them perfect command over their own movements and of freeing them from dependence upon the attention of others. The other set of cocks is used in passing buckets or materials through the air-locks. One cock, communicating between the chamber and the atmosphere, is placed in charge of a man inside the cylinder, who,

having closed the door, can then let off compressed air, and so pass a bucket from the in, to the out, side.

Another communicating from the interior of the cylinder to the chamber, is worked by a man outside, who has thus the power, on closing the flap, to fill the chamber with compressed air, and to pass a bucket from the out, to the in, side.

The bell is lighted by six strong glass lenses, 9 inches in diameter.

Compressed air is supplied to the cylinder pier by a double barrelled pump, 12 inches in diameter and 18 inches stroke, with double action patent valves, and driven by a 16 horse-power non-condensing engine. The air-supply pipe is 8 inches diameter, formed of iron lapwelded tubes, with hose pipes at the ends, so as to accomodate it to the various positions in which it may be required. The air pipe is terminated within the cylinder by a valve opening inwards, to obviate any accidents that might arise from the bursting of the pipe.

When the nature of the soil, at the bottom of the cylinder in process of sinking, is such as to prevent the ready exit of the water through the lower end of the pier, it is then forced up a pipe provided for this purpose, and allowed to escape just above the surrounding water level.

Lastly, a windlass is fixed on the outside for the purpose of hoisting the loaded buckets out of the air-locks, and for lowering the empty ones into them or the reverse. This completes the mechanical arrangements of the apparatus.—[*From the E. B. Railway Hand-Book.*]

No. CL.

IRRIGATION IN MYSORE.

(2nd Paper.)

Abridged from a Report by MAJOR R. H. SANKEY, R.E., Chief Engineer, Mysore.

I now beg to offer some observations on the anicuts, channels, and other works falling within the shaded portions of *Plate XXV*. And at the outset, as giving an idea of the capacity of the several rivers, and the vast field for improvement open to the Engineer, in utilizing the water which still escapes to the ocean, I would request an examination of the following table, of their maximum and ordinary monsoon discharges. This is not quite complete or reliable on all points, but much of it is so.

Mysore river systems.	Maximum flood discharges, in cubic feet per second.	Ordinary monsoon discharges, in cubic feet per second.
I. Kistna,	2,87,843	39,500
II. Palar,	40,000	3,000
III. Pennair,		
IV. Pennaur,		
V. Cauvery,	4,09,000	32,000
Totals for Mysore and Coorg,	7,87,243	74,500

This estimate does not include the Western coast rivers, which, so far as can be judged, are, with the exception of the Sheravutty or Gairsoppa river, altogether useless to Mysore as regards irrigation.

The provincial river works are much more numerous and extensive than would at first be supposed; as, in addition to the anicuts across such rivers as the Cauvery, Lutchmunteerth, Yegachy and Hemavutty, a large number of minor streams have been put under contribution, as shown by General Green, for feeding tanks, &c.; and as will further on be observed, in adverting to the many irrigation channels in the Cuddoor and Shemogah divisions.

The antiquity of these works, though necessarily of later date than the tanks, is still apparently very remote. The date A. D. 894 is for instance assigned to the great Tulkád anicut, which is the lowest down on the Cauvery, and said to have been constructed by one Madawa Row. Many more are said to belong to the sixteenth century, while others are evidently of an earlier date, and the constructors unknown. After observing that the anicuts had been much neglected under Tippoo Sultan's Government, we find Major Wilks remarking, "that the dreams which revealed to favored mortals the plans of these ingenious works, have each their appropriate legend, which is related with reverence, and received with implicit belief."

The only essentially new works, with the exception of Poorniah's channel—constructed in the first years of the present century, for the purpose of leading the sacred waters of the Cauvery to Mysore and Nungengode, and which will presently be adverted to—are comparatively of minor importance.

Excluding the minor channels drawn from rivers on the East of the Province, and which are mostly for feeding individual tanks, the following are the aggregate lengths of channels from the Western rivers, and the gross assessments levied:—

Divisions.	Aggregate length of channels.	Assessment.
	MILES.	RUPRES.
I. In the Mysore Division from the Cauvery, Lutchmunteerth, Shimsha and Noogoo,	461·5	2,40,250
II. In the Hassan Division from the Cauvery, Hemavutty, Yagachy, a branch of the latter river, and the Shimsha,	231·75	59,097
III. In the Cuddoor Division, from the Vadavutty, Beerunjee, and Keerisundisamudrah,	147·75	34,557
IV. In the Nuggur Division,	362·2	37,917
Total, ..	1,203·2	3,71,821

Rough stone anicuts at the heads of these channels, raise the water level to the required height, the lowest on the Cauvery being 7 feet, and the highest 25. The channels are for the most part supplied with regulating sluices at their heads, escapes for getting rid of flood water, silt sluices for creating a local scour to aid clearances, silt dams to arrest the deposit brought down by cross drainages, irrigation sluices for distribution to the fields, &c.

To enter upon any very detailed account of the various constructive features of each and all of these works as at present found to exist, would simply be a waste of time. I shall therefore confine myself to the most general remarks, pointing out particularly the faults which call for rectification.

As regards the anicuts, I do not think I can do better than quote from the report, sent up to Government in March 1864 with the Estimate for rebuilding the Sreeramadavara anicut across the Hemavutty river, and the work connected with which is now in hand.

"The dam as originally constructed, had a section similar to that shown in the margin A, and consisted of

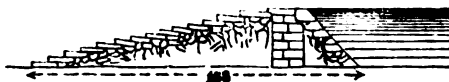
Section A.



a mass of rubble and large stones; the front casing being composed of stones (about $3\frac{1}{2}' \times 1\frac{1}{2}' \times 1'$), while the aprons consisted merely of large rough stone blocks (averaging $9' \times 3\frac{1}{2}' \times 2'$) laid in uneven courses; each stone projecting about one-third its length, beyond the one above it. All the interstices between the larger stones were filled in, with small and large rubble. From such portions as still exist, it is very clear that the first repairs were carried out with considerable skill and care; the stones were well shaped and laid in regular courses, each course projecting about $2\frac{1}{2}$ feet beyond the upper one.

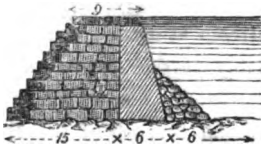
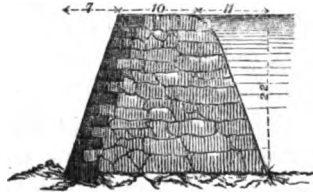
"The repairs during the years 1842-44-59-60, were carried out on a different plan. The general section of the dam was retained, but an attempt was made to divide the dam into three

Section B.



separate parts, viz., the body, the front slope and the rear apron (or as called by the natives, the *narraincuttoo*, *goodercuttoo* and the *soojicuttoo*). The body of the dam was composed of large stones, the largest of which were laid on the top as cap stones. The remaining portion of the dam was constructed with large and small blocks of stone."—See section B.

The above is a very fair sample of the section given by the natives to this kind of work, and shows the fallacy of trusting, as before observed, to the size and position of the material instead of to the homogeneity and cohesiveness of the work as a whole. Here, spite of the employment of the largest blocks and most skilful application of the material, the dam was breached five times between 1842 and 1863.

Muddoor Dam.*Sreeramadavara Dam.*

The remedy is, of course to do away with all loose material; as has been done in the reconstructed Muddoor Dam across the Shimsha, on the section given by Colonel Lawford, and carried out by Captain Johnson, and as now being adopted for the new Sreeramadavara anicut. (*See sections above.*)

The natives having invariably selected rocky sites for works of this kind here, there are not the difficulties of a sandy bed to be contended with; and, consequently, with a sound rock apron, and solid left wall of rubble stone in chunam, there is little to be feared. The chief defect, next to the instability of the native section, is unquestionably the leakiness of works so constructed, which allows all summer water to escape without rising into the channels. They are thus only practically in action, while the rivers are comparatively full.

General Green, while adhering to the native section, successfully corrected this latter peculiarity, by building an impervious brick in chunam

Section C.

face wall against the upper side of the anicut, section C. but a little consideration must show, that while the main

constructive defect is left unremedied, this will not suffice. The work still remains exposed to danger during periods of excessive flood. The mere blow of the overfall at such periods, will in time loosen the best constructed rubble-work (soojicuttoo); or a tree, as sometimes occurs, hanging on the work, may do the same. And, once the very smallest stone is washed

or torn out, its neighbour instantly follows, and shortly after the mighty flood concentrating with indescribable fury rushes into the gap, tears out the largest masses of stone and transports them as mere straws to any distance down the stream, leaving behind a clean breach. As regards the material of face walls, it is also evident that from the want of clay in the soil, the brick manufactured is very unsuitable for hydraulic works and is readily worn away by water. Crabs moreover drill holes through a wall of this kind.

With the object of decreasing the depth of water flowing over the anicut during flood, and also no doubt to throw the stream at other times directly into the channel heads, the natives invariably carried the work in a curved line, its general direction tending up stream. The length of the work is therefore ordinarily about double the actual breadth of the river. For other reasons also, we find that the crown of the work is at different levels, the part next the head sluice being almost invariably lower than the rest, to relieve the head of water against this work during flood.

All these features, dictated by experience as desirable with the peculiar native section, are so many defects, with the solid watertight work now adopted.

As regards the regulating or head-sluices they mostly consist of a series of rough stone posts (4 or 5 feet apart) with caps, and a parapet wall above, affording means of stopping the openings with rough baulks of timber, brushwood, &c. They fulfil their objects most imperfectly, and frequently the flood enters the channel almost uncontrolled, causing breaches, &c. This inability to regulate the stream, led the natives to place an escape in the channel bank close behind the head-sluice, to divert, as much as possible, the surplus flood which entered back again into the river. This latter work would not be absolutely essential with properly constructed head sluices. It is often a decided weakness.

The channels themselves, as may be premised, are rough trenches, carried round spurs and up to the head of the intercepting valleys, altogether in very tortuous lines to suit the undulations of the country along the river banks, from which, as before explained, they never withdraw to any great distance; partly on account of the rapid side slopes, and partly from defects of levels in original construction. The whole of the irrigation as well as the banks, lie invariably of course on the river side of the channel, and in these banks are placed the sluices (till lately frequently simple

open cuts through the bank itself, called by the natives *muddaways*), as also the escapes at intervals for surplus water.

On the upper side of the channel, the cross drainage from the adjoining high grounds would necessarily enter the channel quite uncontrolled, were it not for rough stone silt dams constructed across them. Where there is no great volume of water, these dams answer fairly, if kept well cleared in rear and in proper order; but with large drainages, they prove quite inefficient, allowing frequently so much silt to be carried into the channels as to choke them entirely and prevent onward flow, thus depriving the fields of all water supply till the obstruction is removed. Sometimes also the cross drainage coming down in unwonted volume, breaches the opposite bank of the channel and brings about the same result. Aqueducts are quite a modern introduction.

In addition to these works, there are solidly constructed outlets at low levels [locally termed *biddigundies*] for scouring out accumulated silt at convenient points; but while an undoubted source of weakness, it is not at all clear that they hold out any adequately compensating advantages.

Lastly, there are the escapes for surplus water, which, being rough stone works precisely similar in character to tank *codies*, call for no special description. It is almost needless to say, that in their present form they are inherently weak.

In addition to the numerous constructive defects of these various adjuncts to the channels, there are others of quite as serious a character, if indeed not more so. I allude to channel offences on the part of the ryots cultivating under them, and whom it is only natural to suppose would be somewhat interested in the preservation of the works, upon which almost their very existence depends. The main defect here has been produced by the system of permitting irrigation direct from the main or trunk canal. Ryots with the smallest patches of ground to irrigate, deliberately cut through the channel bank, and not only took often fifty times the quantity of water actually required, but left an opening, which, unattended to in flood time, became an open breach, stopping all irrigation and entailing great outlay on the State.

This defect has, it is true, been to a considerable extent remedied by the construction of masonry sluices by this Department, and the practice has been followed by the lately constituted Conservancy establishment. Still, however, the direct irrigation from the main channel goes on, and is the

fruitful source of that reckless waste which not only interferes seriously with the profits of the State, but encourages a spirit of almost lawless independence on the part of the cultivators.

As showing the effect upon the revenue, I beg here to append an abstract of the *actual* yield in revenue, compared with what it *should* be, under the measured discharge of the channels in the Mysore division :—

	Length of channels in miles.	Measured discharge in cubic ft. per second.	Capable of irrigating at 40 acres per cubic ft. per sec.	Assessment at 7½ Rs. per acre.	Actual revenue as realised in 1864-65.	Yearly loss sustained by the State.	
			Acres	Rupees	Rupees	Rupees	
	461.5	2,677.5	107,100	808,250	240,250	569,000	
Averages per cubic foot of discharge per second,	..	1	40	300	90	210	

To remove any doubt as to the moderate hypothesis upon which this calculation is based, I may observe that while I have only assumed that one cubic foot of water per second is capable of irrigating 40 acres of rice, it would appear by late experiments of the Madras Government, that 44 acres was the result, without taking into account tail water. On the Eastern and Western Jumna canals, 90 acres, it seems, are irrigated by the same quantity; and the Consulting Engineer of the Madras Irrigation Company, in lately fixing the water-charge, advocated the standard of 144 acres per cubic foot of discharge (i. e., 4000 cubic yards of water for bringing an acre of rice to maturity).

The direct inference is, that from the numerous constructive defects, and the wasteful habits into which the ryots, almost without check, have been allowed to fall, no less than rupees 5,68,000 are lost yearly to the State. I have not the gauged delivery of the channels in the Hassan division, but judging simply from the length, 232 miles, I must conclude that the loss would be half as much again, making in the gross for the Ashtagram river channels [rupees 5,68,000 + 2,81,500 = 8,44,500] a sacrifice of nearly 8½ lakhs per annum. The Oudoor and Shemogah division channels, though doubtless equally defective in their way, have not been sufficiently investigated to warrant more than general conclusions being drawn. In making the above statement, my only desire is to bring clearly

under view the wide field open to improvement, by adopting such alterations in the works themselves as science may dictate, and by putting a stop to all unnecessary waste of water. But in this, as in the case of the tanks, extensive enquiry appears requisite, to determine the general principles of engineering, as well as legislative, action.

It will here perhaps suffice to indicate the general direction which, it appears desirable that improvement in the works should take.

The first and most important point, is the substitution of solid water-tight anicuts for the old native section, as before adverted to. This change, already initiated in the reconstruction of the Muddoor anicut under Colonel Lawford, and being now extended to the Sreeramadavara dam, would, I have little doubt by the simple force of circumstances and effluxion of time, have extended itself gradually to all the old works. But with the present determination of Government to deal thoroughly with all irrigation works, it appears desirable to secure a definite recognition of the principle. I may therefore be excused some further observations on the point.

Leaving entirely out of account the distress and loss to the village communities dependent on these river works, I cannot but think that the certain and frequent failure in weirs so constructed, makes their restoration on the same plan extremely undesirable, if on no other ground than their being financially unproductive. The substitution of the new solid anicuts advocated, would cost, it is true, at starting, about three times as much; but in the *first* place the expenditure is once and for ever; and in the *second*, a weir of this kind, does three and four times the work of the other. With the leaky anicuts and the excessive waste of water now going on, a second and third anicut is always required lower down, to pick up and redistribute the water; which percolates through the upper dam, or is thrown back unutilized from the channels into the river. Nothing of this kind would be required with works constructed on proper principles, and consequently, several existing anicuts could be dispensed with, with manifest advantage financially and otherwise.

The channels drawn from these works might moreover be extended immensely in length, opening up wider sheets of cultivation than has yet been practicable. Above all, from the new anicuts being impervious, every drop of water below their crowns would be passed down the channels, thus affording a certain and constant supply at all times in the dry season, and

allowing such valuable crops as sugar-cane and mulberry, to be raised in addition to rice.

The second point, which is almost of equal importance, is the prevention of irrigation direct from the channels before alluded to. The cure here is to isolate entirely the main channel, placing it under scientific control, and allowing the distribution of water to take place only at certain intervals into secondary channels, from which alone the ryots should be allowed to draw their supplies—to adapt in fact the *rajbuha* system of the northern canals, to the different requirements of Mysore. The chief distributory or *rajbuha*, would of course here run everywhere alongside of the main channel on the river side; and delivery into it would be made by a separate and responsible agency, the main channel being fenced off and otherwise protected from all interference, precisely in the same manner as the railway.

As regards the other essential changes, such as substituting proper regulating sluices to all channel heads, providing aqueducts or other means for passing objectionable cross drainages, &c., the necessity for all these improved arrangements are too well recognized to call for any special remark. They have already been initiated and should now be adopted systematically.

I shall only allude to one more general principle, which might with advantage obtain definite recognition. The defective construction of existing anicuts and channels, have led to the water passed down, being wholly expended in direct irrigation. The only instances to the contrary, with which I am acquainted, are the great Chickdevasagur and Muddoor channels, which, in addition to carrying water for direct irrigation, pass down during freshes sufficient extra water for feeding terminal tanks. With shutters on the new description of anicut, and an increased section and bank to the channels, large quantities of surplus water could no doubt be frequently passed down during moderate freshes, and numerous storage reservoirs supplied at the end of the improved channels.

It may, I think, be safely pronounced, that all the existing Mysore channels are improvable to an almost unlimited extent as indicated above, and that in the legitimate development of these works, the most ample and profitable employment of capital may at present be found, without seeking for essentially new undertakings. The materials are to a great extent on the spot, and the population is both fixed, and from time immemorial, accustomed to rice cultivation.

There is, I believe, only one channel in Mysore, which does not appear

to be improvable to any extent. I allude to Poorniah's nullah, before adverted to, which was undertaken in the "hope of introducing into a Hindoo town the holy stream of the Cauvery," and which, even if finished to the full original intent, would have conveyed but an insignificant stream, with "little perceptible motion." From the head at Tippoor Anicut, the total length is some 78 miles, and the excavations are on the vastest scale—a portion of the latter, near the town of Mysore, being 100 feet in depth through solid rock. Failure of funds or other cause, put an end to this gigantic and profitless religious conception.

In quitting this portion of the subject, I would beg briefly to note the number and extent of channels under the Hemavutty and other rivers in Chickmugloor and Cuddoor Talooks, including the minor ones in the Shemogah and Cuddoor Divisions.

Number of anicuts,	..	..	..	..	..	314
„ channels,	..	..	..	..	..	444
Gross length of ditto,	..	..	..	..	..	miles, 501
Gross revenue,	..	..	..	..	..	Ra. 72,474

It remains only to review briefly the chief works under this head, lately completed or now under execution, before stating what projects it is proposed to bring forward in next Budget.

The chief completed work is the reconstruction of the Muddoor anicut, across the Shimsha river, and 10 miles north of a town of the same name. For section of the work, *see* page 215. The dam is 900 feet long, and raises the water level about 14 feet. It is capped with granite slabs and backed with dressed stone. The channel leading off from the right flank of the work [there is no left bank channel] feeds 8 tanks, including the large Cusbah tank of Muddoor, under which the present assessment is rupees 7,190 per annum. The scheme has by no means as yet received its proper development, but in a report previously submitted to the Commissioner (dated 3rd October, 1865), I was enabled to show, that while the total outlay, all included, should not exceed rupees 92,000, the actual returns, after deducting rupees 4,000 for repairs, ought to amount annually to rupees 41,540, or 45 per cent. on the outlay.

A similar project now in hand for reconstructing the Sreeramadavara anicut across the Hemavatty, near Nursipoor, in the Hassan division, is estimated, for anicut and head sluices alone, at rupees 1,81,000. The length of the dam is over 1,000 feet, and its average height 22 feet—rock

bottom as in Muddoor. (For section, *see* page 215.) The extension of the old channels has not as yet been estimated for in detail, but it was roughly calculated that their aggregate length would be 80 miles, with a delivery of 400 cubic feet of water per second, and that the total cost of the improvements, including the anicut, would be rupees 8,50,000. Allowing 40 acres of rice land to each cubic foot of discharge, and 6 rupees per acre as assessment, after deducting repair charges, the net receipts would be rupees 96,000 per annum, or over 27 per cent. on prime outlay. It will, no doubt, take some years before this project is fairly worked out, but much of the material is already prepared.

On the great Chickdevasagur channel, two large aqueducts, the Anchayhulla and Lokani, are now in hand, and many other works of restoration and improvement have been completed both in the Mysore and Hassan divisions, with some of still less importance in the Bangalore, Cuddoor, and Shemogah divisions; but they do not call for any special mention here.

As regards the works to be brought forward in this Budget, there is only one which it seems requisite to notice, namely, the project for reconstructing the Marchully anicut, across the Lutchmenteerth river, the old work having been breached in 1863. The new dam on the solid principle will be built above the present site, using, however, the material of the old work. Its length will be 268 feet, raising the level some 12 feet, costing in all rupees 23,889, in which is included rupees 6,000 for a new right bank channel. The returns from this project should be quite as favorable as the Sreeramadavara dam.

It would of course be impossible, with the present information on the subject, to hazard more than a guess at the probable cost of improving the Mysore river works, on the principles now advocated; judging, however, from the work already accomplished and estimated, I should suppose, it would not exceed 30 lakhs of rupees. With the 90 lakhs before approximately estimated for the Tanks, the total would thus be £1,200,000. On the supposition, however, as pointed out by the Commissioner, that the agriculturists themselves would bear a considerable portion of the burthen, not more than £800,000, or at the outside a million pounds sterling, would have to be furnished by the State, in order to accomplish this great, and, as I submit, truly national work.

Only a short time ago, I believe, the amount required (one million) was

actually in hand as surplus deposit, but although a considerable portion has been absorbed in paying the Rajah's debts and investing funds for His Highness's family, there is still a fair sum over; and so elastic has the revenue proved, that last year there were nearly 8 lakhs of surplus after meeting all charges.

The proposal which, with the utmost deference, I would venture to submit for the consideration of His Excellency the Governor General in Council, is, that accepting one million as the probable outlay required for bringing all existing irrigation works up to standard, the actual execution be spread over 10 years; giving in fact an average outlay of 10 lakhs per annum (over and above the normal departmental Budget), which should either be met from existing surplus funds, or by small loans from time to time, as occasion may require.

The raising of wet crops is what the nation can do best and cheapest, besides being the avocation to which all its instincts have tended from time immemorial; and, as I have sought to show, that in the repair and development of existing works of irrigation lies the true method of obviating the horrors of drought and famine, it is only reasonable to conclude, that, while following the dictates of humanity, the outlay thus rendered necessary, happily under the peculiar physical condition of Mysore must at the same time prove by far the most profitable investment that could be made. Inadequately, therefore, as I have brought this vitally important question under notice, I trust that it may command the fullest and most favorable consideration.

I have hardly adverted to the subject of actually new irrigation works, for reasons previously explained. This should, however, not by any means be supposed to indicate either my indifference to such works, or my holding an opinion as to their inadvisability when the means admit and proper opportunity presents itself.

An examination of the Table given in page 212, shows at once the great quantity of water escaping to the ocean, and there can be no question that a large proportion of this could be turned to account in Mysore, without in the least interfering with any vested interests in Madras. This is a subject which was disposed of with great ability in March, 1807, by the then Acting Resident, Major M. Wilks, and the Surveyor-General, Captain C. Mackenzie of the Engineers (*see* their reports, dated respectively 22nd and 21st March, reprinted 1863); and by all acquainted with the subject, it will

I think be unquestioned that, in addition to storage (or rather intercepting) reservoirs at the head waters of some of the rivers, the great streams of the Toonga, Buddra, Cubbany, and others hitherto untouched, might yet be utilized to almost any extent. With the extensive reconstruction of existing works in the next 10 years which I have advocated, and the completion of the great net-work of communications already well advanced, the revenue will, it can hardly be doubted by that time, have received an impetus which will not only render the construction of great new works of irrigation, a matter of comparative ease, but perhaps as great a necessity as the repair and development of existing works is at this moment.

R. H. S.

No. CLI.

DE LISLE'S CLINOMETER.

Reports on the results obtained by the use of DE LISLE'S Clinometer for Tracing Hill Roads.

Description of the Instrument.—The drawing represents the first instrument made: it is in two parts, separating at the dotted line in *Fig. 2*.

The lower part can be fitted on in three positions.

1st.—For packing in its case; with the weight *e*, to the left of the mirror.

2nd.—For descending slopes; with the arc and weight *e*, behind the mirror.

3rd.—For ascending slopes; with the arc and weight *e*, in front of the mirror.

In the instruments now supplied the lower part does not draw off, but revolves on the axis of the mirror, and is retained in the required position by a small spring.

The semi-circular arc has two radial bars, one light *C*, the other *f* loaded with a weight *e*. For level, set the bar *f* against the stop *g*, and bring the light bar *C*, home in the groove formed for its reception in the weight *e*, see *Fig. 1*. For a slope of 1 in 50, leave *f* against *g*, and move the light bar *C* against the stop *h*, as shown by dotted lines in *Fig. 1*.

For any other slope, leave the bar *C* against the stop *h*, and set the bevelled edge of bar *f* to the required division on the graduated limb of the arc; see *Fig. 8*, where the instrument is set to 1 in 20.

In practice it should be remembered, that a flatter slope should be used in tracing than that intended for the finished road, in order to allow for

the increased slope due to flattening the curves of the line; thus for a road at 1 in 20, the instrument should be set to 1 in 21 or 22, according to the nature of the ground.

In using the instrument, a levelling staff with sliding vane is convenient. The vane on the staff must be adjusted to the height of the observer's eye. The observer stands at the initial point of the trace and sends an assistant forward with the staff to any convenient distance; the observer then holds the instrument up by the ring, and makes his assistant move the staff up or down the slope of the hill, until he gets the reflection of the pupil of his eye in the mirror and the vane to coincide, as indicated in *Fig. 2*. A peg is then driven in at the foot of the staff. The observer moves forward to this peg and sends his assistant on for the next station, and so on.

In taking cross sections of streams, the instrument should be adjusted for level, and the vane on the staff moved up or down at each station until the requisite coincidence is obtained. The level is then read off on the staff and entered in the usual manner.

In windy weather, it may be convenient to suspend the instrument in a wooden box, with sight holes. The box should be mounted on a light staff, and the vane on the levelling staff must be set to the height of the mirror.

When the line is pegged out, and considered satisfactory, a gauge path should be cut, and the line surveyed either by theodolite or spirit level for the plans and estimates.

The great advantage of this instrument, will be found on Ghaut lines along steep cliffs, where a theodolite could not be taken without much risk of injury. It will also save the tedious labor of setting up and levelling a theodolite at numerous successive stations.

The ingenious arrangement of the arc and radial bars is the invention of Mr. A. Cooke, of Messrs. T. Cooke and Sons, 81, Southampton Street, Strand, London.

From LIEUT. DUCAT, *Executive Engineer, Northern Konkan, to* LIEUT.-COLONEL DE LISLE.

I beg to return the clinometer you lent me, and to forward a report on it by Lieut. Osborn, R.E.

DE LISLE'S OLINOMETER.

A new Instrument for tracing roads.

Fig. 1.

Instrument in position for packing in case.

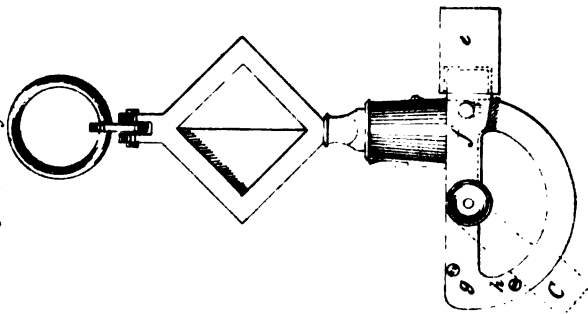


Fig. 2.

Front view of instrument adjusted for descending slope.

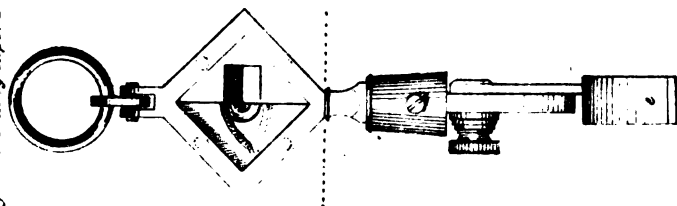


Fig. 3.

Side view of instrument adjusted for laying off an ascending slope of 1 in 20.

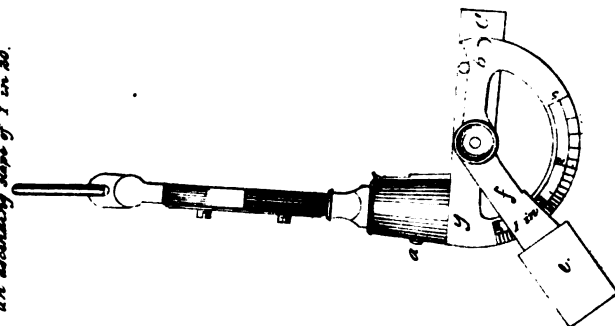


Fig. 4.

Side view of instrument adjusted for laying off a descending slope of 1 in 10, mens adjusted for ascending slope.

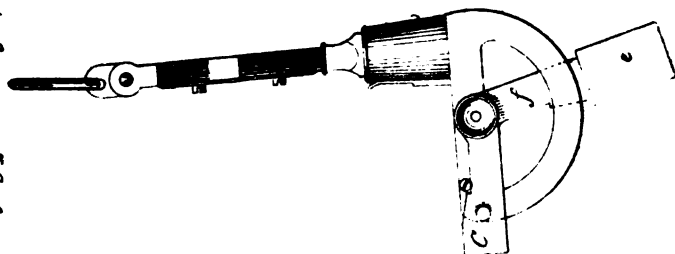
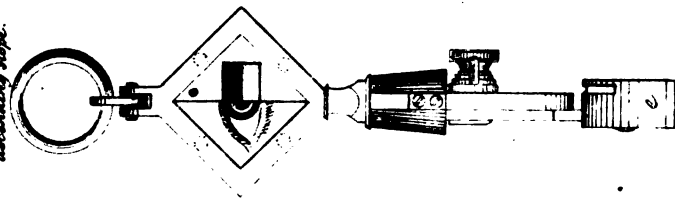


Fig. 5.

Front view of instrument adjusted for laying off a descending slope of 1 in 10, mens adjusted for ascending slope.



I have seen the country over which Mr. Osborn has been working, and can testify both to the very difficult nature of the ground and to the highly satisfactory results obtained by means of your clinometer.

In a hilly country like the Konkan, this clinometer is of inestimable value, and I hope after Mr. Osborn's report, that Government will be pleased to furnish at least one for the use of this office.

Lieut. Osborn's Report.

The Ghauts over which I have used the instrument lie between the villages of Ghowk and Warsace; the Khind, through which I propose to carry the road joining those two places, being just under the hill fort of Maneckghur. When I first began to use the instrument I was not sufficiently acquainted with the difficulties that might arise from the nature of the ground, and thought that sufficient accuracy would be attained by merely taking the inclination of the slope between my own eye and that of another man whose height was the same. This answered sufficiently well as long as the slope of the hill was not great, nor the jungle dense, but when I came to more difficult ground, serious errors arose from the impossibility of standing erect. Accordingly, I prepared two staves made of strong and straight bamboos. Each staff was about 7 feet long and cut off square at the bottom, so that it might not sink into the earth. To the staff I myself carried, was firmly fixed a small bamboo about 3 feet long so as to form a cross, and at such a height that, resting my right hand (on the fore-finger of which I carried the instrument) on one end of the cross piece, and holding the other end in my left to keep the staff perpendicular and often to form a support, I could see comfortably into the reflecting glass. To the other staff I attached a cross piece only one foot long, but at such a distance from the lower end of the staff, that when I placed both staves side by side on level ground and held the clinometer in the working position, the short stick was exactly the same height from the ground as the mirror of the instrument.

This second staff was carried by a native, whose only instructions were to hold the staff perpendicular on any given point; then setting the instrument to the required slope and moving my own staff till I brought into one line my eye, its reflection, and the cross piece of the second staff, I had only to make a mark on the ground where I held my staff; a line joining the two points on which the staves were held would of course be

parallel to the line joining my eye and its reflection, and therefore at the required slope to the horizon. By this means I found that I could work with the greatest accuracy and very quickly, driving in pegs at each point where the staff rested. These served both to mark out the line and as points on which the other staff should be held. With this instrument I marked out the line for a trial-path, putting in pegs enough for the men to work from, at the rate of a mile in about 6 hours, through very thick jungle and across very steep slopes; in open country of course it is far quicker work. As to the accuracy obtained, the error in a slope of 1 in 33 for a distance of 480 yards was 1·5 inches; I should state that this was in thick jungle where it was impossible to see more than 30 or 40 feet, and the slope of the hill was very steep and difficult to stand on.

It is impossible to over estimate the assistance afforded me by this instrument. A trial-path which would have taken me weeks to lay off with the chain and level, (inasmuch as I should have had to cut down the jungle and dig regular platforms on which to place the instrument,) was laid off in a few days and with, I believe, quite as great accuracy. The only mistakes that can arise, are from the accidental slipping of one of the cross pieces and from the moving of either of the arms of the instrument. It is only requisite to take a glance at the instrument while the hand rests on the cross piece to ensure its accuracy. In working up hill it would add to the ease with which this is done, if both sides of the arc were graduated. I find that the mirror is a little affected by the heat, the coating of quicksilver being injured, but I have used the instrument mostly in the very hottest part of the day: probably neither the morning nor evening sun would be strong enough to affect it so. I can only add that the ease and quickness with which the instrument is used, have made the laying out of the trial-path a pleasure to me, and I should feel much like *Pegasus* deprived of his wings, had I to do another trial-path of the same kind with the level and chain, instead of the clinometer.

From LIEUT. J. BROWNE, R.E., *Executive Engineer, Kangra Roads Division, Punjab.*

I have several times tried the instrument in the most difficult ground I could select, comparing the results obtained with the pegs laid out

on the hill side with a spirit level. As the instrument would have saved me a vast deal of labor and trouble, I did my best to obtain good results from it, but found it quite untrustworthy. In laying out half-a-mile of slope at 1 in 20, the instrument differed from the spirit level 32 feet; and I therefore cannot recommend it for road making, except of the very roughest description. A gunner's quadrant tied to a stick is equally portable, and gives far better results, differing only $2\frac{1}{2}$ feet in the same distance from the spirit level. I do not think the instrument will ever be found to be of any practical use.

From the Executive Engineer, Salt Range Division, Punjab.

The instrument answers very well, but in the opinion of the undersigned, is not so convenient as "Bow's Gradient Indicator," which is merely a spirit level in a wooden case, the latter 6 inches long, $1\frac{1}{2}$ inches deep, and 1 inch wide; at the end there is a piece of window glass protecting cross wires suited to several gradients, and at the other end a piece of black wood pierced with upper and lower eye holes.

Inside the case, fixed at an angle, there is a mirror which reflects the state of the spirit level. This simple instrument can either be fixed on a tripod, held in the hand like a telescope, or pressed against an alpenstock at the same height as the poleman's vane. It has this great advantage over the instrument under reference, that it is little influenced by wind.

The indicator can be carried in a holster attached to the surveyor's waist belt, and is ready for application without any preliminary adjustment.

From the Superintending Engineer, Assam Circle.—Cherrapoonjee, 29th September, 1866.

I forward Lieutenant Hills', R.E., report on the hill tracing instrument received.

I have tried the instrument myself, and think it handy and useful for Military reconnoissance and marking out trial lines; but for accurate tracing of roads on a selected line through the hills, I prefer the common clinometer.

A cross wire to the mirror frame, and the doubling the size of the instru-

ment, as suggested by Lieutenant Hills, R.E.; also the addition of a tripod stand, would be improvements.

Lieut. Hills' Report.

I have not had many opportunities of testing the instrument, but from the little experience I have had in working it, I consider it an ingenious and tolerably handy instrument, and well adapted to determine, if a certain point on the face of a hill is accessible at a certain gradient, or what gradient is required to reach that point.

I do not, however, consider that it possesses any peculiar advantage over the ordinary clinometer in use in hill road making, and I question if one could work as accurately with it as with the clinometer.

I think the instrument would be improved if it had a hair or wire attached to the diagonal of the mirror part, and if it were twice its present size.

From STANLEY ALEXANDER, Esq., Assistant Engineer, Bundelcund Road Division.—Nowgong, the 24th November, 1866.

The clinometer used by me on the Nugaha Ghaut, I found to be most useful, in that it saved me a great amount of labor in tracing the line down the hill side. Having set the instrument to the required decline, no further trouble was entailed than great care in its use to avoid going astray. Not having a proper staff with cross vane I cut a light rod to a length corresponding to the height of my eye. The bark peeled off the head of this made it sufficiently conspicuous, and it was moved up or down the hill, at 50 feet distance, till the proper position had been attained. One great advantage consists in the facility of altering the gradient to suit the nature of the hill.

The instrument however appears to me to be too light for the work. The ground on which I used it was very rocky, and consequently my hand was not very steady. In fact, I found it necessary to carry a staff, which I held simply in order to steady the instrument. The slightest wind also affects it, and renders work impossible during its continuance. I imagine that the box recommended to be used during wind would not answer; as if the apertures were too large, the wind would get in, and if small, the instrument, delicately suspended, would be liable to turn, and consequently the mirror would not face the eye. I fancy if it

were made about three times as heavy as it now is the objections would be removed in a great measure, especially the vibration caused by the unsteadiness of the hand on difficult ground; I should also recommend that the body of the instrument be suspended from the ring for the finger by a small chain about an inch in length. This would render it more accurate.

Also that the diamond cut in the brass be bisected horizontally by a strong wire to guide the eye.

Under favorable circumstances with good smooth ground, and no wind, I do not see why a very fair degree of accuracy could not be got out of the instrument. Nothing could be better for tracing out a line on steep hill sides, when 50 feet cannot be seen and the planting of a theodolite among the rocks is a matter of no small difficulty.

From CAPTAIN F. W. PEILE, R.E., Superintending Engineer, 1st Circle, N. W. Provinces.—12th January, 1867.

The line of road, 16 miles in length, from Chokarata to the valley of the Oumlao river, lately surveyed with the theodolite, coincides very nearly with the trial line taken out by Lieutenant Bisset in June last, with the clinometer sent to me to be reported on. This test was necessary to ascertain what dependence could be placed on the accuracy of the instrument.

It appears to me that for running trial lines in hilly country, before engaging in more perfect instrumental observations, and for filling in details of lines of which the courses have already been determined, the instrument is well adapted.

Some practice is required before an observer will be able to work with any degree of accuracy with the clinometer. In holding the instrument close to the eye, the reflection of the pupil in the mirror is large, whilst the vane on the levelling staff at 100 feet distance only appears very small; and if care is not taken in every observation to bring the vane and the centre of the pupil into range, considerable errors will result.

On the whole, from its portability and the rapidity with which observations may be made, even on very bad ground, I consider the instrument valuable, and would recommend its use wherever trial lines have to be run for projected hill roads.

I do not, however, think it would be safe to place it in the hands of

an ordinary Native Surveyor, as the moveable limb which adjusts the instrument to a certain gradient, must be seen to at every sight taken, lest it should have moved. Moreover, the whole of the instrument revolves, its reversal determining the ascending from the descending gradient. For use then by a native, I think the American A level, which can be fixed in adjustment, and be used without any exercise of thought—although not nearly so portable—would be preferable.

No. CLII.

TREE SPURS ON THE RAVEE.

Memorandum on Tree Spurs, constructed on the River Ravee, at Lahore.
 BY LALLA KUNHYA LALL, Exec. Engineer, P. W. Dept., Punjab.

TREE spurs having proved very effective in stopping the encroachments of the river Ravee at Lahore, and also reclaiming a vast extent of land encroached upon by the river, the following account of the mode of constructing them, will, it is thought, be of use in similar situations elsewhere.

Since the year 1855, the river Ravee has had a tendency towards its right bank, between the bridge-of-boats and the Emperor Jehangeer's tomb, at Lahore; and during the years 1863 and 1864, it took such a set towards it, that a strip of land measuring about 6,000 feet in length, and 1,500 feet on an average in breadth, was cut away from the right bank, and upwards of 3,000 feet in length of the Peshawur road, which extended to the gate of the Baraduree at the head of the bridge-of-boats, was washed away.

This will be understood better from *Plate XXXIII.*, in which the dotted line ABCD, represents the right bank of the river previous to 1855; EF, the bridge-of-boats; G, the Baraduree at its head; and HK, the Peshawur road, as it *was* previous to 1855. During the years 1855 to 1864, the river cut away its right bank so much, that it encroached some 2 to 3000 feet behind the Baraduree, completely washed away the Peshawur road from H to K, and had a tendency to cut a passage for itself straight through the road at L, leaving the Baraduree on its left bank.

To stop this tendency of the river, and to reclaim the land encroached upon, the Punjab Government in 1865, directed tree spurs to be put up

from the right bank (between the bridge-of-boats and Jehangeer's tomb) across the river, so as to check its course, and protect the bank, threatened. These spurs were constructed in the following manner:—

A place on the right bank marked A [*Plate XXXIV.*], (where the ground was firm and somewhat elevated), having been selected as the starting point of the first spur, a strong moonj rope, 1,250 feet long, 10 inches in circumference, and of a strong tight twist, was stretched into the river, on poles, along the line AC; the end C, being secured to a heavy crib anchor, 10' × 10' × 10'; and the end A, which stretched as far as D, 250 feet inland, was firmly fastened to a beam of deodar wood, about 14' × 8" × 8", buried horizontally in the ground at a depth of 5 feet, and placed at right angles to the direction of the rope.

The poles on which the rope was stretched, were driven from 4 to 6 feet deep into the bed of the river, and were from 10 to 20 feet apart. The rope was fastened to the heads of these poles, and was further secured in its position by anchors,* each 6' × 6' × 6' placed at every 20 feet; and when it was thus firmly secured in its position, trees were fastened to it at short intervals, with moonj ropes passing through holes made in their butts. Large trees were placed where the stream was deep and rapid, and small ones near the bank, where the water was shallow.

After the spur was thus got in position, numbers of other trees were fastened to the main rope, so closely together, as to form a dense line of considerable substance, which had the appearance shown in the rough sketches, of which *Fig. 1, Plate XXXV.*, is an enlarged plan of part of the spur; *Fig. 2*, its longitudinal elevation; and *Fig. 3*, its cross section; A, A, &c., represent anchors; the firm arrow lines show current of river before the spur was constructed; dotted arrow lines, after the spur was put up.

After the above spur was completed, a second spur 600 feet long was constructed at BE, in exactly the same manner as the first, to check the course of the river above, and thereby help the lower spur. The ends of the main cables of these spurs, near their starting points, were thoroughly secured, so as to prevent their being turned by the river.

* The anchors are similar to those used for anchoring the boats of a bridge-of-boats, but somewhat heavier; and are made of bullees and net-work of moonj ropes, filled with broken bricks, and masses of pukka masonry. They are fastened to the main rope, with a well-twisted moonj rope of 6 inches circumference. 100 feet of such rope is used for each anchor.

PLAN OF TREE SPURS ON THE RAVEE, AT LAHORE.

Fig. 1.

PLAN.

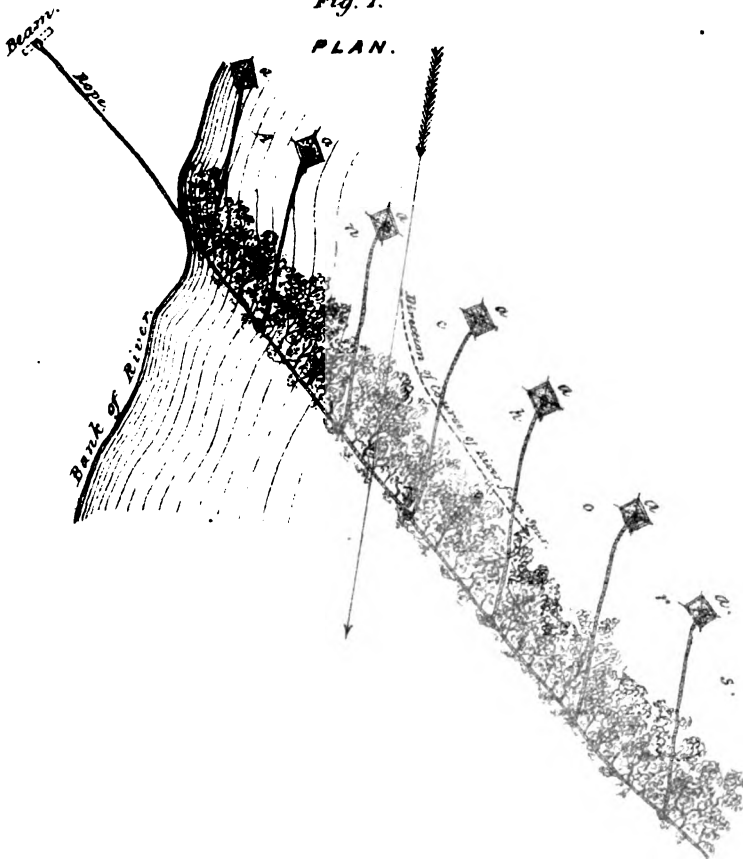


Fig. 2.

ELEVATION.



Fig. 3.

CROSS SECTION.



When these spurs were started, the river flowed immediately below the right bank; but as the spurs were pushed into the river, and lengthened from time to time, the current below them, gradually ceased, depositing large quantities of silt, and forming shoals, which afterwards turned into large sand-banks [*Plate XXXIV. and XXXVI.*], and the final result is, the complete turn which the river has taken in its course, as shown in *Plate XXXVII.*

These spurs affected the river not only below them, but also for a long distance above. The current meeting with a check in its course at the spurs, was dammed back for a long distance, and the bed of the river was silted up, both *above* and *below* the spurs.

The above spurs, after having been put up, required constant repairs and attention. Every flood that came down the river, turned and twisted their ends which projected into the river, and caused gaps in them in certain places, which were repaired immediately after the flood went down a little; and the whole of the spurs restored to their original state in about a week after every flood, so as to resist the river more effectually in the next floods.

The river has been checked in its course in this way since April 1865, and the right bank, which was threatened in 1864, has now been completely protected. Also, the land, upwards of 300 acres in area, which was encroached upon by the river during the last 12 years, has been reclaimed and rendered fit for cultivation again. The spurs have, therefore, proved advantageous, both to the people and the Government; the former will derive profit from the cultivation of the land reclaimed, and the latter, get an annual addition to the revenue, in the shape of land-tax on the reclaimed land.

Spurs of the above description, cost about Rs. 3 per foot run at Lahore, and answer best for large rivers. But on small nullahs and petty streams, the same result can be obtained much more cheaply by putting up spurs made of stakes of bullees and broken bricks.

In 1865, a small branch of the Ravee, which flows to the north of Lahore, about a quarter of a mile from the city, set towards its right bank above the pukka bridge on the Grand Trunk road [*Plate XXXVIII.*], and threatened to breach the road behind the right abutment of the bridge.

To stop this tendency of the stream, and to protect its right bank and

the road from the action of the current, three spurs, each about 50 feet in length, were put up at A, B, and C, on the right bank, projecting into the river at an angle of about 45° with the current, and constructed in the following manner :—

Strong stakes of bullees 8 to 14 feet long, were first driven (from 4 to 6 feet deep in the bed of the stream) in a row, as close as possible, round the place selected for each spur. The stakes after having been thus driven, were fastened and secured to each other, with strong moonj ropes and fascines; and then the space enclosed, was filled up with broken bricks and masses of old pukka masonry, and the work was complete. The bank above the right abutment, was also protected in the same way, with a row of stakes of about the same length as for the spurs, driven from 4 to 6 feet deep into the bed of the river, and broken bricks filled in the space behind them. The bank of the nullah between the spurs, was also sloped back, and the foot of the slope protected with a row of stakes, driven flush with the bed, and their heads secured together, with ropes and fascines.

The result of all this was, the *complete silting up* of the stream *between the spurs*, and the formation of a new bank, shown by the dotted line *a, b, c, d*. The old bank was protected, the road saved from being breached through, and the nullah straightened and confined to a channel, the water in which flowed *straight* on to the pukka bridge.

Similar spurs were tried at one or two other places on the same nullah, and proved most effective in protecting the bank below them.

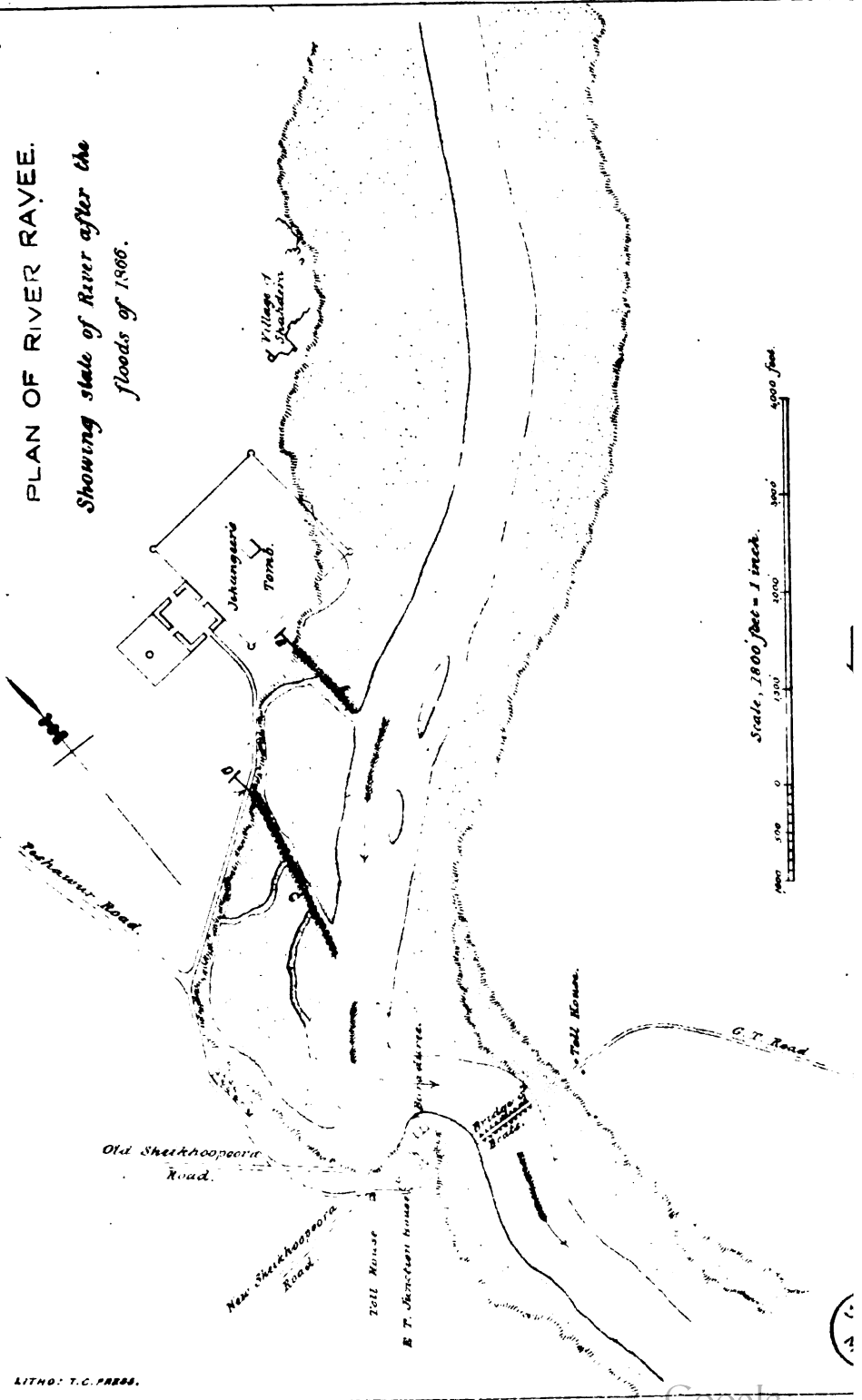
These latter spurs cost Rs. 2 per foot, but wherever old bullees and broken bricks or masses of old pukka masonry can be obtained cheap, the cost can be very much reduced.

Both the above kinds of spurs require to be very firmly secured to the bank; because, so long as the starting point is secured, the spur is certain to produce its effect on the river, but if the river gets *behind* the spur, it is sure to wash it away. Great care should therefore be taken in securing the starting point and keeping the spur in repair, from time to time, so that it may always be in a state to resist any sudden floods in the river.

The following few particulars regarding the position, direction, and length of the spurs, may also prove of use to persons who have not had experience of this kind of work.

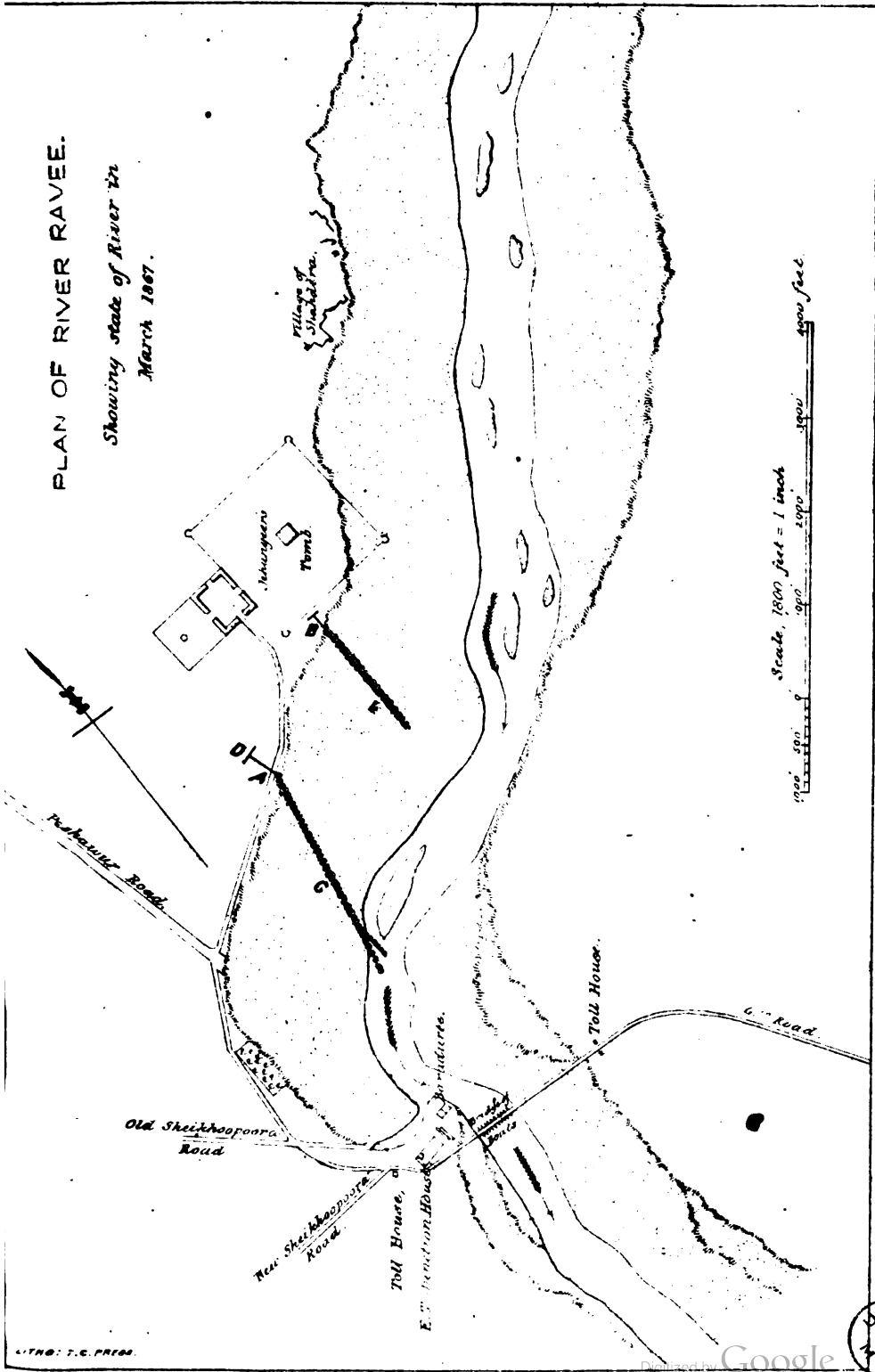
PLAN OF RIVER RAVEE.

Showing state of River after the
floods of 1866.

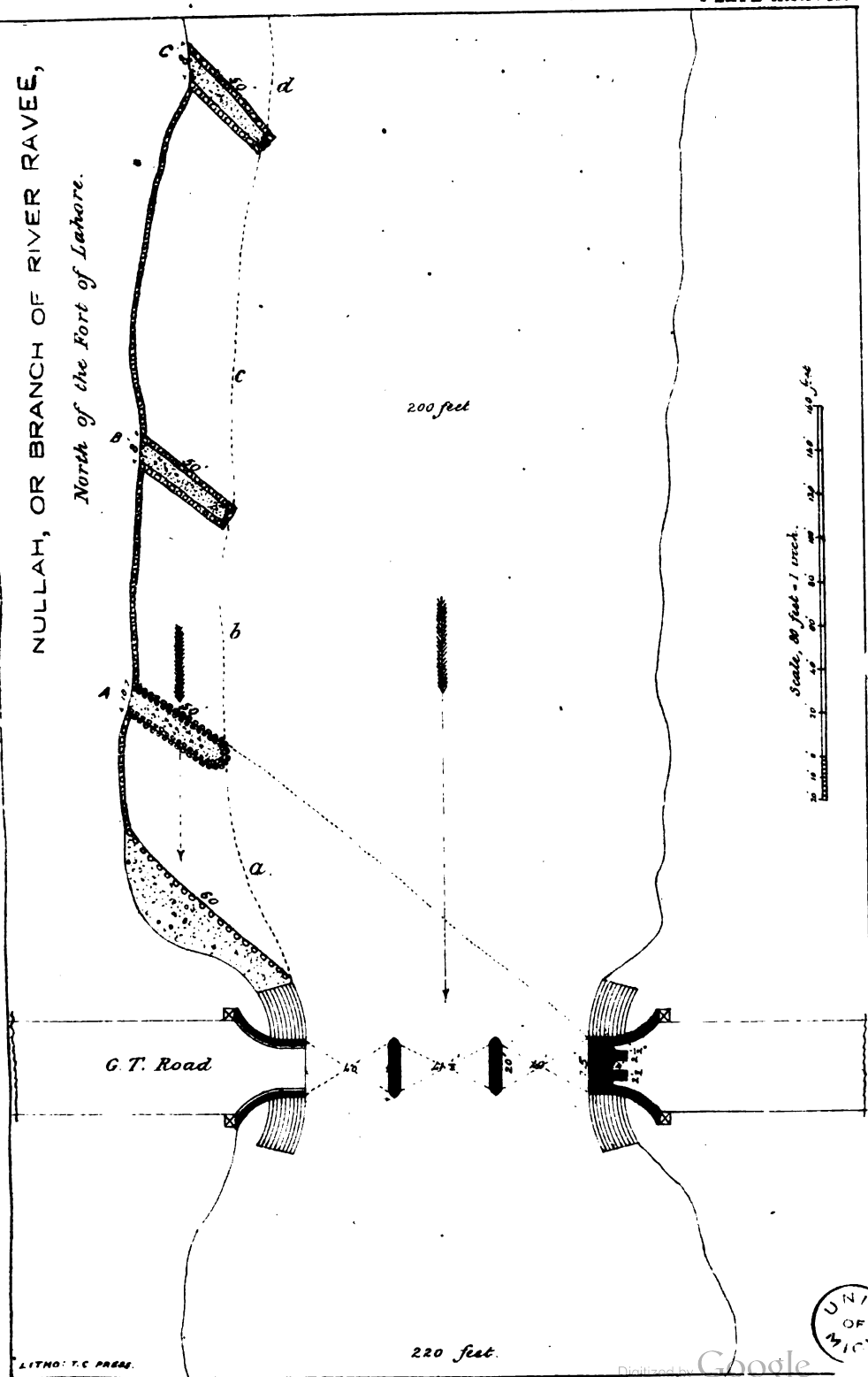


PLAN OF RIVER RAVEE.

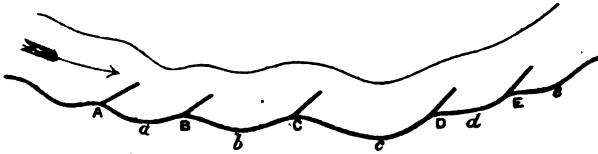
Showing State of River in
March 1867.



NULLAH, OR BRANCH OF RIVER RAVEE,
North of the Fort of Lahore.



No exact rules can be laid down ; but experience shows that to protect a bank, or turn the course of a river, the spurs should be put up *above* the bank to be protected, at such places where the river has even the least turn or tendency towards the opposite bank. For instance, in the sketch below, the spurs should be put up at A, B, C, D and E, but never at *a, b, c, d* and *e*. The *least turn* in the river, from the bank to be protected, should be taken advantage of ; and for this purpose, the course of the river, for some distance above the place required to be protected,



should be first carefully inspected, or an accurate survey made thereof, and any points similar to these shown above (which should also be somewhat elevated and firm), should be made the starting points of the spurs.

With regard to the direction of the spurs, it has been found in practice, that spurs which project into the river at an angle of 45° with the current, prove more effective and economical than those placed at any other angle ; spurs placed at an angle of less than 45° are less expensive, (as they are less liable to damage from the river, and thereby require less repair subsequent to their first construction,) but less effective ; while those placed at a greater angle than 45° , are a little more effective, but very much more expensive, (owing to their being more liable to damage from the river, and requiring very heavy repairs to restore them).

The spurs should, therefore, be placed making an angle of about 45° with the current.

With regard to length, spurs required to protect a bank, may be made one-fourth or one-third the length of the bank requiring to be protected ; but it is scarcely practicable to name the length of a spur required to *turn the course* of a river. Spurs for this purpose should first be made about 1000 feet long,* and *lengthened* subsequently, till the desired end is attained.

The trees for the spurs should not be very small, but of sufficient size

* This must depend so much on the size of the river, width and strength of the current, and a variety of other considerations, that it is hardly possible to name any particular length.—[ED].

to have some effect on the water impinging on them. The trees should be of "keekur," or some similar wood, which is heavy, and will not easily rot.

If the tree spurs are required to last for some time after the immediate end, for which they were put up, has been attained (*i. e.*, if they are to be kept up as a protection to any future possible attack of the river), chain cables of iron, $\frac{3}{4}$ -inch diameter, should be used in place of the moonj rope. The iron chain being much heavier than rope, will require to be stretched either on pukka masonry pillars built on wells, sunk to some 25 or 30 feet below the bed of the river, or on piles of deodar or sál wood, 12" $\times$ 12", and driven not less than 25 feet into the bed of the river. If pukka masonry pillars are preferred, they should be not more than 100 yards from each other; but if wooden piles are used, the intervals between them should not exceed 100 feet.

The tops of the pillars or piles* should be from 3 to 6 feet above the bed of the river, and the chain cable, &c., be well secured to them, so as to be beyond all chance of sinking into the river; for if it does sink, it will soon get imbedded in the sand, and be irrecoverably lost.

Where iron chain cables, supported on pukka pillars or piles, are used, there will be no need of the anchors, that are required to keep moonj rope cables in their position.

The cost of spurs with iron chain cables supported on pukka pillars, will be about Rs. 5 per foot run; and the same with wooden piles, Rs. 4 per foot.

K. L.

* Pillars or piles above the bed of the river, will be required only where the spurs have to be put up *in water*, and their height will, in a great measure, depend upon the depth of the water; but if the spurs are required to be put up in the *dry bed* of a river or nullah, the chain cable may be laid *simply* on the bed, and secured to wells or piles, in a proper manner; and then trees may be fastened to it, as described above.

No. CLIII.

THE MADRAS RAILWAY.

Abridged from the Transactions of the C. E. Institution of Ireland.

By T. H. GOING, Esq.; and from the Proceedings of the Institution of Civil Engineers. By BRYCE McMASTER, Esq.

MADRAS was the latest of the three Indian presidencies in entering upon the construction of railways; the first having been inaugurated in the summer of 1853. This is now known as the South-west Line, and runs from Madras to Beypoor on the West coast, thus giving a direct railway communication across the peninsula. Not that Beypoor can boast a harbour superior to any other river-mouth along the coast; for they all, more or less, share alike the natural effects of sand-bearing currents, which, checked by the action of the south-west monsoon, create a bar across their entrances. There is not a harbour along the west coast, from Cape Comorin to Bombay, which can afford security to vessels of any considerable tonnage, except, perhaps, Sedasheghur, where a barrier of coast islands might be so connected, by artificial means, as to constitute a good harbour, sheltered from the effects of this reflux of sand. Beypoor is in fact an open roadstead, and was probably selected for the terminus chiefly on account of the Iron Company, which the existence of extensive beds of rich hematite in this locality called into being some years back, and whose works, now in a semi-ruinous condition, stand as a costly proof that in the absence of a local supply of fuel the manufacture of iron is not a profitable speculation.

For many miles after leaving Madras the line traverses a flat country

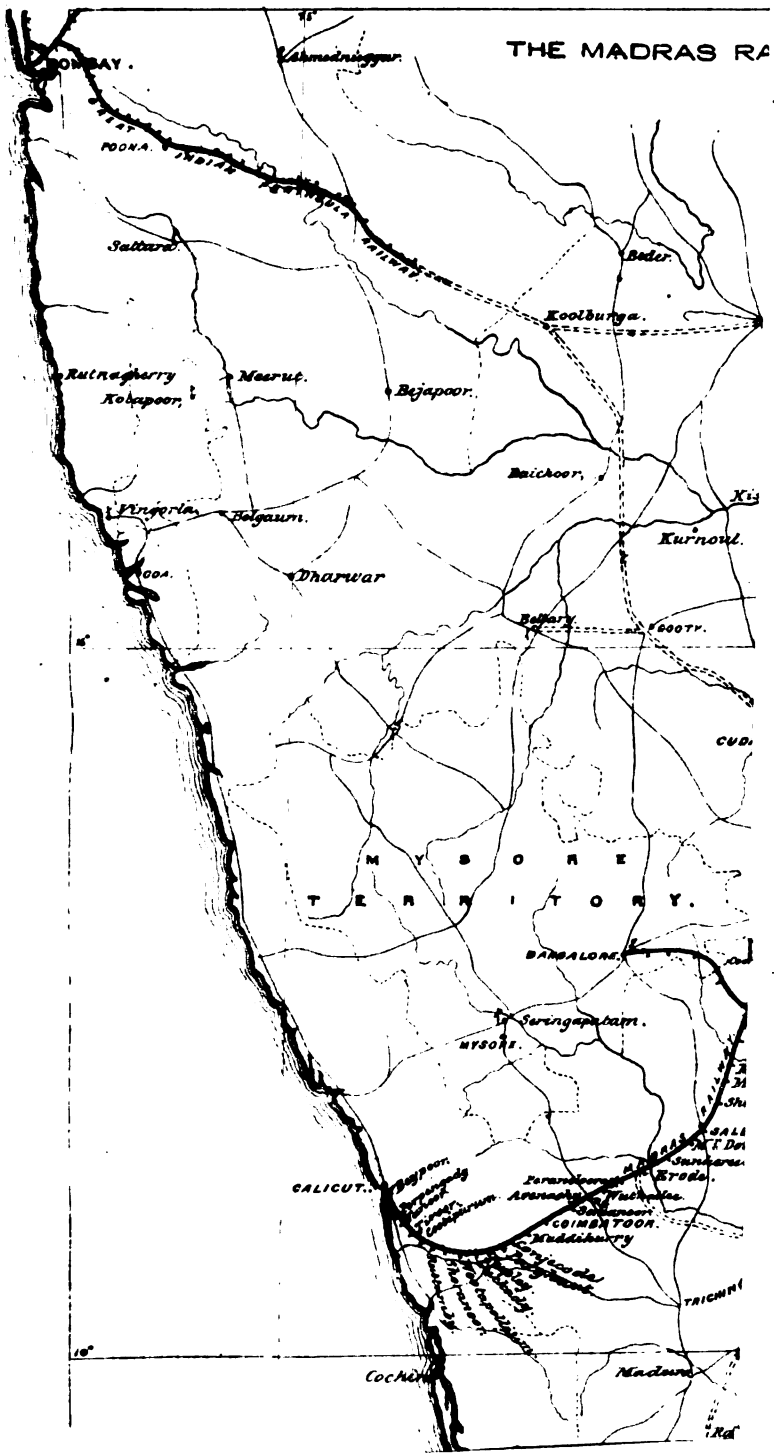
of no great geological interest. Everywhere beneath the soil the great underlying stratum is decomposed granite, which becomes more and more consistent in proportion to the depth,—as may be readily observed in the deep wells for irrigation purposes, so frequent in Indian cultivation,—till it finally merges into solid rock, yielding only to the quarryman's art. These sections would lead one at once to conclude, from the texture of the material, and veins of chloride, quartz, &c., which they display, that this decomposed stratum is the result of decay gradually advancing downwards with the lapse of time, and do not anywhere indicate the character of drift.

When undulations of the surface of the ground necessitate railway cuttings, it is generally found that the nucleus of the cutting is the ridge of a greenstone dyke, of which the upper portion is more or less decomposed. It may be supposed that in a country of this character, clays, valuable for pottery uses, will be encountered, as indeed is the case; and the railway cuttings have laid bare some fine deposits of cayolin and other clays, which are turned to useful account in the School of Arts at Madras. Further west, near the Poiney river, gneiss rocks begin to show, diversified by numerous trap-dykes and granite veins of all sizes. This character continues till within a few miles of Salem, where the line cuts a bit of ground intersected by veins of carbonate of magnesia, the so-called "Chalk hills." Near Sunkerry Droog, and again near Coimbatore, it crosses some not very extensive bands of metamorphic limestone.

The great geological feature along the eastern part of the line is the magnetic iron hill near Salem, close to the southern slope of which the line runs for about six miles. The ore from this hill supplies the Porto Novo Iron Company.

The next remarkable feature in the geology of the railway, as we proceed westward, occurs after crossing the Cauvery river, and approaching the foot of the great triangular spur of the western ghats, known as the Neilgherry hills, round the southern skirt of which the line curves towards the west coast. These hills are a solid mass of gneiss, cut up with dykes in all directions; and the railway through that district has the same tough substance to encounter in many of its cuttings.

There is a peculiar deposit known as *Laterite*, which occurs indiscriminately in all parts of Southern India, and is probably not referable to any special geological period; but which reaches its greatest development on the



western coast, where it may be seen composing the entire mass of hills, some hundreds of feet in height. It may be described as a gritty, porous clay, indurated by ferruginous infusion. It is massive and easily worked, though at the surface very hard for some inches in depth. It is used for building purposes in the place of bricks (as the derivation from the Latin might suggest), being cut out in blocks, which are further shaped by means of a hatchet. Of course, in a climate subject to frosts, the use of such a material in building would be out of the question; and even in India it can hardly be considered as a material of sufficient durability for railway building, except it be for stations and small drains. It is also used as ballast.

From the foregoing remarks it is evident that there is no lack of good material for railway construction across the southern peninsula. Even throughout the plains of the Carnatic, there are few localities in which a granite quarry, within tolerably accessible distance, may not be looked for. In some instances the mere stripping of the soil for a few inches of depth reveals the surface of a granite plane many acres in extent. The writer is not aware whether it may be considered as one of the characteristics of granite, that near its surface it is disposed in successive layers, analogous to the coats of an onion; or whether, when such a character is observed, it should not be rather attributed to the effects of aqueous deposit than the action of cooling. It is certain that the so-called granite of the Madras presidency may be thus raised in successive layers of varying thickness, and hence it is doubtful whether it should not be regarded as gneiss.

The mode of quarrying granite in the Madras presidency is peculiar, and a description of it may be interesting to those unacquainted with the process. There is in India a caste of people known as *Wudders*, who may, in general terms, be described as the navvies of India. They are of two classes—those who work in stone, and those skilled in the manipulation of earth. Arrived at his quarry, the Wudder's first care is to lay in a stock of firewood, which he cuts in the jungle and removes by means of a peculiar bandy or cart with low wheels of solid timber, drawn by a pair of buffaloes—an important part of his equipment, which was omitted before in the list. The wood is piled in small quantities on the surface of the rock, and ignited, usually during the night, their favorite time for work. After the fire has been steadily kept up for some hours, the upper layer of the

rock expands sufficiently to produce a separation from the substratum. The separation is accompanied by a dull bursting sound; and the extent of the severance is ascertained by a series of taps with the crowbar, the response of which is conclusive to a practised ear. The next operation is to break up this loosened bed of rock into fragments of a size convenient for handling, and this is effected by means of a round boulder of greenstone, as large as can be lifted to his head with the assistance of another man. This he dashes down with all his might on the rock, and sometimes succeeds in making a fracture with a single throw; but it often requires to be repeated many times; and it is wonderful, considering the clumsiness of the method, with what success he turns out handsome square blocks of stone, of dimensions well suited for building. This, however, is more to be attributed to the natural tendency of the stone to square fracture, than to the skill of the Wudder. The greater part of the earthwork in Madras presidency, on the railway, in tanks, &c., is done by people of the same caste as the stone Wudders just described; and these people always perform their work by contract.

In speaking of the materials for construction, a few remarks on lime will be proper. The slight development of limestone in the Salem district has already been mentioned; but for burning purposes the concretionary carbonate of lime common throughout Madras is most used.* In this form it occurs in beds of varying thickness, as well as disseminated through the soil and over the surface of the ground. The nodules are of various sizes, from that of a pumpkin down to the bulk of a pea. A very common variety is shaped like the ginger root, and this is always found to possess slightly hydraulic properties. In the neighbourhood of Madras, as well as on the west coast, almost the only kind of lime used is procured from the burning of shells found in beds a little below the surface, in low lands near the sea coast. The lime made from these shells, being very fine and white, is admirably suited for plaster, and is susceptible of a high polish, which is administered during the period of its setting by means of a smooth stone or crystal, rubbed assiduously over the surface so long as any dampness remains; a little of the powder of soapstone being sprinkled on to assist the polish. Most of the public buildings, as well as the private dwellings, in Madras are finished in this way; and when the work is new it gives the effect of white marble. The action of the atmosphere, however, soon tar-

* This I presume is *Lunkur*.—[Ed].

nishes the exterior of buildings thus finished, and they look shabby enough after three or four seasons; but the interior preserves its beautiful purity of appearance.

It may be in place to observe, while speaking of lime, that that used for building purposes in Ceylon is all produced from the calcination of coral. Indeed, on the coast, the buildings are mostly constructed of coral blocks, cemented by mortar, of lime made from coral.

The average annual fall of rain in Madras, on the eastern side of the peninsula, is about 50 inches, but as much as 80 inches have been registered as the fall for three several years since the commencement of the century. Within a single month the rain gauge has indicated a fall of 42 inches; and on the 25th October, 1857, 12 inches of rain descended from the clouds in a steady pour of 12 hours' duration. From these data it will be understood, that the question of drainage is one of some importance in the construction of a railway across such a country. The rivers, indeed, constitute the principal difficulties to be overcome, all the more so from the fact that being, during the greater part of the year, little more than broad shallow channels of sand, the great proportion of their duty is concentrated into the short space of a few weeks, during which the rains of the north-east monsoon descend. Those of the west coast must however be excepted from this general description, because the cloud-barrier of the western ghats, whilst arresting the eastward progress of the south-west monsoon, pours back its deluge of waters to the ocean which washes the shores of Malabar; so that while this vapoury region monopolises all the waters of that monsoon which come laden with the moist breath of the Indian ocean, the Coromandel coast must content itself with such watery stores as are picked up by the north-east monsoon in its shorter flight over the bay of Bengal. A corresponding difference of climate accordingly characterises the country on the two sides of the western ghats. Innocent of water as these sandy channels of the east appear, however; when the question arises of laying the foundations of a bridge, this uncompromising element is found but to lie dormant within a few inches of the surface of the sand.

The engineers of the Madras Railway have not taken kindly to the ordinary Indian system of well foundations, and it has been only resorted to in a few instances. In laying the foundations of the granite bridge over the Naggery river, of thirteen 40-feet arches, on the north-west line of the Madras Railway, the resident engineer, Mr. Smart, adopted the method of

curbs. The curb consisted of a strong teak frame 40 feet by 9 feet, divided by cross scantlings into five compartments of 4 feet square, and equidistant. The thickness of the curb from under side of beams to upper surface of planking was 2 feet. It was placed accurately above the site of the pier on the surface of the sand, and the masonry built to a height of 10 feet; making an entire height including the frame, of 12 feet; this being the depth of sand above the solid substratum as ascertained by a prickler. Cross walls partitioned the structure into 5 cells, corresponding to the compartments of the curb on which it was built, and every course of the upper 4 feet had layers of hoop-iron worked into it longitudinally. It was then ready for sinking; a diver being set to work in the bottom of each cell to remove the sand, and hand it up by lifts to the top, where it was discharged. The sinking too, was found to be greatly facilitated by keeping the sand well cleared away round the exterior. After being sunk some feet, a crack appeared in the masonry, which alarmed the divers; and it was with difficulty they could be got to proceed with the work. The structure went down in sudden jerks of a few inches at a time, and was finally deposited on its resting-place below the sand within ten days from the commencement of the sinking; and though a few cracks showed in the masonry, it was of no practical consequence. The total cost of the curb, for materials and workmanship, was about 180 rupees, and the sinking cost 90 rupees; 220 rupees, or say £22. The cells were finally packed with stone, which was then grouted, and a level platform thus prepared for the superstructure. Such a mode of getting in foundations would of course be only practicable where the sand was free from boulders.

The principal rivers crossed by the south-west line are the Cortiliar, the Poiney, the Goriathum, the Palar, the Cauvery, the Thootha, and the Kuddulhoondy. It was originally contemplated to cross all these rivers by means of arches of masonry. A great improvement has however been introduced by the substitution in many cases of wrought-iron girders, whereby the number of costly and tedious pier foundations is diminished. The total length of the south-west line, from Madras to Bellore, is 405 miles, and the summit height attained at Mooroor, near the foot of the Shervaroy range, 1500 feet above the level of the sea. At Coimbatore, where it passes near the base of the Neilgherry range, a second summit of 1801 feet above the sea is attained; and between these two, intervenes the

deep valley through which the rapid Cauvery washes its way southwards. The elevation of this, at the point of crossing above the sea level, is only 495 feet. The gradients are for the most part favorable, the maximum being 1 in 60, necessitated in descending from the last-named summit towards the plains of Malabar.

Only the south-west line of the Madras Railway has hitherto been mentioned—as being that for the construction of which the company was originally raised, and which is now nearest to completion. In August 1858, the Government entered into a further contract for the construction of the north-west line, which is designed to strike out from Madras in as direct a course as is expedient, towards Bombay, and form a junction with the railway from that town, near Moodgul, in the territory known as the Raichoor Doab, lately restored to the Nizam of Hyderabad. Two branches, one to Bangalore, the other to Ootacamund, have also been sanctioned; but construction has only been commenced on the former. The object of these lines is to give ready access to two such important stations, Bangalore being the great military head quarters of the Madras presidency, and Ootacamund its sanitarium.

On this line the bridges again constitute the chief engineering difficulties. There are twelve principal rivers to cross; among which the largest are the Naggery, Cheyair, Paupugnee, Chittravutty, Penair, Hugry, and Toongahudra; the channel of the Cheyair being some 60 chains across, and the others varying from 10 to 40 chains, making an aggregate of bridging over these twelve rivers alone of more than 3 miles in length. The designs are principally for masonry piers, and superstructure of wrought-iron girders in spans of 60 feet, adapted for a single line of rails. The cuttings and embankments too, of the Madras railway are, it may be observed, all adapted for a single line, the masonry being constructed for a double line.

The total length of the north-west line, to its junction with that from Bombay, is 330 miles. Two ranges of hills are crossed; the first at Ballapilly, involving a heavy cutting through quartzite, and a gradient of 1 in 60. For about 180 miles the earthwork is tolerably heavy; but to the north of Cuddapah the great plains of black cotton soil prevail, and the earthwork will consequently be light.

The *Permanent Way*, between Madras and Arcot, 65 miles, is laid with

a double-headed rail, weighing 84 lbs. to the yard, in lengths of 20 feet. The rails are fish-jointed, and six sleepers are used to each rail length; the end sleepers being placed 1 foot 3 inches from the joint, and the others respectively 3 feet, 3 feet 9 inches, and 4 feet to the centre. The chairs, wooden trenails, and keys are all of the ordinary construction. West of Arcot, the line is laid with rails weighing 65 lbs. to the yard, which is considered sufficient for the requirements of the traffic. These rails are laid on seven sleepers to the same length of 20 feet. The gauge is 5 feet 6 inches. The expense of freight, from England to Madras, for the first portion of the line was very heavy, owing to all the materials being sent out during the Russian war, when vessels were obtained with more difficulty, and the charges were higher. This, together with the greater weight of the rails, has rendered the first portion more expensive than the rest of the line may be expected to be; although the greater distance to which the materials will have to be conveyed, as the works are extended into the interior, will add to the cost, as the line advances. The cost per mile of the materials landed at Madras was as follows:—

	£	s.	d.
528 rails, at 84 lbs. per yard = 182 tons, at £16 4s. 6d. per ton,	2,141	14	0
3,168 chairs, at 21½ lbs. each = 80 tons 1 cwt. 8 lbs., at £8 5s. per ton,	247	18	10
6,836 trenails, at £6 7s. 7d. per 1000,	40	8	5
3,168 keys, at £6 9s. per 1000,	20	8	8
528 pairs of fishing-plates, at 28 lbs. per pair = 6 tons 12 cwt., at £16 per ton,	105	12	0
2,112 bolts and nuts = 1 ton 3 cwt. 2 qrs. 14 lbs., at £23 10s. per ton,	27	15	2
1,584 sleepers, at 6s. each,	475	4	0
	£3,059	1	1
Carriage—average of 65 miles, per mile,	60	0	0
Laying, including all labor and superintendence,	40	0	0
Total,	£3,159	1	1

At the commencement of the undertaking, tenders were invited in India, for the supply of chairs, fishing-plates, bolts and nuts; but the prices offered were, to use the words of the Government Consulting Engineer, so extravagant, as to furnish no ground for hope, that the Indian iron could compete with the English, or that the Indian railways could look for any considerable supply from local sources. The same officer

subsequently stated, as his opinion, that there was no reason why many, if not all, the materials required for the construction of the permanent way should not be made in India; but that, although much might be done hereafter, to the advantage of both parties, when the iron wanted is that merely consumed in the ordinary wear and tear of the works; and although it might be hoped, that castings of the nature of those required could be turned out at Porto Novo, cheaper than they could be brought from Europe, yet the means of the Indian establishments appear at present so limited, that only small and tardy supplies can be hoped for, and Europe must still continue to be looked to, for the chief supply of chairs for the construction of the line. These opinions are supported by the following facts. The East Indian Iron Company contracted for the supply of chairs, from their works at Porto Novo. These chairs were delivered at Madras at a cost of 72·8 rupees (£7 5s.) per ton, which was under the price of English chairs, as mentioned above; but about the same price, as that for which they were brought from England at a more favorable time. The casting of the Porto Novo chairs was found to be as good as the English; but unfortunately, the supply was very limited. The same Company, having recently established works in the vicinity of Salem, near the centre of the peninsula, have undertaken to supply 300 tons of chairs, at the rate 76½ rupees (or £7 12s. 6d.) per ton, a somewhat higher price, but still a saving when the carriage from the coast, a distance of 200 miles, is considered.

The material for the supply of which the country can be depended on, is sleepers. Its forests and jungles afford a great variety of hard and durable woods, well adapted for the purpose. On the Madras Railway, twenty-eight different kinds of woods, have been used; which with few exceptions, have been found to answer well, when carefully selected. Much has been said of the damage anticipated from the white ants; but although few woods are not attacked by them, while lying exposed, and the sap wood, in particular, is much eaten away, yet in two years after the trains began to run on this railway, there was not a case known of a sleeper being attacked in the road. The vibration of the passing trains, and the frequent opening out of the ballast by the workmen, appear to be sufficient to prevent the attacks of this universally destructive insect. This will be better understood when it is known that the white ants never work but under a thin covering of earth, which they build over themselves; and this being shaken

off, their depredations cease until it has been renewed. Many woods are liable to the attacks of other insects, which bore holes into them; but the sleepers, when covered with ballast, appear to be free from these also.

Great numbers of creosoted fir sleepers were sent out from England, at a cost of $4\frac{1}{2}$ rupees (or 8*s.* 6*d.*) each at Madras, or about $4\frac{3}{4}$ rupees (9*s.* 6*d.*) each when conveyed fifty miles to the works; while the sleepers procured in the country vary in price from 2 rupees (4*s.*) to $3\frac{1}{4}$ rupees (6*s.* 6*d.*) each. These creosoted fir sleepers were found to be very durable. The wood itself is perishable in India, probably from the heat causing the turpentine, &c., to evaporate rapidly; but the creosote has the effect of preserving it, and of preventing the depredations of all kinds of insects, even when the wood is most exposed to their attacks. With reference to this class of sleeper it was stated, in a Report on the sleepers on the East Indian Railway, that some of a rectangular cross section were quite sound, after being laid for three years. It was also remarked, that the heat and the great drought have the effect of dissipating the volatile parts of the creosote, so that its peculiar odour is scarcely discernible, in sleepers that have been long exposed to the sun. From this cause, the sleepers of a triangular cross section, were found liable to split in the hot weather, the edges becoming dry and brittle. Various native woods were creosoted on the East Indian Railway, and the following statement, showing the cost of preparing four different kinds, is taken from the Report above referred to.

Description of wood.	Amount absorbed per cubic foot.	Contents of sleeper.	Total creosote absorbed.	Cost of creosote at 6 <i>d.</i> per gallon or 8 lbs.	Add for labor.	Total cost per sleeper.
	lbs.	cubic ft.	lbs.	<i>s.</i> <i>d.</i>	<i>d.</i>	<i>s.</i> <i>d.</i>
Sál,	2	$3\frac{1}{2}$	7	0 5 $\frac{1}{2}$	1	0 6 $\frac{1}{2}$
Teak,	4	$3\frac{1}{2}$	14	0 11	1	1 0
Soondry, . . .	6	$3\frac{1}{2}$	21	1 4 $\frac{1}{2}$	1	1 5 $\frac{1}{2}$
Sissoo,	9	$3\frac{1}{2}$	31 $\frac{1}{2}$	2 0 $\frac{1}{2}$	1	2 1 $\frac{1}{2}$

This is exclusive of the original cost of the apparatus; but it includes fuel and attendance on the engine, together with all other labor and superintendence.

On the Madras Railway, a few thousand sleepers were kyanized, experimentally, with corrosive sublimate. This operation was effected by a

person who erected the apparatus at his own expense. The cost was about 4 annas (6*d.*) a cubic foot. The sleepers thus treated were all half round sál sleepers, in themselves very durable. After they had been laid for twelve months, there was no perceptible difference between the sleepers which had been kyanized, and those of the same wood, laid in the same place, but not so prepared; both being perfectly sound and good. It is worthy of remark, that a specimen sleeper, which had been kyanized, and kept in a covered verandah for about six months, had its sap wood bored by insects, in the same way as those which were unprepared. The great difficulty in the way of kyanizing, or otherwise preparing, any large quantity of sleepers in India, is the fact of their being received all along the line; involving the expense of collecting them, at certain points, for the purpose of being prepared. The same reason, however, does not exist to prevent sleepers being prepared for the *maintenance* of the way; as they can then be easily and expeditiously carried from the places where they are prepared, to the points where they are required.

In the neighbourhood of Arcot, granite blocks were obtained, measuring 2 feet square by 1 foot in thickness, at a cost of $1\frac{1}{4}$ rupee (2*s.* 6*d.*) each, and were made use of on some parts of the line, instead of sleepers. The cost of two blocks fixed was only about 6 annas (9*d.*) more than one sleeper fixed; but on account of the roughness and rigidity of the road, they were not used to any great extent. Near the coast, laterite abounds, and one mile of the line was laid with blocks of this material, as an experiment. It was found, however, that the blocks split, and their use was consequently abandoned. The price per block was 11 annas (1*s.* 4½*d.*).

A few native-made keys and trenails were used; but the former were not pressed, and although they answered well in wet weather, in the hot season they shrunk so much as to be unfit for use. The trenails, which are of teak, succeeded perfectly. A few lengths of rails were laid at one of the railway workshops, for the purpose of fitting up wagons to gauge. These rails have been laid for two years and a half, and, as might be expected, have not received much attention. Both the English elm keys and the oak trenails have, in the time mentioned, been riddled by insects. The trenails had not been driven home, but stood 2 inches, or 3 inches above the chairs, and the exposed parts had been attacked. This shows that, unless constantly watched, even English oak suffers in India. The insect alluded to is not the white ant, but a species of beetle, which, as

before stated, bores holes in wood left exposed, although covering up the wood with ballast seems to be a sufficient protection. It may be remarked, that the sleepers on which these rails were laid were of a native wood called "yengay"—botanical name, "*Acacia odoratissima*"—and although not covered by ballast, the sleepers were left untouched by the insects, while the oak trenails were almost entirely destroyed. In the curves of sidings, iron spikes were substituted for the wooden trenails, on account of the frequency of accidents from the trenails giving way.

In laying the road at first, the natives were found, as in almost every other kind of work, intelligent and apt, when care and patience were taken in their instruction. The gangs generally consisted of one mistry, or ganger, and twelve men; the pay of the former being about 6 annas (or 9d.) a day, and that of the men $2\frac{1}{2}$ annas (or $3\frac{3}{4}$ d.) each. In order to give the men some inducement to remain, the pay was increased, gradually, to 4 annas (6d.) a day, in proportion to the length of service. A day's work for a gang of the strength mentioned was usually twelve lengths of rails finished up. A European inspector had charge of four or five gangs. The cost of laying was, as above stated, about £40 per mile.

In the maintenance of the way and works the arrangements were as follows:—A Resident Engineer in charge of 72 miles; one European inspector to each length of 12 miles; one gang of workmen consisting of a mistry, or ganger, and seven men to each $1\frac{1}{2}$ mile; one watchman to each mile; one timekeeper to every length of 6 miles; one paymaster to the division of 72 miles; and one storekeeper to the same length. Extra gangs were employed for ballasting and repairing any serious damage.

No. CLIV.

SAND PUMPS FOR WELL FOUNDATIONS.

A Description of the Sand Pumps employed in sinking the Well Foundations of the Bridge Piers on the Delhi Railway. BY CHARLES GENESTE, ESQ., C.E., in charge of Sutlej Bridge Works.

THE following pages contain an account of the "Sand Pump" from the first time it was used, in its primitive form, up to the present time, when, with the numerous alterations it has received, it is considered one of the most effective machines for sinking foundations in sandy soil.

In 1860, Mr. Howard Kennard took out a patent for the Sand Pump, or, as it was then called, "Sand Excavator;" and in the latter part of the same year, one was sent out to the Tagus Bridge, on the Lisbon and Badajoz Railway, where Mr. Kennard tried it, for the first time, himself. It then consisted [*Plate XL., Fig. 1*] of a cast-iron cylinder, 3 feet diameter and 2 feet high; closed, top and bottom, with covers with air-tight joints; each cover having a circular hole in the centre about 6 inches diameter. Through the hole in the lower cover was a cast-iron pipe protruding for 2 or 3 inches below, and carried up, inside the box, to within 4 inches of the top cover. On the top cover was fixed the pumping apparatus; a bell-shaped leather bag 10 inches deep, the mouth being about 2 feet diameter and the top 6 inches; this was closed with an iron weight having a ring in the centre to which the pumping tackle was attached. Outside the bag, in the top cover, were several holes, closed with leather valves, for the discharge of the water. The body of the pump had iron lugs for lifting it, and a small wrought-iron door closing with a water-tight joint.

The principle was, that a vacuum should be formed by opening and shutting the leather bag when under water, thus causing the sand to come in with the water through the suction pipe. As the pump filled with sand, the water was discharged through the valves in the top cover, and when full it was lifted and the sand removed through the door; the sand being prevented from escaping, until the door is opened, by the inside pipe.

Mr. Kennard tried it in the bed of the river under a travelling crane; the pumping gear he worked by means of a single purchase crab, placed on the scaffolding which carried the traveller; the men turning and reversing the crab quickly, thus caused the leather bag to be extended and closed alternately. He worked it the whole of one afternoon, but without any marked success; the pump sometimes coming up half full, but generally with only 1 or 2 inches of sand in it. This pump was then put on one side and not used a second time.

Soon afterwards, Mr. Kennard sent out two more pumps [Fig. 2.] to the Tagus, slightly different to the first one. The leather bag, instead of being made bell-shaped, was cylindrical, about 10 inches diameter, with a heavy iron plate on the top, fitted with four valves working in the same way as those in the upper cover of the pump. The leather cylinder had also light iron rings sewn inside to cause it to close in folds. These pumps were sent out to the Tagus, but, Mr. Kennard having left, they were tried by the foreman, condemned, and laid on one side.

About the middle of 1861, the writer went out to Portugal for Messrs. Kennard with Mr. Wilson, who had charge of all the bridge work; and as the latter gentleman wished to see what could be done with the pumps lying useless at the Tagus, they were sent to the Mondago river, where the writer was about to commence a bridge.

The first time one was tried was on the 13th October, in a *six foot* cylinder, in about 4 feet of water. It was soon found that the iron plate on the top of the leather cylinder was not sufficiently heavy; so an extra hundred weight was put on, and it worked much better; at the first lift the pump coming up *one-third* full of sand. Owing to several stoppages this day, only six lifts were made, and the pier was sunk *one foot*, equal to 28 cubic feet of sand. The next day the pier was sunk *four feet*, equal to 112 feet of sand. A day or two afterwards, it was found that the rings inside the leather fell out, and so instead of closing in folds it fell over on the side, and of course did not work. To remedy this, a guide was

SAND PUMPS FOR WELL FOUNDATIONS.

Fig. 1.

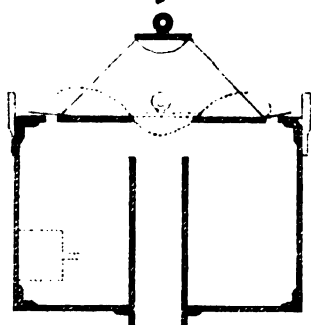


Fig. 2.

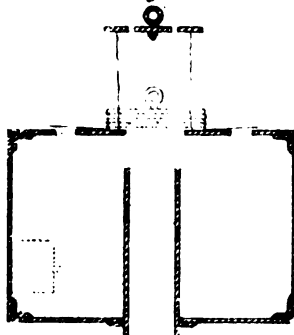


Fig. 3.

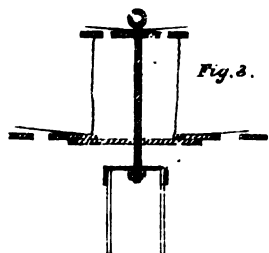


Fig. 4.

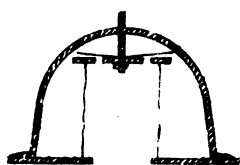


Fig. 5.

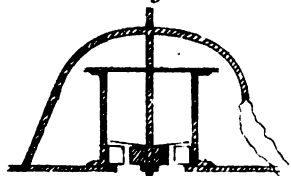
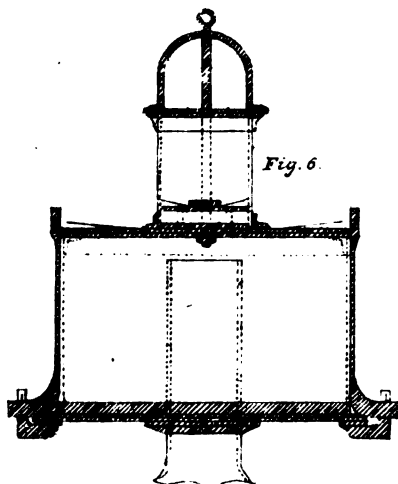
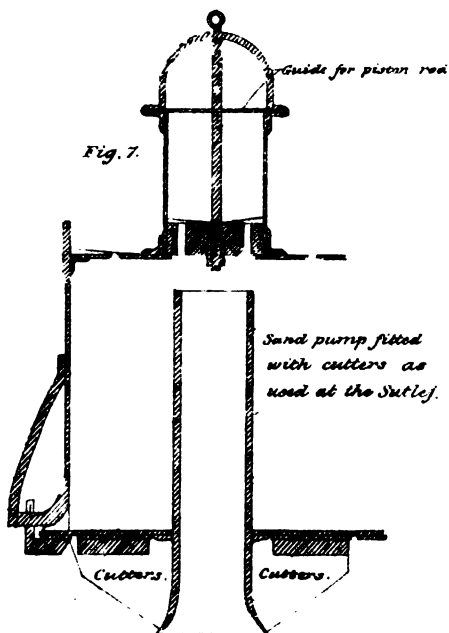


Fig. 6.



*Sand pump with removeable bottom
used at the Sulej.*

Fig. 7.



fitted to keep it straight. An iron bar [Fig. 3] with a hole in it, was put across the top of the suction pipe, and another across the opening in the top cover; there a long bolt worked through these holes, having one end connected with the iron plate on the top of the leather, and on the other end was a nut below the bar across the suction pipe.

This, on trial, was found to answer so far as keeping the arrangement straight was concerned, but it entirely destroyed the working powers of the pump; the bar being across the suction pipe, and the bolt working inside, evidently prevented the flow of sand. An outside guide [Fig. 4], was therefore fitted, which was found to work much better; but the next thing to be contended against, was the wear and tear of the leather, which, after a few days' work, was out through, and of course rendered the pump useless until repaired. The final remedy for this was [Fig. 5] a piston for the leather cylinder. A cast-iron cylinder, about a foot long and 10 inches diameter, was bolted on to the top cover, and a leaden piston cast to work in this rather easily, having four holes in it, fitted with valves for the discharge of the water. In the centre of the piston a long bolt was fixed, about 2 feet long, having an eye on the upper end for the pumping tackle. This bolt passed through outside guides to keep it perfectly straight, and the piston had a leather belt round it, drawn in at the bottom and rather loose at the top, so that in the up-stroke the piston should be tight, and in the down stroke loose.

It was soon found, however, that this leather did not answer, the sand getting in between the leather and the lead, and so causing the piston to jam. It was then cut away, and in its place two iron rings were put, to take all the rubbing, but not fit too tight. With this the pumps worked very well, and from 6 to 12 feet a day could be counted on, according to the nature of the sand and the height of the lift. They would also work in shingle, but not so well, but in clay they could do nothing. The suction pipe was also found to work better with the lower part rather longer, and instead of 3 inches below the bottom, they were made 9 inches below. With these sand pumps, nearly all the foundations for the two large bridges over the Mondego were sunk by the writer.

In the latter part of 1862, the writer returned to England, and as he was then engaged on a railway without any large bridges, he lost sight of the sand pumps, and believes they were very little employed, until again brought into use on the Delhi Railway.

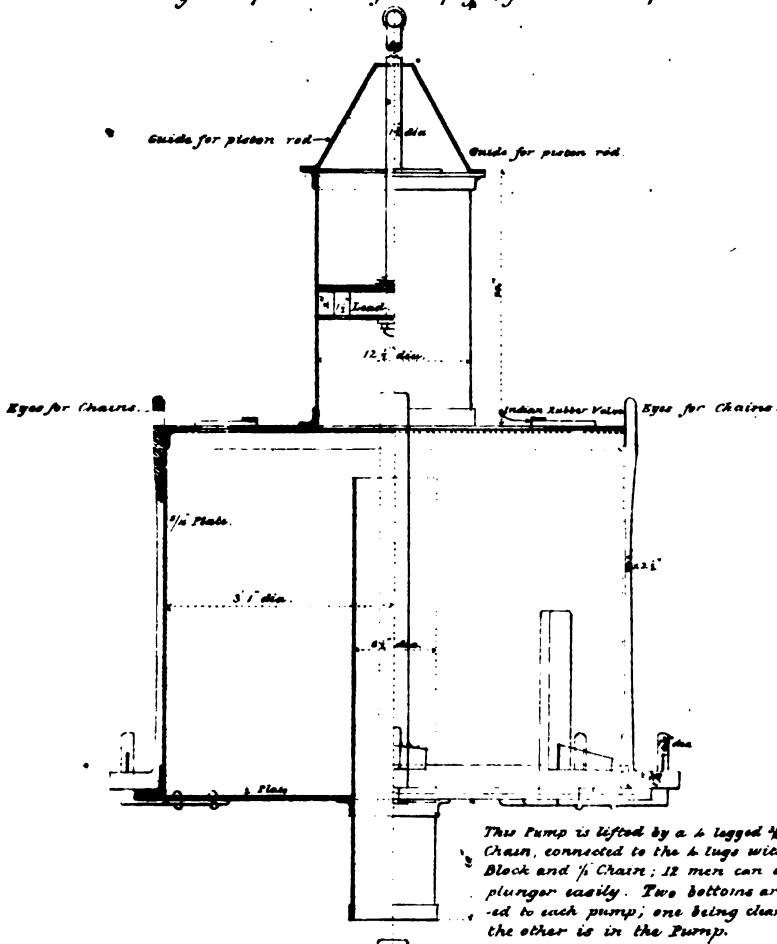
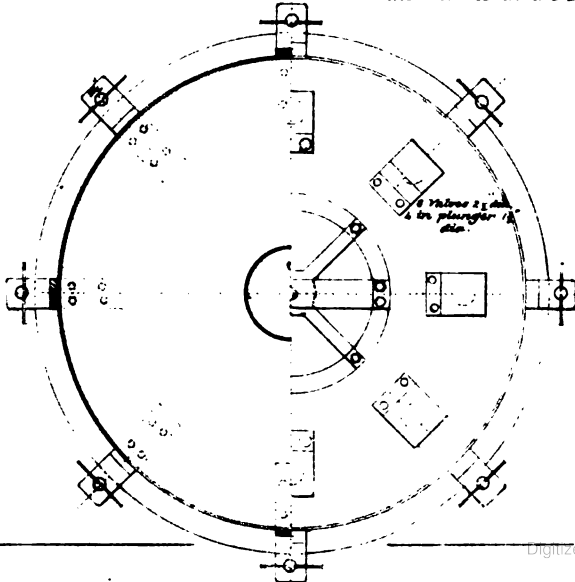
When the plant was ordered for this line by Mr. Henfrey (Messrs. Brassey, Withes and Henfrey, the contractors for the whole line,) the Sand Pump was mentioned as likely to be useful in the sandy beds of the Indian rivers, and, at the writer's suggestion, a number were sent out, together with steam hoists to lift them, the want of this having been felt in Portugal. In April last, the sinking of the piers was commenced at the Sutlej Bridge with both "Sand Pumps" and the "Jham;" and at the present moment, after ten months work, more than 1000 feet have been sunk; the sinking being about equally divided between the two: the sand pump during one day, of *seven* working hours, performing the extraordinary feat of sinking a pier, 12 feet 6 inches diameter, *six feet*, or excavating 736 *cubic feet of sand*, the pier at the time being about 36 feet in the ground. It also sunk 15 feet in *eighteen hours*, part of the time working in black clay and kunker.

Before, however, arriving at this state of proficiency, it was found necessary to make another improvement [*Fig. 6*] at the suggestion of Mr. Marellier, general Superintendent of the bridge work, which has almost doubled the working powers of the Sand Pump. This was the introduction of the removable bottoms, thus making the machine self-emptying, and allowing it to be kept continually at work with little or no delay. Formerly, the principal thing against them was the time lost in getting the sand out; the actual filling of the pump is merely a matter of about three minutes, and, by means of the steam hoist, it can be both lowered and lifted from the bottom in two minutes; but the emptying, although they were furnished with two doors, took about fifteen. This difficulty was partially got over by working two pumps on one pier with two trollies, one to take away the full one, and the other to bring up the empty one; however, naturally some time was lost in changing the lifting tackle, as each pump had to be disconnected every time. The greatest depth sunk with two pumps in one day was 3 feet 6 inches; and now, with the moveable bottoms, 4 feet 6 inches and 5 feet can be easily calculated on.

The pumps now are made without any doors, and the bottom, with the suction pipe, is made quite separate from the body, and held in its place by means of lugs fastened with colter pins. Each pump is fitted with two bottoms. When working, the pump is lowered to the bottom of the well, filled and lifted in a very short time; then one of the trollies, which work on a tramway, being run over the centre of the pier, receives the pump. The

SAND PUMPS FOR WELL FOUNDATIONS.

Beas Bridge-Improved Self Emptying Sand Pump.-



colter pins are then knocked out and the lugs turned round, the steam hoist then lifts up the body of the pump, and the bottom is left in the trolley with its cargo of sand. This trolley is then pushed away on one side, and the other run under with the second bottom; this is fitted, the pump again lifted, trolley pushed away, and then the pump goes to the bottom and is filled a second time. When it is again lifted, the first bottom has been unloaded and ready to take its turn. Of course this is very hard work for the men, and they soon get tired; but when they are worked sharp for about an hour, one can actually see the pier sinking.

One other improvement [Fig. 7], I think, makes the Sand Pump perfect; this was applied to get over the difficulty encountered when coming on patches of clay or kunker. On the lower part of the moveable bottom, radiating cutters have been fixed made of plate iron, half-inch thick, sharpened and steeled at the edge; these are about 9 inches deep. When anything hard is met with, the pump is lifted about 4 feet, and is let fall again, several times, and by this means the clay, kunker, or whatever it may be, is generally broken up, and can be easily drawn into the pump. This last alteration has converted the "sand pump" into a "clay pump," and has enabled all the piers to be sunk 2 feet into the solid clay foundation. Up to the present time about 30 feet have been sunk in hard yellow clay, under a head of upwards of 40 feet of water, entirely with these pumps. This is in addition to beds of clay and kunker which have been passed through, some of them as much as 4 and 5 feet thick. The pumps will also lift bricks and stones (and have lifted many of 14 lbs. weight) if not too large for the suction pipe. Of course great care and judgment are required in the manufacture of them; every joint must be tight, and the piston must be a perfect fit, neither too tight nor too loose in the cylinder.

Plate XL. shows the different stages they have passed through, before arriving at the present form, and the writer has no doubt that now there is nothing so efficient and economical for sinking any foundations in sand. The original outlay is not large, and the cost of working small. Then the facility of transport and small preparation required for working them, are also great things in their favor: any depth of water is no drawback to them, in fact they work best in a depth where a *jham* would be perfectly useless, and nothing can sink a pier straighter on account of all the sand being removed from the centre of the well. In the writer's opinion, before

many years, the sand pump will be generally used, not only in India, but in England, and all over the world. Wherever there is sand, wells are now very generally used as foundation for bridges, and there is nothing more suitable for sinking them than "The Improved Sand Pump."

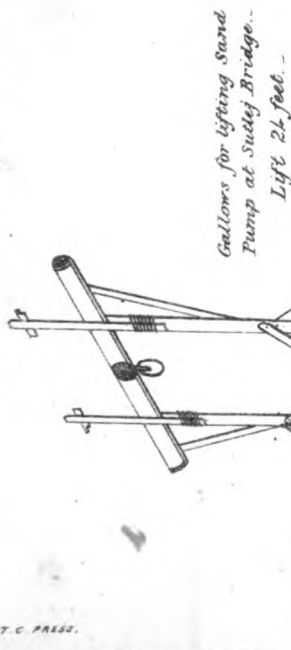
C. G.

NOTE BY EDITOR.

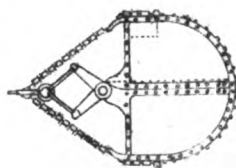
I had the pleasure of seeing the Sand Pumps working in January last, at the Jumna and Markunda Bridge Works, on the Dehli Railway; the $12\frac{1}{2}$ feet wells being then sunk 40 feet through sand, with an intervening stratum of clay, 6 feet thick at 16 feet from the surface: and have no hesitation in saying that it is one of the most admirable inventions ever applied to Indian Engineering. Even without the more expensive aid of the steam hoist, and lifted by coolies with a chain and block, working on the *gallows* shown in *Plate XLII.*, there can be no question of its superiority over the jham, and every engineer who has such work on hand will do well to provide himself with the apparatus, when procurable.

The cost of the pumps in England is £25, exclusive of the patentee's royalty. The invention has been, I understand, protected in this country, and at present Messrs. Brassey and Co., enjoy the exclusive right of using it in India. It is probable, however, that in another month or two arrangements will be made for supplying other parties on fair terms. The price of the Steam Hoist as used on the Delhi Railway is £270—it is of 4 horse-power and is manufactured by Messrs. Jas. Taylor and Co., of Birkenhead.

SAND PUMPS FOR WELL FOUNDATIONS.

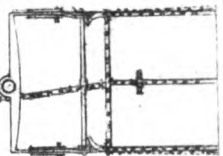


Gallows for lifting Sand Pump at Sully Bridge. Lift 24 feet.



Jib Derrick used for lifting rails &c. at Sully Bridge, made of Cheir timbers & Railway metals. Lift 50 feet, rad: 16 feet.

about wrought iron Skip for lowering Concrete into the Cylinders.



Scale 1" = 1'

No. CLV.

REWAREE SLATE QUARRIES.

Account of the Slate Quarries in the Goorgaon District. BY CRAWFORD CAMPBELL, Esq., Executive Engineer, Delhi.

IN accordance with the verbal instructions of the Chief Engineer, I proceeded in January last to visit the slate quarries near Rewaree, in the Goorgaon district.

My route thither was a circuitous one, as business led me first to Noh and Malubbut; this deviation from the direct road enabled me to examine carefully the geology of the district, and from the information thus procured, and from notes made in previous years, I have compiled the accompanying Sketch Map of the Lithology of the Delhi and Goorgaon districts. I wish I could have expanded this into a regular geological map of the whole system; of the fringe (or edge) to which they form merely a small portion; but time was wanting for even the most cursory examination of the Ulwur, Narnoul, and Dadree Hills; a survey of which would doubtless be productive of very beneficial results, as a reference to the notes on the sketch will show.

The rocks in the districts under notice are wholly metamorphic; and form two distinct masses, of which the Sahabee nullah may be taken as the dividing line. The easternmost is of gneiss in large broad masses, forming a continuous ridge from Meolee to Delhi; where it dies out under the waters of the Jumna, and does not again appear. The more western of the two consists of detached hills, projecting above a sandy plain; which become fewer in number and smaller in size as they approach the

great desert, and cease, rather than die out, on the southernmost boundary of Hurreana and Bhuttiana. These hills, as far as I have examined them, are wholly and purely clay slate.

The strata composing them dip to the north; the strike lying nearly due east and west; whilst the lines of cleavage run pretty uniformly in a direction N. 14° E., and are generally inclined to the horizon at an angle varying from 48° to 76°. In some few places they are quite perpendicular; and at the top of the Palee hill, I found the uppermost bed curved over, from what cause it is difficult to say; but certainly not from either of those to which similar phenomena are generally attributed in the slate quarries at home. The quality varies much, and but little of it is fit for roofing purposes. In most of the hills the cleavage planes are wide apart, and the slate becomes a mere argillaceous flagstone, more or less hard and compact. In this condition it is used as rubble in masonry walls, and forms a capital building stone. For lintels, the natives use Kirwanee stone, a mica schist, from a place in the Ulwur territory, lying 25 miles south-west of Rewaree. I mention this to show that the clay slate passes into mica schist as it approaches the hills of Mewat.

My examination of the slate hills was necessarily a very superficial one; but I only noticed three places where good roofing slate is likely to be obtained—they are Palee, Manatee, and a small hill, three miles east of Rewaree. At Palee there is a ridge about one mile long, with three crests reaching to a height of from 300 to 450 feet above the plain. At the very summit are a few places from which roofing slate is sometimes extracted; but, unfortunately, the quality rapidly deteriorates lower down the hill, until at the bottom it becomes unfit for anything but building purposes. This is clearly seen, as a quarry was opened here, some 80 years ago by the then Raja of Rewaree, who took hence the stone used in the construction of the famous tank in that city. Even in the uppermost layers the beds are very irregular, and there are a good many veins of quartz: in fact but little good roofing slate could be got, and it would be useless opening any regular quarry here.

In extracting the slate, the natives use only the wedge and hammer; they never resort to blasting, and pick out purposely the softest stone where the cleavage is the coarsest. In fact they appear to consider hardness and tenuity a positive disadvantage, and do not care to get out anything under half an inch in thickness.

LITHOLOGICAL S

FLEXIBLE
SANDSTONE

GNEISS

KOOTB

SONAH

HOT SPR
GNEIS

KARNOUL

REY MARBLE

PELTINGWA
CLAY



Three miles from Palee are the quarries belonging to the village of Manatee, whence have been procured the roofing slates used in the Goorgaon and Rewaree school-houses. They lie at the southern extremity of the Khole hill, a large and imposing mass covering some square miles of ground, the highest peaks of which rise about 1,000 feet above the plain, and are over 2,000 feet above the level of the sea. The site of the quarries is however a low flat plateau, barely rising above the plain, about half a mile long by half that width. The cleavage plains and beds are regular and well defined; the slate is of good quality and color, and there are no veins of quartz and fewer foreign substances in the slates itself than is the case at Palee. In fact, we have here a capital site for a quarry, and if the upper beds were blasted away, slate equal to any in Wales could be procured.

I should state that the quality of the Manatee slate cannot be judged from the specimens sent to Goorgaon and Rewaree. These latter have been taken from the softest beds about, which were evidently selected by the natives as being the easiest to work. They are deficient in hardness and tenuity, are of a very bad color, and will never form a good lasting roof.

There is a smaller hill to the south, and in continuation of the one containing the Manatee quarry, from which it is only separated by a narrow nullah. The slate is of good quality, but the beds are much thrown and distorted, and the cleavage plains are irregular and highly inclined from the perpendicular. I could not detect any likely place for a quarry here.

The nearest point to Delhi at which the slate protrudes above the plain, is about three miles east of Rewaree, close to the Patondie road, where there is a mass of rock about 100 yards long and 30 feet high, on the top of which stand a mosque and two tombs. It appears to be considered a sacred place, so that there might be some difficulty in quarrying here; but this is of less moment, as, although the slate is hard and of a good color, there is but little of it, and the bedding and cleavage are very irregular.

The only other place in the Goorgaon district where good roofing slate is found, is said to be a hill at Papree, near Pentungwa. I was unable to visit it, but it is described to me by competent eye-witnesses as closely resembling the Manatee quarry, a long low reef of slate, where the natives pick out the softest places and extract what they require with coarse wedges and hammers. Judging by the specimens sent in to me, the quality of the slate is inferior to that of the Rewaree system.

From what I have said, it will be seen that true clay slate is to be found in these districts, and that it can be readily made available for roofing purposes in the Delhi division. It will also be gathered that the quarries at Manetee give the fairest promise of good material. They are, besides, much more accessible than those at Papree, or than any other unexplored ones that may hereafter come to light; for they are only 18 miles from the projected railway *via* Rewaree to Rajpootana. I therefore beg to recommend that measures be taken to open them out in a systematic manner. For this purpose English supervision should be largely employed. Blasting must be resorted to, and proper tools for dressing and splitting the slate will have to be introduced. All this will cost money, and the slate will at first be an expensive article compared with the terraced roofs now in use; but its lasting qualities and other excellencies as a roofing material will, I believe, more than compensate for this disadvantage.

C. C.

No. CLVI.

POONA WATER-WORKS.

Project for the Water Supply of Poona and Kirkee. Abridged from a Report by LIEUT.-COL. FIFE, R.E., Superintending Engineer.

THE supply of water to Poona has always been a difficulty; and in 1848 the Jamsetjee Bund, across the River Moolla Moota, was constructed, and machinery erected for pumping what was then considered a sufficient quantity of water up to the Cantonment. How very imperfectly this work has supplied the deficiency is well known to Government and all residents at Poona, and the lucid report of the 5th September, 1865, by Dr. Leith, the President of the Sanatory Commission, has most completely proved the utter hopelessness of our ever obtaining a supply of pure water from that source.

The cantonment of Kirkee has recently been shown by Dr. Leith to be actually, if possible, in a worse position than Poona as respects good water, but less has been heard of the hardship, from the station being so much smaller.

The supply of water to the City of Poona has also always been defective, and though the proverbial public spirit of wealthy natives in constructing wells and conduits has done almost everything that could be done, a very large portion of the population is still dependent on the river for water, and as the stream ceases to flow in February, the people take the water from stagnant pools or pits excavated in the bed. The water obtained from the latter would be pure in any open part of the river, but at the City, where both banks are crowded with houses, and every sort of filth finds its way

down to the river bed, the water cannot be pure; and the quantity is moreover very small, as the Moota, like most of the Deccan rivers, has rock close under the bed, and in places the bed itself is rock. During a drought which occurred about 30 years ago, the people were reduced to such a condition of distress that they excavated a cut in the river bed to tap some pools situated about 12 miles off. During the past season an attempt was made by the Public Works Department to bring water down to the city in the same way, and it was of some use.

The City of Poona has not enough water for ordinary purposes; much less does the supply suffice for sewage, for which, practically speaking, there is none at all except during heavy rain. Government has already been made acquainted with the condition of the sewers from a report dated 8th August, 1865, submitted by a Committee composed of Dr. Leith, Mr. Duff the Collector, and myself. It was found by the Committee that the present sewers were choked up from the proportion of solid matter finding its way into them being too great, and that they were in fact nothing more than elongated cesspools, polluting the ground in every direction. To improve the sewage was simply impossible without a copious supply of water, such as is afforded to European cities.

No project was ever prepared for affording Poona an adequate supply of wholesome water, but it is probable that the city, with a population of 70,000, will require as much water as the Cantonment, or 1,500,000 gallons a day.

Briefly summarizing the history of the question of the water supply of Poona and Kirkee, and of the City of Poona, it appears; 1st, That the supply of wholesome water has always been inadequate, and that the increasing population, with the location of the Powder Works and Arsenal at Kirkee has rendered it now imperative that water-works should be at once undertaken.

2nd. That the cost of affording an adequate supply on the small tank and pipe system will be as follows:—

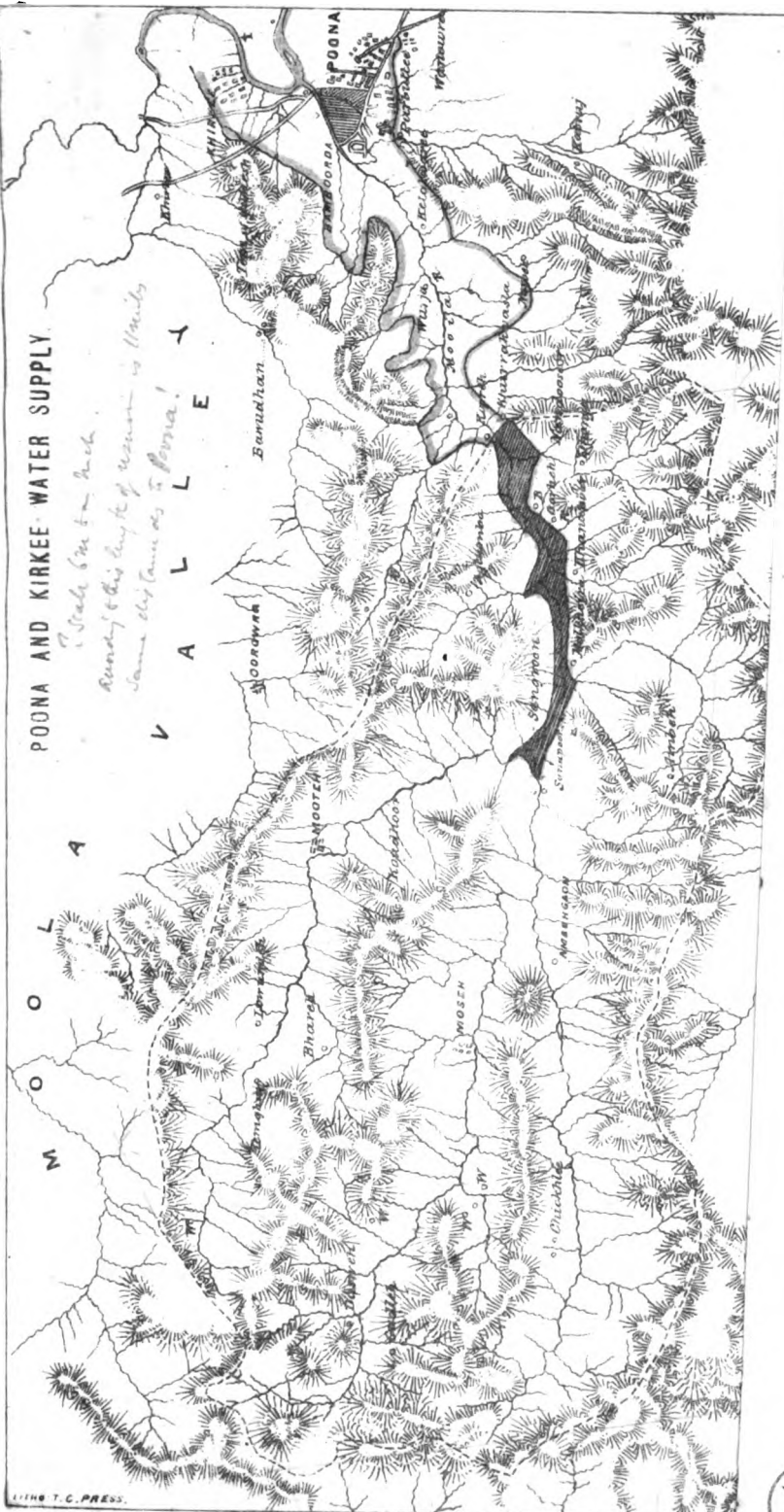
	rs.
Poona Cantonment—1,500,000 gallons per day, ..	14,17,840
Kirkee Cantonment and Powder Works—934,665 gallons per day, ..	6,91,339
Poona City—1,500,000 gallons per day, ..	7,19,846
Total probable cost, ..	28,29,025

3rd. That the water which will be obtained will be of inferior quality in the hot season, when the reservoirs sink to a low level.

POONA AND KIRKEE WATER SUPPLY.

*Scale 6 m. to 1 inch.
 Run of this supply of water is 11 m. by
 same dist. as to Poona.*

V A L L E Y



The project I am now about to describe will not be quite new to Government, nor, I may add, is it really new at all as far as the source of supply goes, but it is on a larger scale than the projects formerly brought forward, and it is principally owing to this increase in size, that after the most careful investigation of the whole question, I have been led to revert to a source of supply that was formerly rejected. This source of supply is the river Moota itself, but at a distance of 11 miles above Poona, a locality thought of so far back as 1855, and strongly urged by the late Hon'ble Mr. Reeves as most suitable for the purpose.

The feasibility of obtaining water from the Moota was considered by Captain Hart in his investigation of the water supply for Poona Cantonment, but the plan was rejected by him in consequence of the want of slope that would be available for the pipe from the river to Poona. For a project to afford the comparatively small quantity of water then contemplated, Captain Hart was right in his conclusion, but the question has now assumed a different aspect. What Captain Hart had to decide was the best means of obtaining 821,917 gallons a day: what has now to be decided is the best means of obtaining 3,000,000 gallons per day, with a demand for much more, (if it can be furnished,) for garden irrigation in the vicinity of Poona, where the extensive European and Native population creates a large demand, I may even say a necessity, for garden produce. Under this altered aspect of the question, it appears that our best plan will be to revert to the Moota river as a source of supply, to form one large reservoir upon it, and to lead the very large quantity of water required by open ducts (for which the available slope is sufficient), to expense reservoirs in the vicinity of Poona and Kirkee, whence iron pipes will distribute the water for the various purposes for which it is required. The advantages of this plan are the greater facilities for storing and conveying a large supply of water, and consequently greater economy; and the greater purity of the water obtained from a reservoir, which, it will be hereafter explained, is never to be less than 50 feet deep opposite the reservoir dam. With these pre-fatory remarks I may now proceed to a description of the project.

The Reservoir.—The site selected for the reservoir is immediately above the village of Kurrukwasla, where the slope of the valley, 6 feet per mile, and the rocky nature of the ground, afford the requisite facilities for obtaining a large capacity for the reservoir, and perfect security from accident for the masonry impounding dam and the waste weir.

From the level of the stream being rather low at this point, and from the necessity for making allowance for silt deposit, as well as to avoid the necessity of completely draining the reservoir to obtain the whole quantity of water required, the feeding level to the ducts which have to lead the water to Kirkee and Poona has been fixed at 65 feet above the lowest part of the bed of the river, and about 40 feet above the banks. At this level the area of the reservoir will be 8 square miles.

The loss by evaporation in this large reservoir during six months, after which replenishment will take place from the showers at the commencement of the monsoon, has been taken at 5 feet perpendicular; and to provide for the whole quantity of water, 715,392,000 cubic feet, to be furnished during the 6 months of perfectly dry weather, the dam is to be 20 feet above the level of the feeding point. The area of the lake at this level will be $5\frac{1}{2}$ square miles. Its average width will be two-thirds of a mile, its average depth 36 feet, and it will be $7\frac{1}{2}$ miles in length.

The Dam will thus be 85 feet high at the deepest part of the valley, or where it crosses the river. Only 400 feet in length will however be of this height. The remainder varies from 60 feet at the bank of the river to almost nothing where the dam is connected with the hills on both sides of the valley. The dam is to be of masonry, and, to check leakage, a bank of earth will be added to its base on both sides. It will be founded on rock throughout its whole length, and is of such a massive construction as to entirely set at rest any fear of such a catastrophe as occurred at Sheffield. The masonry dam, as will be seen from the calculations given in Appendix A., is in excess of what is required to resist the pressure of the water when the reservoir is filled up to the highest possible level, or when there is a stream 5 feet deep running over the waste weir. The total length of the dam is 2,900 feet, and the average height 48 feet.

The Waste Weir.—The waste weir is one of the most important portions of every water supply project, and in the present case, when the works are to be on a large scale, more than ordinary care and attention have been bestowed upon it. The heaviest flood which has been observed during the past two years, during which the state of the river has been daily gauged and registered, amounted to 45,405 cubic feet per second; but from reliable information obtained from the villagers of Koprah, whose village stands on the bank, it has been found that during an extraordinary flood which occurred in 1861, the river rose 6 feet higher than our gauge has indicated during

the past two years. The flood discharge on that extraordinary occasion has been carefully calculated, and amounts to 82,079 cubic feet per second. The waste weir has been designed to discharge this volume. It is true that with the large reservoir the effect of a flood must be modified, and that instead of rushing past Koprah with a discharge of 82,079 cubic feet per second, and lasting at that height only an hour or so, it will raise the level of the water in the reservoir gradually, and escape by the waste weir in a smaller quantity per second, but will last many hours. Still, to be on the safe side in this important matter, it is better to give the waste weir dimensions, which will enable it to discharge the greatest flood that has ever been known to occur with the river in its present unobstructed state.

The waste weir provides for the escape of 82,079 feet per second, and the control of so large a stream as this has been very carefully studied. We have not been contented by an appearance of rock where the overfall will occur, but have actually blasted portions away at intervals all along the site to be quite sure that the rock is really solid and sound, and not a mere superficial covering to some softer stratum below. A defect in the rock would certainly not cause a catastrophe, but it would cause a leak, which would allow the water to be wasted in the first instance, and it would afterwards lead to a great deal of trouble and expense for repairs. I am glad to say, however, the result of the examination of the rock has proved satisfactory. After removing from one to five feet of the surface it has proved perfectly sound, and the bed extends from the waste weir site to a nullah in rear, and thence to the river bed again, at a distance of 1,200 feet below the dam. The nullah forms the depression by which the waste water will find its way back to the river again. The water is prevented from spreading towards the dam by means of a massive wing wall as strong in construction as the dam itself. The waste weir has an average height of 9 feet, and is 1,660 feet long. The water will flow 5 feet deep over its crest during the heaviest floods. Calculations for this work will be found in page 280.

The Ducts.—For Kirkee the ducts will have a slope of one foot per mile, a bottom width of 5 feet, depth $2\frac{1}{2}$ feet, velocity of current 1.4745 feet, and the theoretical discharge of 32.2775 cubic feet per second. This duct will supply 26 cubic feet per second for the irrigation of 4,000 acres of land, and 1.75 cubic feet per second, or 934,665 gallons per day for Kirkee, the quantity fixed by Government Resolution, of the 10th August, 1865.

The duct will be of uniform size, that a week's supply for Kirkee may be carried in a few hours to the expense reservoir in order that the water may not sustain injury from passing in a slender stream along an open channel. The length of the duct will be 16 miles, as the unevenness of the ground makes the route circuitous. At that distance from the head works, settling and expense reservoirs are provided on the high ground opposite to Kirkee hill, with a command of 37·08 feet over the European Barracks, and 25·72 feet over the highest delivery point in the Powder Works on Kirkee Hill. The water will be conducted from the reservoir by means of an iron pipe, varying from 14 inches in diameter in the portion from the reservoir to the barracks, to 12 inches in diameter at the delivery point at the Powder Works. Smaller branch pipes distribute the water from the main pipe. The main pipe passes over the ground which will be occupied by the proposed Fort.

There is nothing in the nature of the works on this duct which demands any great explanation. All drainage is passed under the duct by aqueducts and culverts, in exactly the same manner as in the irrigation works constructed in Khandeish. The water will be admitted into the duct from the reservoir by a simple sluice, the head of water to contend with being only 12 feet. The settling and expense reservoirs on the hill opposite Kirkee will contain one week's supply, and are formed in a small depression close to the watershed. The water is retained on the low side by a masonry wall backed with earth, and the bed of the reservoirs will be rock, all the overlying soil being scraped away.

On the Poona side of the river less fall is available than on the Kirkee side, and the slope of the duct is therefore only 6 inches per mile. The bottom width will be 10 feet, the depth 3 feet, the velocity 1·2023 feet per second, and the theoretical discharge 52·30 cubic feet per second. This discharge provides for 2·75 cubic feet per second, or 1,500,000 gallons per day for Poona Cantonment (the quantity fixed by Dr. Leith), 1,500,000 gallons per day for Poona City, and for 2,000 acres of irrigation. As in the Kirkee duct, there is no diminution of section towards the tail, and for the same reason, viz., that the water may be run off from the great reservoir to the expense reservoirs for Poona Cantonment and city, in a few hours.

The Poona duct will be altogether $11\frac{1}{2}$ miles in length. At the 9th mile it passes the Parbuttee Tank, which it commands. This tank is in-

variably dry when there is a great scarcity of water, but may now be used as an expense reservoir by the Municipality of Poona. It is unnecessarily large, but a portion may be easily shut off so as to form a reservoir of the requisite size. The Parbuttee Tank commands the whole of the city, hence the distribution of the water throughout the city by means of pipes will be a matter of no difficulty.

At the $11\frac{1}{2}$ mile, or termination of the duct, two quarries now used as tanks, and situated near St. Mary's Church, are entered. The first one will have a retaining wall, averaging 5 feet in height built round it, and will be used as a settling reservoir. The second will have its lower edge raised 6 feet by a masonry wall, and it will then hold a week's supply of water for the Cantonment. The water will be distributed from this reservoir to the Bazar, Native Infantry Lines, Civil Lines, and Ghorepooree, by iron pipes and gravitation. For the Wanowree Lines, now occupied by H. M.'s 38rd Regiment, the water, if distributed through the Barracks, must be raised by machinery, and this is provided in the estimate. The quantity of water to be raised is 300,000 gallons per day, and the cost of raising it 90 feet, capitalized, is Rs. 85,600.

There is nothing in these works which demands any particular explanation. The drainage will all be passed under the duct. Fencing is provided for both sides of the duct when it gets near Poona, that people may be prevented from drawing water directly from it. At the expense reservoir, side chambers are provided for the people to draw water from, that there may be no necessity for taking water direct from the reservoir. All natural drainage will be excluded from the reservoirs.

The cost of the works for the whole project will be as follows:—

	RS.	A.	P.
Main reservoir dam with waste weir and sluices, ..	9,52,121	14	9
Kirkee open duct,	78,458	6	4
„ settling and expense reservoirs, ..	16,642	8	1
„ main pipe,	1,06,881	8	4
„ distribution pipes in Powder Works, ..	56,277	0	0
„ distribution pipes for Cantonment, ..	24,795	0	0
Poona open duct,	1,22,000	2	2
„ settling and expense reservoirs, ..	23,887	8	0
„ cisterns,	41,646	0	0
„ main pipe,	82,358	14	4
„ distribution pipes by gravitation, ..	79,129	13	8
„ steam power for raising water, ..	94,600	0	0
„ distribution pipe for Wanowree Lines, ..	24,801	4	0
Total, ..	16,58,049	10	8

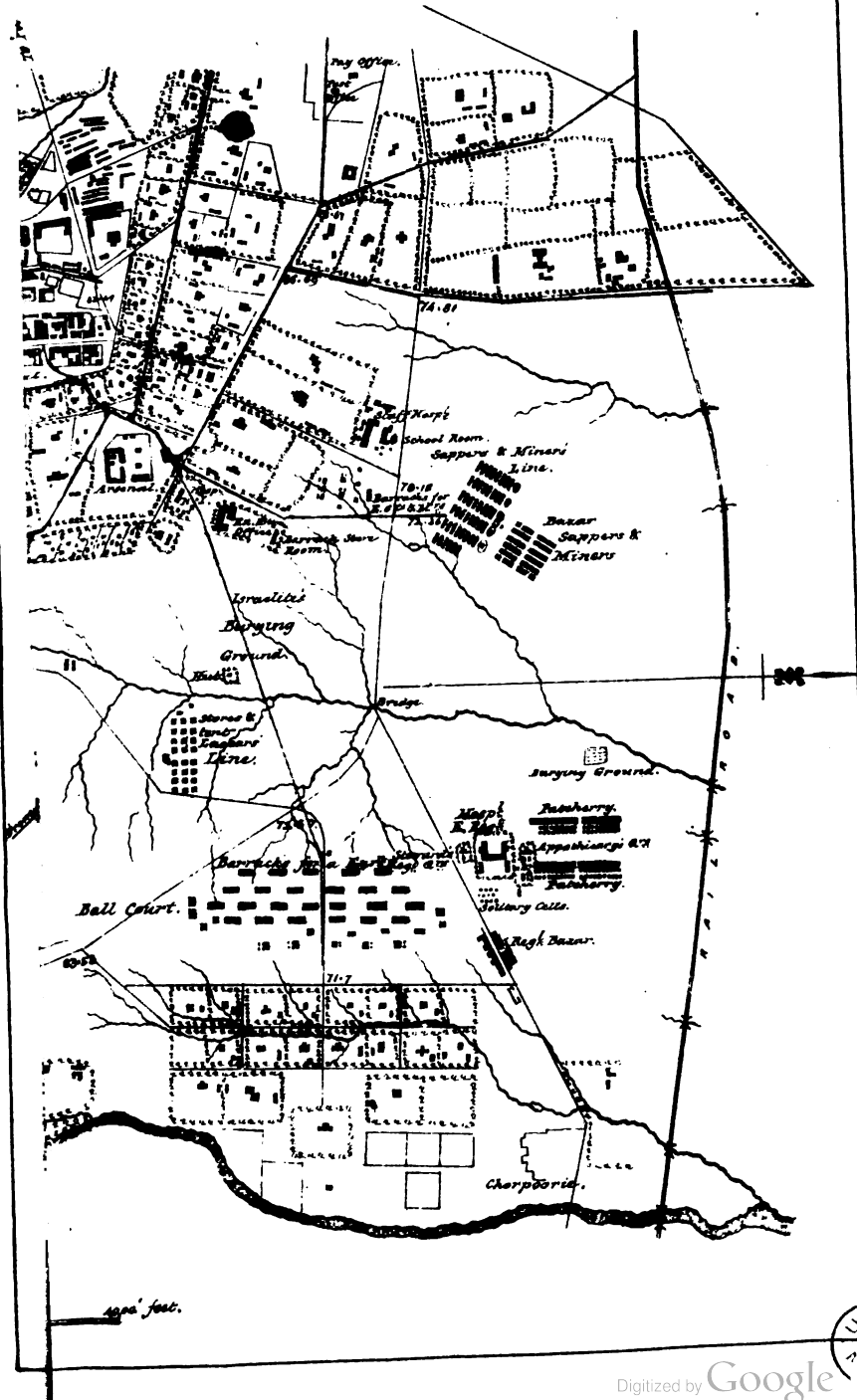
This estimate, it will be observed, provides for both supplying and distributing the water in the most complete manner; but as our present position is one of absolute want of water, it would be a great boon merely to have the water brought into Poona and Kirkee to central reservoirs, whence it might be conveyed by carts and bullocks as at present practised from wells, leaving the more perfect distributing arrangements to be carried out afterwards, as rapidly as funds may be available. The distribution through the Powder Works is however essential immediately, as also a pipe to lead the water from the central reservoir in Poona to the Ghorepooree Lines. The remainder may be easily deferred. If, therefore, Government should prefer for the present simply to obtain an abundant supply of good water, which will be at least within reach of all the inhabitants, but not distributed in detail except to the Powder Works and Ghorepooree Lines, the estimate will become as follows:—

	RS.	A.	P.
Main reservoir dam, with waste weir and sluices, ..	9,52,121	14	9
Kirkee open duct,	78,458	6	4
„ settling and expense reservoirs, ..	16,042	3	1
„ main pipe,	1,06,831	8	4
„ distribution pipes to Powder Works, ..	56,277	0	0
Poona open duct,	1,22,000	2	2
„ settling and expense reservoirs, ..	28,887	8	0
„ pipe to Ghorepooree lines, ..	10,673	4	0
Total, ..	13,66,891	14	8

The distribution of the water afterwards throughout the Bazar, Civil Lines, and environs of Poona might be carried out with the aid of Bazar and Municipal Funds, and a cess on houses, which owners would be quite willing enough to pay, for property beyond Municipal limits.

The cost of supplying the troops and Government Departments with water, according to a statement received from the Quarter-Master General of the Army, and other data obtained from the Public Works Department, is Rs. 36,180 per annum, taking the average of the three past years. This average, however, is not a fair criterion, because the increasing expense during the latter year is in a great measure owing to the rise in the rate of hire for bullocks, &c. To guide us, therefore, with respect to future expenses, supposing delay should occur in constructing water works, it would be more correct to take the expense of the last year shown in the statement. This expense may be divided under two

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heads; the cost of supply, which comprises the expense of pumping the water from the Jamsetjee Bund, and its maintenance; and the cost of conveying the water by bullocks and carts from the river or wells and the central reservoir near the Poona Arsenal to the troops and Departments. Dividing the expense in this manner we find that the cost of supply is Rs. 11,750, and of distribution Rs. 29,544.

It is not easy to say what the cost to private individuals is for bheestees, but from what I have learnt from the Bazar Master at Poona of the number of bheestees in the Cantonment, I feel sure I am understating the expense when I set it down at Rs. 60,000 per annum. Much of the annual cost of distribution is caused from the great distance the bheestees have at present to carry the water, and the time they lose in drawing it from deep wells, where they have not only the labor of hauling the water up, but are also kept waiting by the crowds of people who congregate to obtain their daily supply of the precious fluid. Government is no doubt aware that it is only by placing guards over the wells that the Brigade authorities can manage the distribution of the small quantity of water obtainable.

If the water-works now under consideration be carried out without the most perfect distributing apparatus, the expense of distribution by the ordinary means will still be greatly reduced. There would be no occasion to have recourse to the river at Kirkee. Water would be obtainable within a few yards of the Barracks and Horse Lines. At Poona the facilities would be similarly increased. Bheestees, instead of having to wander about from well to well, and carry the water a mile to its destination, would obtain it at the central reservoir at St. Mary's Church, at a point near the Arsenal, where the pipe to Ghorepooree will pass, and within a few yards of Ghorepooree Barracks. The expense of distribution will certainly be reduced to one-fourth of what it costs just now. Government would thus be saved—

	RS.
1st. The cost of supplying water,	11,750
2nd. Three-fourths of cost of present distribution (Rs. 29,544),	22,158
Total Rs., ..	33,908
The public would be saved three-fourths of Rs. 60,000, or,	45,000
Total Rs., ..	78,908

Should the project now submitted be approved, I would strongly urge an immediate commencement of the dam at Kurrukwasla, that the foundations may be got in and the work raised about 20 feet, before the monsoon floods commence, otherwise a whole year will be lost, as it is only between the present time of the year and April, that impounding works can be commenced. If commenced early, the dam could be brought up to a height of 20 feet during the present season. During the following season it could be brought up to the level of the site of the waste weir, the foundation of the waste weir only being put in, to give the water a free escape at a low level. By February 1868, or in two years and three months from the present time, the works could be completed to their full height, and as the reservoir would be filled by the monsoon of 1867 and the stream which continues to flow after the monsoon is past, the water supply works, except for irrigation, could be in full operation from December 1867, or even earlier, as the surface of the reservoir would be above the feeding level of the ducts. As another reason for recommending the immediate commencement of the works, I should mention that my assistant, Lieutenant Buckle, R.E., who has been engaged on the project during the past year, and who is fully acquainted with all my views and the whole of the details of the plans, is now on the spot, and Government is well aware of the great advantage of employing an officer to carry out a large work who has been engaged in the preparation of the plans.

SPECIFICATION.

The works are to consist of a dam across the river Moota to form a reservoir, two open ducts to lead the water thence to settling and expense reservoirs at Poona and Kirkee; and iron pipes to distribute the water throughout the Cantonments and Powder Works, as also a horse-power engine to raise the water for a small portion of the Poona Cantonment, viz., the Wanowree Barracks. The general description of the arrangements is given in a more complete manner in the transmitting report on the Works.

Detailed Description of Dam, Waste Weir, and Wing Wall.—The dam, waste weir, and wing wall will be founded on rock throughout the whole length. The dam, which is to be of masonry, is to have a section in which the base = $\cdot 55$ of the height, measured up to the highest water line; the thickness at top = $\frac{1}{4}$ th of the base. Batter on water face = $\frac{1}{10}$ th of height. Batter in rear to be $\frac{1}{4}$ ths of height.

The dam to be raised 3 feet above highest water line, or 8 feet above the crest of waste weir, and to be surmounted by a parapet wall 2 feet thick and 3 feet high. This section will give a top thickness to the dam of 10.56 feet where it is highest in the centre of the valley. Where the height of the dam is much less, and where the proportion given would reduce the total thickness to less than 4 feet, the section to be modified by omitting the batters first on the water face, and then on the rear face, so that the top thickness may never be less than 4 feet. The dam will thus become rectangular in section where it is very low, and the mass of masonry will be unnecessarily heavy; but this cannot be avoided, as 4 feet must be regarded as a minimum for the top thickness.

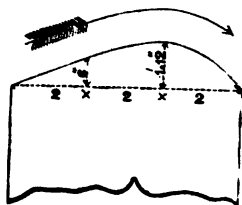
At the south end of the dam, four small sluice openings to be constructed, with valves working vertically against the water face. The sluice openings to be 3 feet wide and 3 feet high, and arched over. At the north end of the waste weir three similar sluices to be constructed to supply the Kirkee duct. The sills of the sluices to correspond in level with the bottoms of the ducts. The sluices to be worked from above by rack and pinion action. When the water is escaping over the waste weir, the sluices in the waste weir may be closed, as the duct will then receive its supply from the waste water. To prevent the waste water flooding the Kirkee duct, a stop gate to be constructed where the duct enters a cutting after getting clear of the waste weir channel.

The wing wall where the dam terminates and where the waste weir begins, to have precisely the same section as the dam itself; that is, in proportion to the head of water it has to sustain, but with minimum top thickness of 3 feet.

The dam and wing wall, though founded on rock, might still not prevent leakage through the rock, supposing any cavities to exist in the rock, and to prevent this, and staunch the water as completely as possible, good puddling earth to be added to both sides of the dam to one-third its height, *vide* sections of dam. The slope of the earthen banks to be one in two, horizontal, where the dam crosses the river bed; all the gravel overlying the rock to be carefully removed before the puddling earth is laid down. The wing wall to have a similar bank of earth, but on its rear side only.

The waste weir to have a stronger section than the dam, as it will be exposed to more severe action. Its thickness to be equal to one-half the

height; to be perpendicular on the down-stream face, and with a batter of one-sixth of the height on the up-stream face. Where these proportions would reduce the top thickness at the low end to less than 4 feet, the batter to be omitted, and the section made rectangular, that the top thickness may not be less than 4 feet. The top to be slightly rounded. See diagram.



Specification of Dam, Waste Weir, and Wing Wall.—The unwatering of the foundations at the deep part of the dam will be best effected by forming a small cut about 10 feet wide through the gravel, from the dam site to the nearest pool, which is at a distance of about 500 feet, and forming a similar cut at the lower end of the pool at a distance of one mile from the site. The water level may thus be lowered, till the rock, on which the dam is to be built, is laid dry.

The whole of the masonry at the dam, wing wall, and waste weir, to be of common coursed rubble, with the exception of the water faces of the dam, wing wall, and waste weir, which are to be of closer jointed work. The joints, however, are not to be fine in the dam, otherwise there will be unequal settlement in the face and body of the work. Half-inch joints will be quite close enough, and the stones should be only hammer-dressed. The wing wall water face should be the same as the dam to within 50 feet of where it joins the waste weir, where the face work should be the same as that of the waste weir. The waste weir's down-stream face and coping to be close jointed work, the joints being one-quarter of an inch only. The coping to be made of stones not less than $1\frac{1}{2}$ feet by 9 inches; the top to be roughly chisel-dressed; the stones on the down-stream face of the waste weir, though close jointed, need not have their faces dressed off with the chisel.

The sluice openings to be of the best close quarter-inch jointed work, and the stones dressed smooth on the face, that the stream may not be impeded; the stones used for the grooves to be not less than 2 feet $\times$ 1 foot 9 inches. The valve or shutter to be of teak wood. The parapet wall on the dam to be of ordinary coursed rubble masonry, with rounded coping, close jointed, but surface unchiselled; the top of the dam to be roughly hammer-dressed.

The lime used for all the work to be hydraulic. Nearly all the Deccan

lime is naturally hydraulic, but that used for these important works must be carefully tested, to prevent ordinary lime being used. The stone to be of durable quality, and quarried close to the works. Very large stones, just as they come from the quarry, may be used for the body of the dam, waste weir, and wing wall; but the greatest care must be taken to fill in all interstices between them with smaller stones, chips and mortar. As far as the shape of the stones is concerned, the very coarsest work will suffice, provided all the interstices are carefully filled in, so as to make the work really solid and water-tight.

In procuring puddling earth for the slopes on both sides of the dam no excavations are to be formed anywhere in rear of the dam, and not within 200 feet of it in front. The material must be taken at a distance exceeding 200 feet in front of, and immediately below, the waste weir.

The Ducts.—The ducts will be generally entirely excavated, as they are too small in section to admit of half cutting and half embanking to answer. The excavated material will be nearly all required to shut out local surface drainage from the fields on both sides, but principally on the high side.

The sections of the ducts to be as follows:—

Kirkee Duct.—Fall 1 foot per mile; bottom width 5 feet; depth $2\frac{1}{2}$ feet; the slopes 1 in $1\frac{1}{2}$; theoretical velocity and discharge 1.4745 feet per second, and 32.2775 cubic feet per second.

Poona Duct.—Fall per mile 6 inches; bottom width 10 feet; depth 3 feet; side slopes 1 in $1\frac{1}{2}$; theoretical velocity and discharge 1.2023 and 52.30 cubic feet per second, respectively. All drainage is to be passed underneath the ducts by means of aqueducts, culverts, and syphon culverts; and all aqueducts standing on a rock formation to have their parapet walls made lower in the centre than at the wings, that they may serve as escapes should too much water ever get into the ducts. At the head of the Poona duct a retaining wall to be carried along the lower side of the duct, rising to 3 feet above water level, as far as Kurrukwasla, to prevent injury to the head-works, supposing anything should get out of order with the sluices, and more water enter the duct than it could carry off. Beyond Kurrukwasla the surplus water would find a ready and safe escape back to the river again by means of the nullah on which No. 1 aqueduct will be constructed. Retaining wall to have a bank of earth against it, and to have a thickness one-fourth of height, and to be founded on rock or hard moorum. At the

head of the Kirkee duct, the lower side of the duct, where it will cross the waste weir channel, for a short distance to be retained by a masonry wall having a thickness = one-half its height, but the minimum thickness to be not less than 2 feet; and where it is attached to the waste weir, and for a distance of 60 feet, its top thickness to be not less than 4 feet, as it will be subjected to a very severe action here from the waste weir overfall.

Specification for Aqueducts, Culverts, and Road Bridges.—Foundations and superstructure to be of the commonest coursed rubble, with all interstices between carefully filled with chips and good mortar, that the wall may be solid and water tight. Copings to parapets to be of dressed stone. All aqueducts standing on a hard foundation to have the parapets lower in the centre (equal to full supply level of duct) than at wings, that they may act as escapes.

The four Poona Road Bridges, for the Sunkersett Road, to have the superstructure and parapets of good coursed rubble, and coping of close jointed work, to be in keeping with other road bridges about Poona. On the Kirkee duct the road bridge for the old Bombay Road is to have masonry of the same character. The backs of aqueduct arches to be covered with 6 inches of concrete, with surface well finished off to prevent leakage.

J. F.

Calculations showing the Stability of the Masonry dam across the River Moota.

Extreme depth or head of water, during heaviest flood, 85 feet.

Height of dam, without parapet, 88 feet.

Thickness at base = 0.55 of head of water.

Thickness at highest water or flood level = 0.25 of thickness at base.

Batter on water face = $\frac{1}{3}$ th of height.

Batter on rear face = $\frac{1}{4}$ th of height.

Weight of one cubic foot of water = 62.32 lbs.

Weight of one cubic foot of masonry = 150 lbs.

First, to find the centre of gravity of the figure.

The centre of gravity of the parallelogram ABEC is at P its centre, and 44 feet, or half the whole height, from the base.

The centre of gravity of the triangle BED is at Q, which is one-third of the whole height, or 29.33 feet from the base.

Join PQ, and through Q draw the horizontal line HQ; from P let fall the perpendicular PF to meet HQ in F.

Then to fix the position of O, the centre of gravity of the whole mass of masonry, we have—

$$\begin{aligned} PO \times ABEC &= QO \times BED \\ &= (PQ - PO) BED \dots\dots\dots (1) \end{aligned}$$

By finding the value of PQ, and the areas of ABEC and BED, we shall obtain the value of PO, and then of OQ.

$$\begin{aligned} \text{Now } PQ &= \sqrt{PF^2 + FQ^2} = \sqrt{\left(\frac{AJ}{3} - JL\right)^2 + (HQ - HF)^2} \\ &= \sqrt{(14.66)^2 + (22.62 - \{2.98 + \frac{1}{3} \times 10.56 - \frac{1}{3} \times 4.4\})^2} \\ &= \sqrt{490.8} = 22.16 \end{aligned}$$

Next the area of ABEC = $10.56 \times 88 = 929.28$

and the area of BED = $18.1 \times 88 = 1592.80$

Substituting the values now found in equation (1), we have—

$$PO \times 929.28 = (22.16 - PO) 1592.8$$

whence $PO = 13.98$

$$\text{and } OQ = PQ - PO = 22.16 - 13.98 = 8.17$$

The weight of the whole mass of masonry, assuming that one foot in length of the dam is taken into consideration, will be

$$2522.08 \times 1 \times 150 \text{ lbs.} = 378312.00 \text{ lbs.} = W.$$

and it may be supposed to act at N in the vertical line dropped from the centre of gravity of the whole mass, O. The pressure of the water will be

$$85.1 \times 42.5 \times 62.32 \text{ lbs.} = 225395.86 \text{ lbs.}$$

and will act at M, at a distance of one-third of the whole depth from the bottom, and in a direction perpendicular to the face of the wall.

This force may be supposed to act at N, where its direction is intersected by the vertical ON.

To facilitate the working out of the result, resolve the pressure of the water, which may be called P, into two forces; one, W' , vertical; the other P' , horizontal, at N.

Complete the parallelogram NVTU.

Then $NV = TU = NT \sin TNU$.

$$\text{Now } \sin TNU = \sin CAJ = \frac{4.4}{88.11} = 0.05$$

$$\text{Therefore } NV = 0.05 \times 225395.86 = 11269.79 = W'.$$

$$\text{and } NU = P^1 = \sqrt{(225395.86)^2 - (11269.79)^2} = 225113.93.$$

The forces acting at N will thus be $W + W'$ in the direction of the vertical OS, and P^1 in the direction NU.

Complete the parallelogram NSRX, making NS and NX proportional to the forces $W + W'$, and P^1 respectively.

$$W + W' = 378312.00 + 11269.79 = 389581.79.$$

$$\text{and } P^1 = 225113.93$$

$$\text{Now } SN : SR :: W + W' : P^1 :: 389581.79 : 225113.93.$$

$$\therefore SR = \frac{SN \times 225113.93}{389581.79}$$

$$\text{and } SN = SY - NY = 29.33 - (Ya + aN) = 29.33 - (1 + aN)$$

$$\begin{aligned}\text{Again } aN &= \frac{1}{10} \times aM = \frac{1}{10} (HF + FY + \frac{1}{10} \times 1) \\ &= \frac{1}{10} (5.28 + \frac{44 - 29.33}{20} + FY + \frac{1}{10})\end{aligned}$$

and $FY : FQ :: PO : PQ$

$$\therefore FY = \frac{FQ \times PO}{PQ} = \frac{16.61 \times 13.98}{22.15} = 10.48$$

$$\therefore aN = \frac{1}{10} (5.28 + 0.783 + 10.48 + 0.05) = \frac{16.543}{20} = 0.8271$$

$$\therefore SN = 29.33 - (1 + 0.8271) = 29.33 - 1.8271 = 27.51$$

$$\text{and } SR = \frac{SN \times 225113.98}{389581.79} = \frac{27.51 \times 225113.98}{389581.79} = 15.63$$

$$\begin{aligned}\text{Now } CS &\equiv HY + \frac{1}{10} \times SY = HF + FY + \frac{29.33}{20} \\ &= 6.018 + 10.48 + 1.466 = 17.959\end{aligned}$$

$$\text{and } CZ = \frac{1}{2} CD = \frac{46.75}{2} = 23.375$$

$$\therefore SZ = 23.375 - 17.959 = 5.416$$

$$\text{and } ZR = SR - SZ = 15.63 - 5.41 = 10.22$$

The resultant R, therefore, passes through the base at a little less than one-fourth the width of the base, which is 11.69 from its centre.

Rankine, who is perhaps our best authority on the subject of the stability of retaining walls, or dams, says, that except when the foundation is rock, one-fourth of the width of the base from the centre is the limit for the resultant, but that in the case of a very firm foundation this limit may be exceeded. It has, however, been thought advisable to give the dam for the Moota Reservoir some extra strength, and the resultant passes even within the limit laid down by Rankine for a dam on an ordinary foundation, though the Moota Dam will be founded on rock. No credit, moreover, has been taken for the aid that will be obtained from the bank of earth which will be heaped against the dam on both sides to check leakage.

The weight of a cubic foot of masonry has been obtained by actual experiment on rubble stone walling at Poona.

Calculation to show that the Waste Weir, as designed, is capable of carrying off a quantity of water equal to the discharge of the River Moota during the greatest known flood.

The greatest flood remembered by the inhabitants of the village of Kopreh, close to the dam site, occurred in 1861, and from information obtained from the people, it has been calculated that the discharge of the river on that occasion was 82,079 cubic feet per second. The waste weir must therefore be of sufficient dimensions to carry off at least that quantity of water.

The length of the waste weir, when the water is passing over its crest at a depth of 5 feet, is 1,858 feet. Of this length 990 feet is more than 10 feet high and consequently has a clear overfall of 5 feet. The remaining portion, 668 feet in length, is less than 10 feet high, and is consequently drowned to a probable average depth of 2 feet 6 inches.

POONA WATER SUPPLY.

Diagram for calculation of the strength of the Dam.

Scale $\frac{1}{152}$ feet

