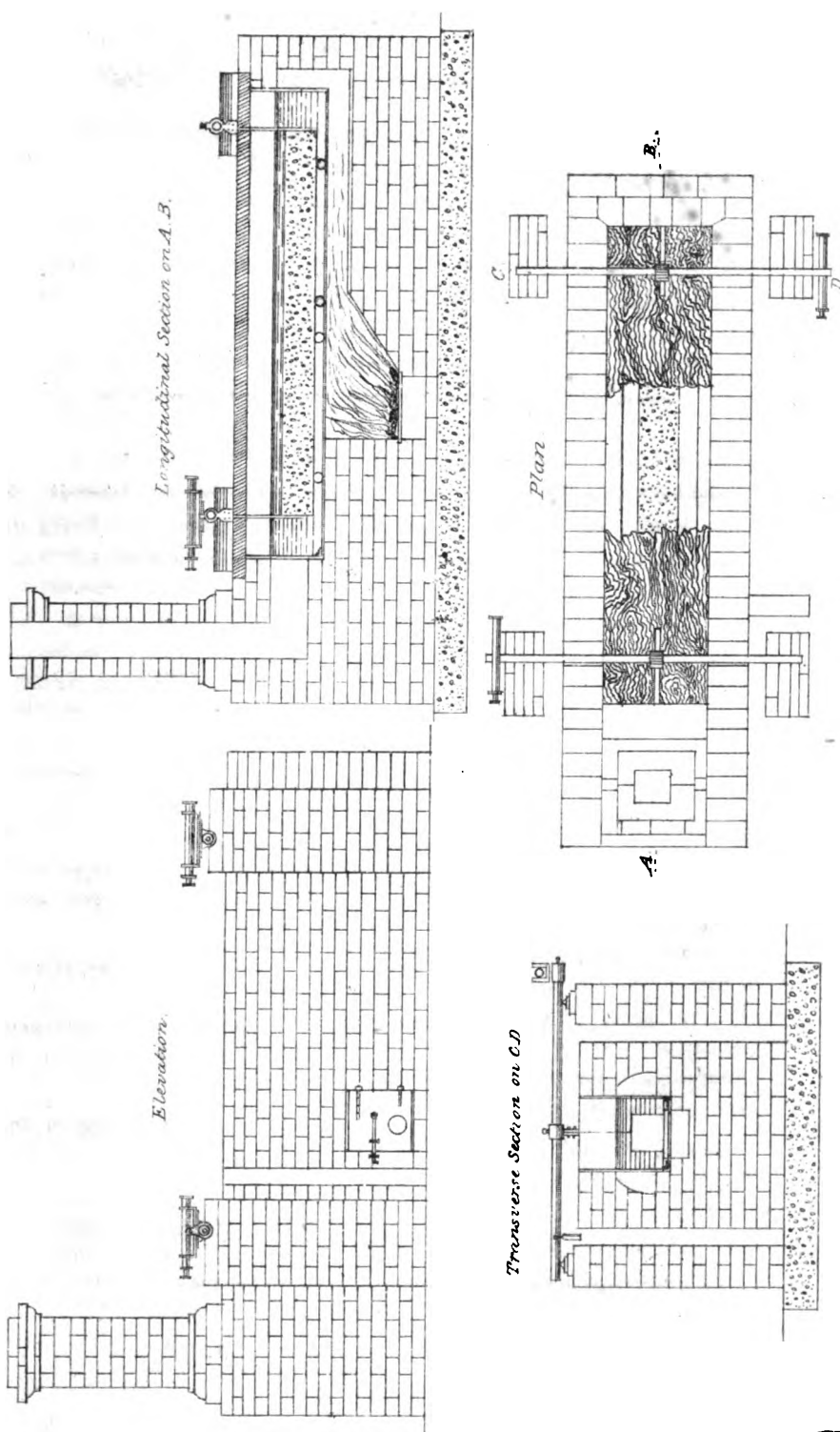


APPARATUS FOR MEASURING THE EXPANSION OF MASONRY



LITHO. T. C. PRESS.

The experiments were made on rectangular bars of masonry from 5 feet 6 inches to 7 feet 9 inches long,* immersed in water, the temperature of which was raised from 50° to 203° Fah.

The bar rested on rollers at the bottom of a tank, and butted at each extremity against the lower end of a vertical lever or rod. This lever was connected with a horizontal axle supported at each extremity; above and to the axle a telescope was fixed. The two supports were separated from the walls of the furnace, and the axles as well as the telescopes were wrapped in cotton wool, so as to guard against the effects of radiated heat (see *Plate*).

A telescope having been placed at each extremity, when the block expanded each telescope became deflected, describing an arc on a scale† placed at a distance of about 100 metres (328·08 feet.) This gave a very appreciable length of arc for a very small elongation in the bar of masonry.

In order to test the working of the instrument, experiments were made on bars of metal, the co-efficients for which were known; the result proved most satisfactory.

Each experiment was tried twice, and the results were rejected if both did not agree.

The arc described by the telescope per millimetre of expansion was determined each time by direct measurement. In short every possible precaution was taken to ensure exactness.

The experiments were made on ten different substances which happened to be at hand, and most commonly used in the work, viz. :—

1st, Portland cement, properly tempered, and allowed to set under water; 2nd, Mortar of Portland cement, containing two parts of siliceous sand to one of cement; 3rd, Brick-work, (set in the mortar above-mentioned,) the bricks laid all stretchers; 4th, The same Brick-work, but the bricks laid all headers; 5th, Bèton, composed of mortar as above, and round siliceous pebbles; 6th, Lime-stone, from Ranville quarry; 7th, Lime-stone, from Maladiène à Caen; 8th, Granite; 9th, Marble; 10th, Gypsum.

Knowing the co-efficients for mortar and stone, that for ashlar may be deduced.

The experiments are contained in the subjoined table.

* The cross section varied—it was generally a square, the side of which measured 7 or 8 inches.

† The arc and tangent are assumed identical.

TABLE OF CO-EFFICIENTS OF THE EXPANSION OR CONTRACTION OF MATERIALS EMPLOYED IN MASONRY.

No. of Experiments.	Nature of Materials.	Length in.	Length of arc per millim. of expansion.		Length of arc observed.		Quotient of		Temperature Cent.	Difference $t - t_1$.	$K = \frac{d + d_1}{(t - t_1)}$.	Mean expansion per metre per degree—Cent.	Expansion per foot per degree Fahrenheit.
			A	T	A'	T'	$\frac{A'}{A} = d_1$.	$\frac{T'}{T} = d_2$.					
			Metres.	Metres.	Metres.	Metres.	Millime- tres.	Millime- tres.	Days.	Days.			
1	Bar of Pure Portland cement,	2.00	0.158	0.149	+ 0.165	+ 0.120	+ 0.044	+ 0.806	12	97	86	0.0000109	0.0000594
2	Ditto,	2.00	0.157	0.149	+ 0.125	+ 0.111	+ 0.791	+ .744	22	95	78	0.0000105	
1	Mortar of Portland cement, ..	2.00	0.157	0.149	+ 0.208	+ 0.060	+ 1.805	+ 0.403	17	94	77	0.0000110	0.0000855
2	Ditto,	2.00	0.157	0.149	+ 0.174	+ 0.102	+ 1.108	+ 0.684	18	94	76	0.0000126	
1	Brick-work (all stretchers), ..	1.69	0.158	0.168	+ 0.125	+ 0.886	+ 0.791	+ 2.000	5	90	85	0.0000084	0.0000466
2	Ditto,	1.69	0.158	0.168	+ 0.072	+ 0.168	- 0.455	+ 0.910	8	95	87	0.0000098	
1	Brick-work (all headers), ..	2.00	0.158	0.149	+ 0.16	+ 0.25	+ 1.012	+ 1.678	22	95	78	0.0000456	0.0000255
2	Ditto,	2.00	0.158	0.149	+ 0.055	+ 0.165	- 0.948	+ 1.107	14	96	81	0.0000469	
1	Concrete in Portland cement,	2.40	0.157	0.162	+ 0.225	+ 0.0224	+ 2.98	- 0.15	13	97	84	0.0000187	0.0000794
2	Ditto,	2.40	0.157	0.162	+ 0.265	+ 0.263	+ 1.43	+ 1.56	22	96	84	0.0000148	
1	Stone from Ravville, ..	2.00	0.161	0.149	+ 0.092	+ 0.10	+ 0.572	+ 0.671	10	90	80	0.0000078	0.0000417
2	Ditto,	2.00	0.161	0.149	+ 0.075	+ 0.072	+ 0.466	- 0.49	26	91	65	0.0000072	
1	Stone from Maladiene,	2.00	0.158	0.149	+ 0.405	+ 0.182	+ 2.56	+ 1.22	18	92	74	0.0000905	0.0000466
2	Ditto,	2.00	0.158	0.149	+ 0.182	+ 0.063	+ 0.835	+ 0.423	16	88	72	0.0000878	
1	Granite, ..	2.00	0.158	0.168	+ 0.070	+ 0.140	+ 0.448	+ 0.888	14	95	81	0.0000079	0.0000489
2	Ditto, ..	2.00	0.158	0.168	+ 0.110	+ 0.098	+ 0.630	+ 1.286	15	95	80	0.0000060	
1	Marble, ..	1.868	0.157	0.149	+ 0.060	+ 0.645	+ 0.818	+ 0.488	19	94	75	0.0000064	0.0000359
2	Ditto, ..	1.868	0.157	0.149	+ 0.072	+ 0.065	+ 0.459	+ 0.869	14	95	81	0.0000065	
1	Gypsum, ..	2.00	0.158	0.157	+ 0.440	+ 0.020	+ 2.78	+ 0.127	9	98	84	0.0000178	0.0000922
2	Ditto, ..	2.00	0.158	0.157	+ 0.200	+ 0.000	+ 1.268	+ 0.000	40	90	40	0.0000016	

The letters A and F represent the two telescopes of the apparatus, K is the co-efficient of dilation.

From this it appears that the contraction or expansion per degree Fah. per foot in length is—

1. For pure Portland cement, - - - - -	·00000594
2. Mortar of Portland cement, - - - - -	·00000655
3. Brick-work in the same mortar, the bricks laid all stretchers, - - - - -	·00000495
4. The same Brick-work, the bricks laid all headers, - - - - -	·00000255
5. Bèton of mortar, as above, and pebbles, - - - - -	·00000794
6. Lime-stone, - - - - -	·00000417
7. Another specimen, - - - - -	·00000495
8. Granite, - - - - -	·00000439
9. Marble, - - - - -	·00000299
10. Gypsum, - - - - -	·00000322

These co-efficients, although they appear infinitely small, sometimes produce very apparent and not altogether harmless effects in works of large dimensions.

Suppose for instance an invert of Bèton in Portland cement, the thickness of which at the crown is 10 feet and span 100 feet, carrying at the springing heavy abutments of such a weight that the force of cohesion on a bed of bèton 10 feet thick is not sufficient to draw the two abutments together.

If the temperature is suddenly diminished by 20° Fah., and the crack be supposed to occur at the crown, its width will be—

$$100' \times 20^\circ \times \cdot 00000794 = \cdot 01588$$

$$- \cdot 01588 \times 12' = \cdot 19056 = \frac{1}{5}' \text{ nearly.}$$

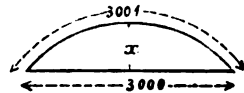
Again take the case of a wall 3000 feet long, and suppose the temperature to change suddenly from 80° to 40° Fah., it will contract nearly a foot.

If the fissure were to become filled up with mortar or rubbish, and if the extremities of the wall are immovably fixed, on the temperature again being raised the wall will become deflected some $33\frac{1}{2}$ feet.*

Practically perhaps it would never amount to so much, because a long wall is composed of a number of relatively very small bricks, often imperfectly bedded in cement.

$$\frac{1}{8} (8 \sqrt{1500^2 + x^2} - 3000) = 3001$$

$$x = 33\frac{1}{2},$$

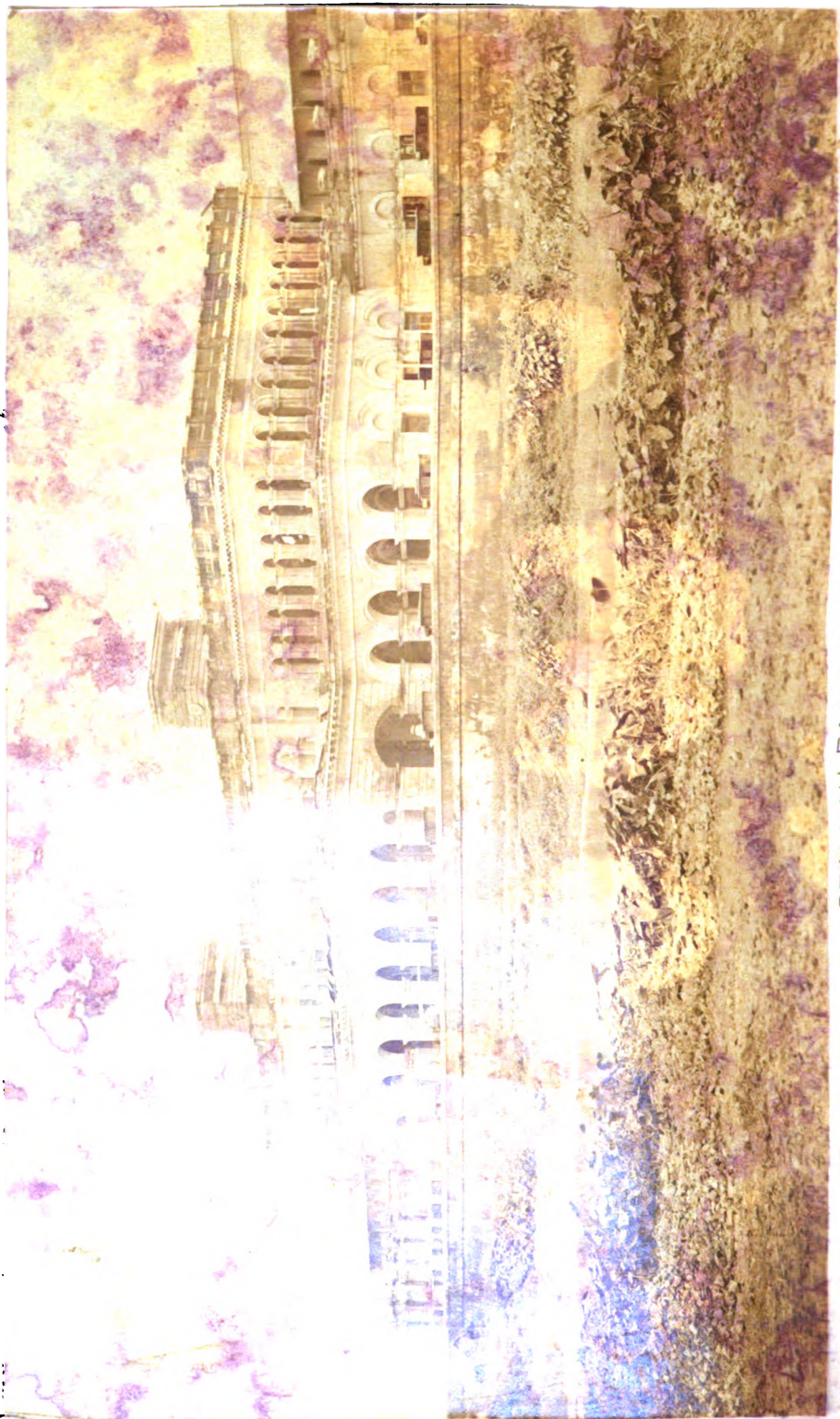


However it would seem advisable to leave small openings of a few inches at intervals in very long walls.

Referring to the experiments it appears that gypsum expands most and marble least.

Béton expands more than brick-work ; it is $3\frac{1}{2}$ times greater when the bricks are laid as stretchers, and three times greater when the bricks are laid as headers.

A. HUGHES, *Assistant Engineer.*



SEALDAH RAILWAY STATION.

The original project of the canal was to irrigate the lands of the Government and the lands of the private owners, and to provide a means of communication between the two. The canal was to be 100 miles long, and to have a width of 100 feet. The project was approved by the Government in 1850, and the canal was opened in 1855. The canal was a great success, and it has been a great benefit to the country. The canal has been a great work of irrigation, and it has been a great work of communication. The canal has been a great work of irrigation, and it has been a great work of communication. The canal has been a great work of irrigation, and it has been a great work of communication.

The general history of the canal is given in the following pages. The canal was designed by Sir Robert Peel, and it was opened in 1855. The canal was a great success, and it has been a great benefit to the country. The canal has been a great work of irrigation, and it has been a great work of communication. The canal has been a great work of irrigation, and it has been a great work of communication. The canal has been a great work of irrigation, and it has been a great work of communication.

But satisfactory as this was, it began to be regarded not very long after that many of the canals of the country were in a state of decay. In 1862 it was estimated that for six

THE GANGES CANAL CONTROVERSY.

THERE are probably few readers of these Papers who have not heard some rumours of the controversy which has now for some time been carried on regarding the alleged defects of the Ganges Canal, which has been thought important enough to find a prominent place in the "Times," and which has been the theme of sundry articles in the Indian papers. The points on which the discussion turns are, however, so purely professional, that I believe it will be of use to Engineers interested in the question, and who have not had the opportunity of reading the pamphlets printed on both sides, to put before them in a brief form an abstract of the questions in dispute.

The general history of the Ganges Canal may be shortly told. Designed by Sir Proby Cautley, and chiefly executed under that officer's superintendence, it was formally opened in 1854; and the various subsidiary channels required for its full development as a great work of irrigation have been since rapidly pushed to completion. Intended primarily (if not entirely) to water the thirsty lands between the rivers Ganges and Jumna, and to secure the population from the horrors of famine; its revenue, arising almost entirely from water-rent, has risen steadily from Rs. 8,571 in 1855, to Rs. 7,05,800 in 1863, while the value of the crops depending on the Canal were reckoned in the latter year at 1½ millions sterling.

But satisfactory as this was, it began to be rumoured not very long ago that many of the important masonry works of the Canal were in a dangerous state. In 1862 it was entirely closed for ~~six~~ 3

months to effect repairs, and though this was a solitary instance, it was known that the cost of ordinary annual repairs was very heavy, while it was reported that the quantity of water carried by the Canal was considerably under what had been originally intended.

At the beginning of 1864, Major-General Sir Arthur Cotton, of the Madras Engineers, whose name was widely known in connexion with the great works of Irrigation in his presidency, and for his able advocacy of the importance of Indian Public Works generally, (including sundry heterodox opinions touching Railways) paid a short visit to the head of the Canal, and a few months afterwards drew up a report, said to be confidential and for the information of the East Indian Irrigation Company alone, who had contemplated the possibility of purchasing the Canal from Government, but which report quickly became to a certain extent, public.

In this pamphlet, Sir Arthur roundly asserted that the design of the Canal was faulty and its execution defective, accusing its projector of no less than *five* great mistakes and *fourteen* minor ones.

To this pamphlet Sir Proby Cautley (who had resigned charge of the Canal soon after its opening, and is now in the Indian Council) quickly published a reply. The five great mistakes he denied *in toto*, and of the fourteen minor ones pleaded guilty to three only, of which two were of no great consequence, but acknowledging frankly that the third (the excessive slope of bed) was a very serious error; and was only justified by the fact that he had had no previous guides to follow, and that its remedy was obvious, and though expensive, involved no difficulty; nor was the expense of the work *in itself* greater than what would have been incurred had it been executed at first. It will be convenient to give the charges, and the replies opposite to them in as brief a form as possible.

Objections.

1st. The head of the Canal is placed too high up, above a tract which has a very great and inconvenient fall, and in which there is a very heavy drainage from the Sub-Himalayas, across which the Canal has to be carried.

Replies.

It was necessary, in order to gain command of level and to have a permanent head not liable to alteration.

2nd. The *whole* Canal has been cut so as to carry the water *below* the level of the surface, entailing a vast unnecessary excavation, and keeping the water below the level at which it is required for irrigation.

3rd. The whole of the masonry works are of brick, while the most suitable stone for hydraulic works is procurable in the Sub-Himalayas.

4th. The *whole* of the water is admitted at the head, so that *some* of it is conveyed *three hundred and fifty miles* to the land it irrigates, while it might have been obtained at a sufficient level at a distance of say 50 or 100 miles.

5th. There is no *permanent* dam across the river at the head of the Canal, so as to *secure* the supply of water, but *temporary* works are thrown up after every monsoon, which are liable to be swept away, and have been swept away, at the very time when they are most wanted.

Necessary for sanitary purposes, and to prevent formation of swamps.

The water level is quite high enough for irrigation.

The stone in general was not suitable for hydraulic works, and to procure suitable stone the expense would have been enormous, as until the Canal was opened, there was no means of carriage.

This implies an entirely different design, which the levels and nature of the river would not admit of. This is more fully answered further on.

A permanent dam was always contemplated and will hereafter be made; but it would have been rash to have made it at first, until the effects of the temporary dams on such a river as the Ganges had been observed.

Besides these *fundamental* mistakes there are the following *minor* ones:—

1st. All the weirs are made of a length corresponding with the full breadth of the Canal, while they need not, and ought not, to have been more than one-third of that length, entailing a more than double expense in their construction.

The weirs or falls are divided into chambers, and with the present arrangement, any accident in one chamber does not necessitate a stoppage of the supply. If their length were diminished this could not be done.

2nd. These weirs are placed in the *direct line* of the Canal, while the navigation line and the locks are placed *out of the direct line*, thus compelling the *whole of the traffic* to go round, instead of the irrigation water.

The Canal is primarily for Irrigation, not for Navigation.

3rd. The whole Canal has *too great a fall in its bed*, from 15 inches to 12 inches per mile, which, with a depth of 10 feet, which it was intended to have, gives a current of $2\frac{1}{2}$ or $2\frac{3}{4}$ miles an hour, which is too much both for the bed and banks of the Canal, and also for effective navigation.

Granted; it is the one great mistake that has been made; but it can be rectified without any departure from the general design.

4th. The Canal has been terminated at Cawnpore instead of being carried on 120 miles to Allahabad, where the Jumna and Ganges unite, and the river navigation begins to be effective throughout the year.

My project was for irrigation above Cawnpore, not for navigation below Cawnpore.

5th. The slope of the Canal is continued to the end at Cawnpore, so that to keep the navigation open there must be a large body of water constantly flowing to waste into the river.

Essential for a Canal of irrigation; the water must be taken down to the furthest point where it is wanted.

6th. The bridges are so low as to prevent a fully loaded boat passing under them.

Granted, for the bridges in the lower part of the line; this can be rectified.

7th. The towing-paths are not carried through the arches of the bridges, so that the line has to be thrown off at every bridge, that is, at every 3 miles.

Granted; it should be rectified; but the Canal was primarily for Irrigation.

8th. The lock channels have such sharp curves that boats of the length of the locks cannot pass through them.

I do not agree.

9th. No arrangement has been made for the disposal of the silt.

It is carried off into the river by the escapes and termini.

10th. There are no *connecting navigation lines* between the different main branches, so that boats can only get *across* the tract by going all the way up to the point where the branch and the main line divide.

It is a Canal for Irrigation. Such connecting lines can easily be made when required.

11th. The Solani aqueduct is made *of the full breadth of the Canal above*,

Length and breadth were fixed after full consideration of the waterway re-

and of the full length of the breadth of the river below, whereas it might have been made of one-third of the breadth of the Canal, and its length of about one-half of the breadth of the river, reducing its cost to perhaps one-quarter or one-fifth of what it has been.

12th. The breadth of the Canal at the lower end is much too small for a large traffic, such as there would be if the navigation were in an effective state.

13th. The slopes of the sides of the Canal are much too steep.

14th. There is no communication between the Canal and the river at Cawnpore; for though there are double locks the gates of the lower one were not in repair.

quired by the Canal and River. The breadth given allows half the aqueduct to be laid dry for repairs without stopping the Canal, and subsequent floods show that the length is not at all too great to allow a proper waterway for the River.

It is an Irrigation Canal.

I am of a different opinion.

Not worth a reply.

On this defence appearing, Sir A. Cotton published a second pamphlet, re-iterating his charges, but dwelling more particularly on the point he had previously put forward, viz., the wrong position of the head of the Canal: and to this point the discussion was thenceforward practically narrowed. Sir Proby Cautley published a dissertation upon the heads of the Ganges and Jumna Canals, entering fully into the peculiar physical aspect of the country and the reasons for his choice of the present head; and in reply to this, a third pamphlet was put forth by his opponent, re-iterating his previous opinion.

Here the discussion virtually rests as far as the two pamphleteers are concerned. The "Times," however, in a long article has reviewed the whole discussion, and summed up dead against Sir Proby Cautley, and the Indian Press has virtually adopted the same side. It is greatly to be deprecated that such hasty opinions should be pronounced by non-professional journals on questions which are essentially technical and professional, and which require much fuller discussion before any proper opinion can be formed, than is likely to be found in the columns of a newspaper.

In order fully to understand the main point at issue, it is necessary to give a brief sketch of the system of irrigation as pursued in India, which may at least be interesting to English readers.

There are two distinct systems in use in Northern and Southern India, which may be called the Bengal and Madras systems, respectively.

The Madras system has been confined to the Deltas of the great rivers,—the Kistnah, Godavery, &c.,—and consists in throwing a Weir (or *Anicut*, as it is locally termed) across the bed of the river to raise the surface level of the water, which is then conducted by Canals whose mouths are just above the dam to the lands requiring it. In low alluvial tracts, especially where the river bed has been raised by successive deposits of silt above the level of the country, it is evident that such a system has great facilities. Moreover, the slope of the ground is gentle; the irrigation channels can easily be made navigable; no expensive masonry works are required beyond the dam at the head, and as soon as the head works are completed, the Canals can be opened and begin to pay.

But the country in Northern India is very different from this: here we have a high table land (the *Bangur*) through which the river runs in a deep trough, with steep earthen banks, often 100 feet high, bounding the narrow *Khadir* or low valley of the river. To get the water on to this high land, we must go to a point high up on the river's course, close to where it leaves the hills, whence it can be conducted without excessive depth of digging along the watershed of the country. And as we have to deal with the river in the upper portion of its course, instead of the lower portion near its mouth, numerous expensive masonry works are required to control the excess of slope and to cross the numerous lines of drainage. So that not until all these are completed can the Canal begin to pay, and the cost is mile for mile very much higher than in Madras.

In the above description I have to some extent "begged the question," as, those who contend that the Madras system is applicable in Upper India, deny the necessity of going so high up for a

head, and would have a weir of sufficient height lower down. It is obvious that the question is one of expense.

In the annexed map the line of the present Canal is laid down. It will be seen that it leaves the Ganges at the point where that river finally leaves the hills. For nineteen miles it is then carried by a somewhat circuitous route across four great drainage lines, involving deep cutting, high embanking, and masonry works of an elaborate and expensive nature, until at Roorkee, it finally arrives on the table land of the Doab, and is carried on the water-shed of the country in its further course downwards. There is very little irrigation above Roorkee, so that the great cost of the first nineteen miles has been incurred simply to bring the Canal to its field of usefulness at and below Roorkee. Rajbhas (minor water-courses) distribute its waters on both sides all the way down, the supply being thus gradually expended, and the size of the channel proportionally contracted.

Now, Sir A. Cotton asserted that, by making a short cut on or near the lines AB or AC, the water might be brought on to the land where irrigation begins, by a much shorter route, the surface level of the water in the river being raised by a weir. He farther set forth that, to employ a series of such dams and short cuts from the river at various convenient points, would be far less expensive than bringing the whole of the water all the way from Hurdwar as at present, by which a very capacious channel was required to carry it some hundreds of miles, before it was used for irrigation in the lower part of the Doab. Not to mention that in the former case a portion only of the river water could be thus utilized, while in the latter there was no Engineering impossibility in using up the whole, for whatever was passed over the upper dams would be utilized by those lower down; while the main channel and works could be very much reduced in size.

There are two questions involved in the alternative projects. 1st, Can permanent weirs be erected and maintained across rivers like the Ganges, with sandy beds and low banks, especially where the fall is above 3 feet a mile? 2nd, Do the levels of the country admit

of channels being excavated from the sites of such weirs, at a reasonable expense, so as to take the water on to the high table land?

As to the first question, Sir Proby Cautley is evidently sceptical. Sir Arthur Cotton says he has made many weirs, but his opponent replies that he has not made them under the required conditions. In one of his late pamphlets, however, General Cotton adduces the case of the Pallaur Anicut, which seems quite conclusive as to the feasibility of such weirs. It is to be observed, however, that for such works an abundant supply of stone near at hand seems essential, a condition only to be met with here and there on Upper Indian rivers, and of which Sir Proby Cautley denies the existence in the present case.

The second question has been investigated lately by the experienced officer specially deputed to Report on the defects of the Canal.* A short cut, such as AB, is out of the question, the top of the high bank forming the boundary of the valley, being 100 feet above the bed of the river. If the line were carried *straight* to the nearest point on the high land to which the levels would admit of the water being conveyed, the great depth of the necessary excavation being far below spring water level, with a sub-soil of pure sand, would involve an expense that puts the project entirely out of the question. If the line were carried by a more circuitous route (such as AC) under the high bank, so as gradually to gain the necessary level without such deep cutting, the cost of the necessary drainage works would equally render this course inadvisable, while in either case the point at which the channel of supply would come out on the watershed, would necessarily involve the abandonment of 70 lineal miles of irrigation above, as may be seen on reference to the plan, (Roorkee to Newarree, 70 miles).

The measures to be adopted for correcting the defects of this noble work are in the opinion of the Canal Officers on the spot, simple enough, as the defects are sufficiently obvious. As the excessive slope has been the cause of all the mischief, so it will be remedied by the introduction of a sufficient number of additional falls, while

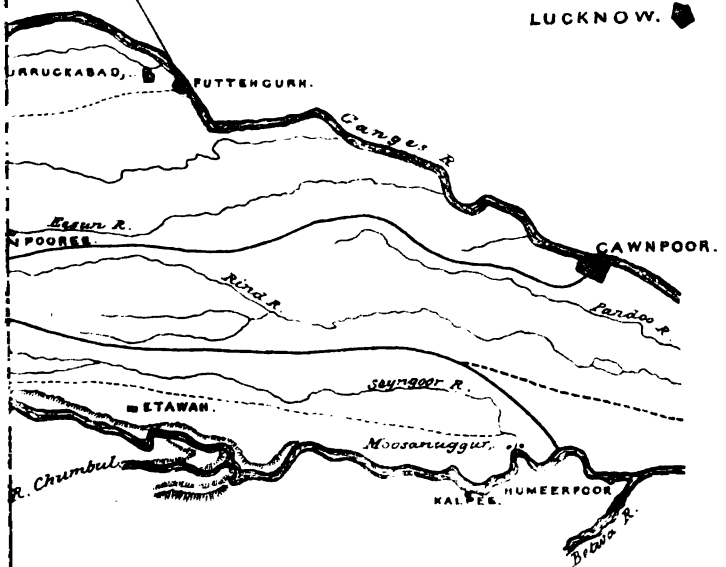
* Captain Crofton, R.E.

Plan
OF THE
GANGES CANAL.

Scale—32 Miles to an Inch.

10 20 30 40 50 60 70 Miles.

A.D. & E. Possible position of Weirs proposed by
Sir A. Cotton.



LITHO: F.C.

the diminution of the slope will necessitate some widening of the bed to carry the same amount of water. This is the real work that has to be done, and it contemplates no departure from the original design, the only difficulty being the necessary closure of the Canal, for perhaps the year which will be occupied in their execution. Unfortunate as is this necessity, it is unavoidable, but when reopened, the Canal will carry its full supply without damage to the works, and with increased facilities for Navigation as well as Irrigation.

I have attempted to set the leading points of this Controversy fairly before the reader; it would be presumptuous in me to give any opinion on the points at issue further than as they involve questions of fact. Had one Engineer been well acquainted with the Madras works when he drew up his design, he would doubtless at least have anticipated most of these objections now made to it, and might have borrowed some hints from Sir A. Cotton and his disciples. Had the other Engineer more fully mastered the data on which his opponent had to work, and seen how much they differed from those with which *he* was familiar, he would probably have modified many of his conclusions. Indian Engineering owes too much to either to do otherwise than regret that professional difference of opinion should have to any extent tended towards personal animosity.

J. G. M.

No. LXXI.

SEALDAH RAILWAY STATION.

Designed and Constructed by WALTER GRANVILLE, Esq., C.E.

THIS Station, which is the Calcutta Terminus of the Eastern Bengal Railway, is situated at Sealdah, just outside the famous ancient entrenchment called the Maharatta ditch. The general appearance of the building is very imposing; and reflects great credit on the taste and practical skill of the architect, who designed and superintended personally all the stations throughout the line.

The building is in an Italian style of oriental architecture, and is on a very extensive scale. The two platforms are each above a thousand feet in length, and 27 feet wide. Three light wrought-iron roofs, each 615 feet in length, cover eight lines of rails. These roofs are painted internally light-blue and white, and produce a very pretty effect. The span of each roof is about 58 feet.

The office accommodation for the Executive Staff is very complete, and the waiting Hall is of the following large dimensions, viz., length, 200 feet; width, 40 feet; height, 40 feet. The roofs over all the offices are flat and formed of wrought-iron girders and brick arches, which have a span of 13 feet; the bricks are 6 inches deep. The upper parts of the roofs are covered with the ordinary *khoa* roofing, composed of broken brick, mixed with Sylhet lime, and well beaten in the usual way.

The method by which the great Waiting Hall is lighted and ventilated is original. The chief light is obtained from a considerable elevation immediately above a lower corridor. It is admitted firstly through a series of arches pierced in the outer and inner walls of an upper arcade, which is

built over the lower corridor. This arrangement obviates the necessity of using windows of any kind, since, during the rainy season, the water falls only in the upper arcade; but in cases of violent storms, when the rain beats at a very acute angle, "purdahs" or canvas screens are provided, which can be let down at pleasure.

Owing to numerous large and deep water tanks that had been excavated, very many years past, on the site of this station, the foundations of the buildings were unprecedentedly extensive and difficult of execution. In several places they are as much as 45 feet below the ground floor level, and some of the walls are from 8 to 10 feet thick. The water had to be pumped out by steam-power, without intermission by day or night, before immense masses of concrete could be thrown down in the trenches, which in some instances had to be encased with sheet piling, owing to the spongy nature of the ground.—(*From the Eastern Bengal Railway Hand-book*).

No. LXXII.

THE SUTLEJ CANAL.

(2ND ARTICLE.)

Project for an Irrigation Canal from the River Sutlej; abridged from a Report drawn up under orders of the Government of India.

BY CAPT. JAMES CROFTON, R.E.

DISTRIBUTION OF WATER SUPPLY.—(See Map, p. 146.)

THE general directions for two of the branch canals for the irrigation of the Puttiala territory are clearly defined by the watersheds on either side of the Sirhind Nullah; the narrow strip of land lying between the Choa and Puttiala Nullas it does not appear necessary to provide with a branch canal when the supply of water is so limited, nor do the Puttiala authorities apparently consider it of importance. The Nirwanah district, lying on the left bank of the Cuggur, below Khythul, was the part of the territory particularly pointed out as being in urgent need of irrigation; the third series of longitudinal levels was accordingly taken on a line on which it seemed possible, from the general slope of the country and the levels obtained by cross sectioning, to carry a line of canal which would deliver the water at the surface on the ridge between the Cuggur and Chittung in that locality. This involves crossing the Puttiala Nullah, and the Cuggur and Sursoottee rivers; the result of that levelling however, shows clearly, I think, that though we might cross the Puttiala Nullah considerably further to the southward, it will still be necessary to cross the Cuggur and Sursoottee separately, while by thus altering the Puttiala Nullah crossing, we lose the opportunity of irrigating a large portion of land between that Nullah and the Cuggur; I have, therefore, for the purpose of this estimate, projected the third branch in the general direction of that line of levels.

I have before alluded to the circumstance of the direction of the drainage

from the left bank of the Seesooan, and eastward as far as the town of Khurr, being south-westerly towards the Sirhind Nullah; to reach the watershed to the east of that Nullah, it is therefore necessary to cross all the country drainage as far down as the village of Bhayr, about two miles north-east of Sirhind, where we first meet the watershed: the cross section from Sirhind to Machewarah showed the watershed to the westward to lie close to the Kotluh Nullah. The neighbourhood of Surranah therefore seemed the most suitable site for the head of the Kotluh branch, the first reach of the line being in such a direction, that the canal embankment would easily divert any small amount of drainage, which might cross from the westward into the heads of the Kotluh Nullah. On the left bank of the central line, from the branch head down to the village of Bhayr, the high spoil banks will answer the similar purpose of diverting the surface drainage into the heads of the Puttiala Nullah; the Nullah passing Khurr, I have before stated, loses its defined section near the village of Kulour, and at the point on the canal line where its flood waters are said to cross, there is nothing but a slight depression in the ground, which the level fails to detect, occupied by rice fields, and some very sandy ground adjoining, to mark the presence of water at some time of the year.

In addition to these for Puttiala, a fourth branch can be taken off from the main channel above Surranah, or perhaps from the Kotluh branch near the town of Budlah, for the irrigation of British territory towards Loodiana, and the districts to the south-west on the left bank of the Sutlej, towards Ubohur in Bhuttiana. The ground not having been examined, no detailed estimate can at present be submitted, but there is no doubt of its practicability, from the known levels of the country near its head and the general direction of the slope of the country; from Captain Dyas's levels I calculate that a channel with the same declivity as the upper portion of the Kotluh branch would deliver the water at the level of the ground surface some distance above Douraha ke Serace on the Trunk Road.

Without entering into abstruse calculations as to the exact quantity of water required to irrigate a given area, and the amount of loss by evaporation and absorption, for which there are at present no certain data, we may, I think, safely follow the method adopted by Sir P. T. Cantley, of estimating the total quantity required for each branch by an average expenditure per mile of irrigating channel, obtained from similar works in these provinces. He has calculated this at a maximum of 8 cubic feet per second,

DISTRIBUTION OF WATER.

Localities.	Position in five thousands.		Length in five thousands.			Discharge, cubic feet per second.				Remarks.	
	From	To	Total.	Non Irrigating.	Irrigating.	Allowance per 5000.	Expenditure.	Required capacity.	Actual capacity.		
CENTRAL LINE.	Heads to Surranah Branch Head, ...		29-32	29-32	29-32	...	...	...	3500	3641	{ Including extra for prolongation.
	Surranah to Nirwanah Branch Head, 29-32		50	20-68	16-98	3-70	6-63	24-53	1186-63	1204	
	Below Nirwanah Branch Head, 50		120	70	...	70	6-63	464-10	464-10	464-00	
KOTLUH BRANCH,	...	101	101	15	86	6-63	570-18	835	363	{ Including prolongation.	
NIRWANAH BRANCH,	...	77	77	5	72	5-68	408-96	698	691	{ Including prolongation.	

per mile, from data obtained on the Jumna Canals. Now, considering the improvements which have taken place since then, and are still in progress, in the economical distribution of water, I believe we may safely reduce this allowance. In the following calculations I have arbitrarily assumed 7 cubic feet per second, per mile, (or 6.63 cubic feet per five thousand,) as a maximum, and for the Nirwanah branch this has been further reduced to 6 cubic feet per second, per mile, (or 5.68 cubic feet per five thousand,) the land adjoining the upper portion of that line not requiring canal irrigation so urgently as other districts, and a large proportion of the country lower down being irrigable from the waters of the Cuggur and Sursoottee.

From these data the accompanying table has been compiled, showing the total lengths of channels now estimated for, with the discharges required at each branch head. From the longitudinal section of the channels it will be apparent that there can be no surface irrigation on either of the lines from the Surranah branch head down nearly to the Grand Trunk Road. Below the points to which the present estimate extends, the Nirwanah line can be extended to a length of 51 five thousands; eleven of these in Puttiala, forty in the British districts of Hissar; the Kotluh line, 10 five thousands in Puttiala, thirty in Bhuttiana; we have then the required discharges on each line, as follows:—

Nirwanah branch, (72 + 51 =)	123 × 5.68 = 698.64 c. ft. per sec.
Kotluh " (86 + 40 =)	126 × 6.63 = 835.38 "
Central line,	74 × 6.63 = 490.62 "

Total, 2024.64

and assuming 3,000 cubic feet per second, to be the maximum supply available throughout the year, 975.36 cubic feet is left for the Loodiana branch, sufficient for an irrigating channel 147 five thousands in length, through British territory; the possible course of this branch is shown in the map. For the calculation of the proportion of the whole supply thus allotted to British territory, we have the following, premising that 22 five thousands of the Nirwanah branch now estimated for, lie in the British district of Thanetur:—

On the Nirwanah line (22 + 40 =)	62 × 5.68 = 352.16 c. ft. per sec.
" Kotluh "	30 × 6.63 = 198.90 "
" Loodiana "	975.36 "
Total,	1526.42

or half the total available supply. The extra 500 cubic feet which can be

passed down the main channel above Surranah, would be allotted to each branch in the proportions of their above calculated discharges. It does not appear necessary to reserve any portion of the supply for navigation, as the depth of the water in the several branches down to the lowest points where such traffic is likely to extend will be sufficient for the purpose.

DIMENSIONS OF CHANNELS, &c.

In determining the dimensions of the irrigating channels, besides the velocity of current, another consideration must be taken into account, viz., the importance of reducing, as far as possible, the fluctuations of the surface level of the water. The reasons for this were so clearly given by Captain Dyas in his Report on the Baree Doab Canal project of 1850, that I need not do more than allude to them here; the proportion of depth to width in fair sections of stream on the Western Jumna Canal, was found to be about 1 to 13. In this estimate it has been taken generally at 1 to 14, (for the Baree Doab Canal channels it is 1 in 15,) except where the stream would thus become too shallow for the passage of boats or rafts. On this account, therefore, the minimum depth of water at full supply has been fixed at $2\frac{1}{2}$ feet. The declivities of bed have been so arranged that the calculated mean velocity of current should in no case much exceed 3 feet per second; the excess of slope in surface of country being disposed of by masonry falls. For the purposes of the estimate the bottom width of channel has been reduced by 2 feet at a time according to the discharge required at certain points.

The form of banks is uniform throughout, side slopes of water channel 1 in 1; tow-paths 15 feet wide, at a uniform level of $1\frac{1}{2}$ to 2 feet above full supply; road banks 20 feet wide, either on the level of the natural surface or raised to a height of not less than 2 feet above the tow-path, with side slopes of 1 in $1\frac{1}{2}$, down to the tow-path. Boundary roads, 20 feet wide, on either side, for the country traffic, are also estimated for. The widths of land to be taken up for the canal channels are as follows:—

<i>Central line,</i>	{ From Surranah to 1st overfall, 550 to 400 feet.	
	{ 1st overfall to Nirwanah branch head, 400	
	{ Below Nirwanah branch head, . . . 250	
<i>Kotluh branch,</i>	{ From Surranah to 1st overfall, 550 to 300	
	{ Below 1st overfall, 300	
<i>Nirwanah branch,</i>	{ 300	

The Escape Channels are calculated to discharge the maximum supply of the Canal at the points where they take off; they will be merely cuts with side slopes of 1 in 1, the spoil thrown up on either side at a distance of 10 feet from the edge of the excavation; the width of land required for No. 1, on the Central Line, will be 200 feet, for all others 150 feet.

The courses of the several branches are shown on the general map (page 146), the figures at intervals along each denoting the distances in lengths of five thousand feet from their respective heads, the central line being numbered from the Canal Head near Keerutpoor; the numbers correspond with those on the sheets of longitudinal sections of Canal Channels.

CENTRAL LINE BELOW SURRANAH.

The course of the line between Surranah and the watershed at Barah, on the Trunk Road, was determined by the necessity of diverting the surface drainage from the north-east into one of the heads of the Puttiala Nullah; an extensive sand ridge occupies the watershed between the villages of Bhayr and Mundophul, on the western side of which there is a very large hollow, covered with water in the rainy season to the extent of $2\frac{1}{2}$ miles in length by 1 mile in width; the floods from the Khurr Nullah and elsewhere, all passing this way towards the Sirhind Nullah. Now, were the line to be carried on a direct course to Barah, this drainage must either be passed over it by a costly masonry aqueduct, or the country to the eastward be inundated for miles, the sand ridge stopping all egress in the direction of the Puttiala drainage. It might be possible to open a passage for it through the ridge, but the cut would be expensive in the first instance and require constant clearing out afterwards; the lengthening of the line, therefore, so as to skirt the eastern edge of the sand ridge seemed unavoidable, besides the advantage thus obtained of a better direction for the spoil banks on the east side which will intercept and divert the surface drainage. From Barah downwards, the line will keep as close to the watershed as possible, skirting the edges of the sand ridges which almost invariably occupy the highest ground in these districts, and terminating in the Cuggur, near the village of Sadunwas, in the Sirsa district. It does not appear to me advisable, with the limited supply of water available, to extend this branch further; the strip of land between the Cuggur and the tail of the Sirhind Nullah below this is very narrow, and so covered with sand, that the loss

by absorption would be enormous. Sand in these tracts is seldom met with in isolated mounds; it usually takes the form of ridges from one to two or three miles in width, along the tops of the watersheds of the courses of drainage lines, lying in greatest quantity to the east of the latter.

The Nirwanah Branch will take off at the 50th five thousand, sufficiently high to allow of carrying the Channel over the Pattiala Nullah, and crossing the surface drainage on its upper portion in a suitable direction for diverting it into the Choa and Puttiala Nullahs on its left bank.

Two Escapes will be required on this line, the first from a point immediately in advance of the deep excavation above the Trunk Road, terminating in the Sirhind Nullah, 10,000 feet in total length. The second, 45,000 feet in length, from the 97th five thousand, into the Choa Nullah, which ultimately joins the Cuggur: the first was originally projected from the 42nd five thousand, near the village of Bhyrompoor into one of the feeders of the Puttiala Nullah, with the view of intercepting the country drainage there, and disposing of it more effectually, but the levels were found to be impracticable. No. 2 should be some miles higher up, but as it is the only line anywhere near the true position, of which we have the levels, it has been taken for the purposes of an estimate.

The *Channel* from Surranah to the first Overfall, is projected on the same declivity as the bed above, viz., 1 in 6,000, in order to reduce the length of deep excavation as much as possible. At the Trunk Road, an overfall of 6 feet drop will be required, below which the slopes of the bed have been fixed as described in page 218; three more overfalls, one of 4 feet, two of 3 feet drop, will be required.

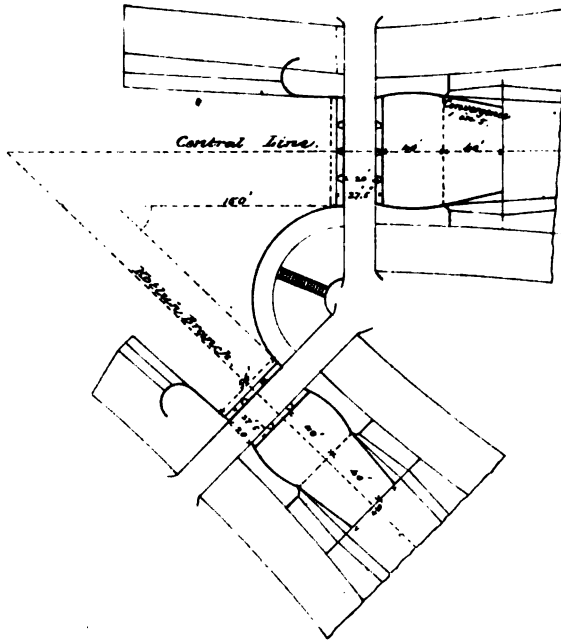
The *dimensions of the channel* from Surranah to Barah, have been fixed at a bottom width of 50 feet, with a depth of water of 7.5 feet, solely with reference to the maximum velocity of current and with a view of reducing the quantity of excavation as much as possible: the calculated depth of the stream above Surranah, with a discharge of 3,000 cubic feet per second, being only 6.2 feet, there will be a back water above the Regulator due to the difference of the depths of water, when the full supply is passing down; this, however, can have no injurious effect on the works.

Surranah Branch Head.—The works at Surranah for the Regulation of the Canal supply, I have reduced in extent as much as possible, but the depth of excavation here necessitates a much greater length of connecting revetment between the two bridges than would otherwise have been given.

SUTLEJ CANAL PROJECT

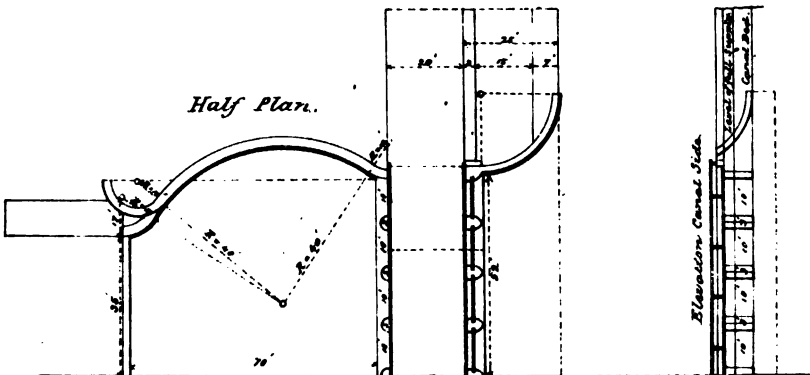
Kottuk Branch Head at Suranah.

Plan.



Escape No 1.

Half Plan.



Longitudinal Section.

*Section of Revetment.
down stream.*



AIRNO: T. C. PRESS

Scale, $\frac{1}{16}$

The Kotluh branch will take off at an angle of 45° from the main channel, the direction of the central line remaining unaltered. The plan of the works is given; a waterway of 64 feet is given to the central line, 50 feet to the Kotluh branch, (the mean waterways of the channels below being 57.5 and 41.5, respectively,) divided on the Central line into four bays, two of 14 feet each, two at the sides 18 feet each; on the Kotluh branch, two at the sides of 18 feet each, with one central bay of 14 feet; the piers nearest the sides 3 feet thick, the central one 2 feet thick, built up to the same level as the tow-path. Masonry floorings of the full length of the piers are carried right across, protected by curtain walls 6 feet deep, up and down-stream; water-wings, sloping tail-walls, and curtains, are added down-stream to preserve the banks from cutting away. The bridges above will be of timber, with a width of roadway of 20 feet; passages 12 feet wide in the clear, are provided for towing under the bridges on either bank; the two will be connected by a circular revetment up-stream. One main object in this arrangement of the works was to bring the bridges as close together as possible, so as partially to obviate the silting up which invariably takes place in the upper channel below the point of divergence. A drop of half a foot is given in the flooring of the Kotluh branch for greater facility in adjusting the supply, as I think it is advantageous to regulate altogether if possible by one bridge, leaving the passage through the central line quite free. The regulation at both heads will be effected by vertical sleepers, their lower ends resting in a groove in the flooring, confined above between two beams resting on the piers or side retaining walls; it was the most economical expedient I could think of, and though in some respects not so efficient as the ordinary method with drop gates, will I believe answer all the purposes of adjusting the supply; it has the advantage of dividing the entering stream into vertical films, by which the impact on the flooring will be diminished, and it can be worked by a couple of men. For the passage of boats or rafts, the side passages can generally be left free, or the cross beams may be raised without difficulty, as in a draw-bridge, by the aid of ropes and pulleys.

At the 45th five thousand, the first *Escape Head* is projected on the right bank, with an aggregate waterway of 80 feet (the main waterway of the escape channel being 75 feet) divided into bays of 10 feet each by piers 3 feet in thickness, the top of the piers level with the tow-path. The roadway over these will be formed by the simplest kind of wooden bridge,

leaving sufficient space on the Canal side for fixing windlasses across the piers; a masonry flooring will be given the full length of the piers, with apron walls 6 feet deep, up and down-stream; circular waterwings and a cross curtain are added down-stream for the protection of the banks. A drop of half a foot is designed in the flooring to assist the egress of the water; the piers are grooved on the Canal side for the reception of sluice gates which will be worked by the windlasses fixed on the piers. A stop dam bridge immediately below the escape could not be conveniently arranged for; regulation however may be effected at the Overfall, a short distance further on, the fall in the bed between the two works being only 1.09 feet.

At the Trunk Road, 1500 feet in advance of the 46th five thousand, the first *Overfall* with a drop of 6 feet has been projected. It is designed as a vertical fall somewhat altered from those which have proved so successful on the Baree Doab Canal; there the cistern below is divided into chambers for facility of repairs without the necessity of turning off the whole supply. It seems to me, however, of more importance to remove as far as possible all sources of injury to the works. Now, the *extent* of the surface of the cistern immediately below the fall, has apparently as much effect in modifying the violent action of the water as its depth; I have, therefore, designed all the falls in this project, with the drop as close as possible to the edge of a cistern of the full width of the canal down-stream. In this and other cases, solely with a view to a saving of expense, the bridge has been placed immediately below the drop wall, which necessitates the building of the piers in the upper half of the cistern; otherwise the best arrangement for the stability of the work would be to place the drop in the alignment of the down-stream head wall of the bridge; were the bridge removed below the fall and cistern altogether, its cost would be much greater. An aggregate waterway of 75 feet is given through the piers; the drop wall has been placed 2 feet above the line of head wall of the bridge, sufficient I think to allow the water to fall clear; the cistern below is 60 feet in total length with a uniform depth of 5 feet below the bed. Waterwings and a cross curtain are added down-stream for a length of 130 feet from the bridge, giving a circular space of about 130 feet in diameter down-stream, in which the water may boil and eddy before resuming its normal velocity in the earthen channel. This arrangement is less costly than the waterwings with sloping tail-walls, and in cases where the action of the water is that of boiling and eddying rather than

that caused by accelerated velocity, it is at least as efficacious, as far as I have been able to judge. It was not adopted in the Surranah Regulator, only on account of the extra width of excavation required which at such a depth would have somewhat increased the expense. The bridge here, being for the passage of the Trunk Road, has been designed of masonry with a roadway 20 feet wide between the parapets; an inlet for drainage, which will collect on the up-stream right bank, has been arranged for, discharging itself into the canal through the abutment.

Another design for this work will be found, with a *Lock Channel* added on the right bank. No provision is made in the estimate, on the score of expense, for a separate channel and locks round the overfalls, but it appears to me possible, with vertical overfalls, to provide for an uninterrupted navigable passage at a small additional outlay; I have accordingly drawn out this second design similar to the first, in all essentials, except the addition of the lock chamber; the addition to the estimate which such lockage would entail will be shown hereafter. I am aware that such an arrangement was adopted in several of the overfalls on the Eastern Jumna Canal, and Sir P. T. Cautley, in his last report on the Ganges Canal, states that none but those in the southern division were ever used, probably on account of the danger arising from the proximity of the open overfalls. The circumstances are, however, somewhat altered here, and the velocity down-stream is not accelerated as would be the case with an ogee fall. The lock chamber on the Eastern Jumna Canal was an integral part of the overfall, and was always left open when not required for the passage of boats or rafts, which, with careless boatmen, must have been a source of great danger. The present design provides a lock chamber attached to the overfall, but *in addition* to the width necessary for the passage of the canal supply, so that the gates, either upper or lower, could be constantly kept shut. The entrance to it would be 145 feet above the overfall drop, and a floating boom composed of logs of wood fastened together at their extremities is projected to extend obliquely up-stream from the end of the lock pier to the middle of the channel, attached there to a screw pile or beam driven into the bed, or (which would perhaps be the best) to a masonry pier built in the centre of the stream, the other end being fixed securely to the wall of the lock chamber; a similar boom would extend from the centre of the stream to the other bank. With such a fender, strongly made and fastened securely at the apex, there would

be in my opinion, little risk of any floating body passing down to the fall.

The three Overfalls below this are similarly designed, but with timber bridges in lieu of masonry.

At the 50th five thousand, we come to the *Nirwanah Branch Head*, the design of which is similar to that at Surranah; the waterways of the channels below are—on the Central line, 49·5 feet; on the Nirwanah branch, 58·1 feet; the corresponding waterways in the regulator are—Central line, 54 feet, divided into three bays of 18 feet each; Nirwanah branch, 60 feet, divided into two bays of 18 feet each and two of 12 feet each; a clear headway of 10 feet above level of full supply is given under the bridges, with tow-paths on either bank.

The *Escape Head* at the 97th five thousand will have an aggregate waterway of 30 feet in three spans of 10 feet each, with a drop of half a foot in the flooring projected similarly to *Escape Head*, No. 1.

Between Surranah and the 77th five thousand, *ten Bridges* will be required, which, with the branch head and overfalls, will give *fourteen crossings*, or about 1 in 3 miles. Below this, to the termination of the line, *eleven crossings* are provided for, or 1 in about $3\frac{1}{2}$ miles, two of which will be bridges on frequented roads, one across an overfall; eight will be *Fords* (where the depth of water does not exceed 2·5 feet) formed by laying a 9-inch layer of kunkur, 20 feet wide across the bed, protected on either side by thin masonry aprons 1·5 feet deep; ramps down to the bed formed on either bank on gradients of 1 in 10.

Rajbuha Heads.—Main water-course (or rajbuha) heads are estimated for at the rate of two (on either bank) in every $3\frac{1}{2}$ five thousands; they will be simple arched culverts of masonry, under the banks, or revetted masonry passages, bridged with timber with a uniform water way of 6 feet, fitted with sluice gates; the direction of the central line of arch at an angle of about 45° to that of the Canal, to obviate, as far as possible, the silting up in the channel at the head. These masonry outlets are an absolute necessity for the proper regulation of the supply to the rajbuhās; though, I believe, it would be advisable at first to give temporary openings; once the discharging capacity of each rajbuha was well ascertained, the sites for the permanent heads could be determined on, and the sooner they were built the better.

Six 1st class, and twelve 2nd class *Chokies*, will be required from

Surranah to the termination, the former at intervals of 15 miles, two of the latter between each pair of 1st class chokies, or about 5 miles apart. The works of this description along the several lines will serve as residences for the European establishment during the construction of the works; ultimately, they are intended only for halting places.

KOTLUH BRANCH.

The position of the head and first reach of this branch has been described before; it is projected in a straight line to a point near the town of Budlah, where it reaches the watershed in a length of about 8 five thousands from the Surranah head. From this onwards it will keep as close to that watershed as possible, except where it is occupied by sand ridges; in the neighbourhood of Sirhind, and for some miles below, it will require some further close examination of the ground to determine the precise line, the several lines of drainage being very confused; in such cases the level is almost useless. The drainage, the head of which is shown near Chumkour, has no defined channel till it reaches Kotluh; its course is marked only by a succession of jheels, with intervening low ground; immense sand hills line its edges in parts, the ridge to the east of Kotluh being some three miles wide, hardly an acre of it culturable; below this, down to Dabwallee, in Bhuttiana, the hollow is more or less defined, edged by sand hills on either side; which, however, are said by the country people to be of no great depth. At a distance of two or three miles on either side, the soil is hard and very fertile. It is locally called "Nahavohul," and tradition has it that a river once flowed in its bed, where river sand is now met with at depths of from 7 to 9 feet below the surface. On the watershed, there is no great extent of sand to be found down to the neighbourhood of Soonam, a noted resort of Hindoo pilgrims, situated on the banks of the Sirhind Nullah. Sand ridges commence here about the 60th five thousand from the head, and continue more or less to the present termination of the line in the bed of an old drainage, communicating with the Cuggur some miles further down. It will be possible to carry it some forty miles further into the Gooduh pergunnah of the Sirsa district, where, as far as we could hear, the soil is hard and little sand to be met with. Our present estimate is limited by the extent of the levelling.

The first 15 five thousands, (down to the Trunk Road,) being almost

all in deep excavation, *the dimensions of the Channel* have been calculated, as described for the first reach of the central line below Surranah. The declivity of bed being 1 in 6000, and the required discharge 885 cubic feet per second, the consequent width at bottom with a depth of water of 7.5 feet, is 34 feet. Below this it will be observed that as long as the slope of the country surface exceeds that required for the Canal, I have given the maximum declivity to the bed admissible within our limit of a mean velocity of current not much exceeding 3 feet per second, the rate of declivity increasing inversely as the required discharge of the channel; below this the declivity of bed is made to conform as nearly as possible to the natural surface. To overcome the superfluous slope *five Overfalls* are required, two of 8 feet drop, one of 6 feet, and two of 3 feet each; all of similar design to those on the Central Line; the first overfall with a drop of 8 feet, being situated on the line of the Trunk Road, will be bridged by masonry arches, the remainder with timber.

Two Escapes are projected, the first taking off on the left bank close below the Trunk Road overfall, and tailing into the Sirhind Nullah, in a length of 15,000 feet, the bottom width 58 feet; a mean waterway of 60 feet is given to the head divided into six bays of 10 feet each. No. 2 will also take out on the left bank and tail into the Sirhind Nullah in a length of 28,400 feet, at a distance of 28 five thousands further down; the interval between the two escapes will be increased at the time of construction; they are projected in their present positions for the reasons assigned in the case of the 2nd escape on the central line, the lines of levels adjoining them being the nearest to their true courses. No. 2 escape head, is designed with a waterway of 50 feet, divided into five bays of 10 feet each; in all other detail they will be similar to the central line escapes.

Twenty-five Crossings are provided for from the head to the present termination of the line, or 1 in about $3\frac{1}{2}$ miles, five at the several overfalls, and twenty by bridges, the latter all of timber. No *fords* have been given, the minimum depth of water in the canal channel being 2.8 feet.

Seven 1st class and thirteen 2nd class *Chokies*, are estimated for, at the same intervals as elsewhere, as well as *Rajbaha heads* below the deep excavation.

NIRWANAH BRANCH.

Between the head of this branch and the crossing of the Puttialla

Nullah, the line more or less intercepts drainage from the north-west. The longitudinal section shows two distinct ridges, that nearest to the Puttiala Nullah being the watershed between its drainage and that of the Choa Nullah; shallow cuts will be required through these ridges to divert this cross drainage into the western feeder of the Puttiala Nullah. Shortly after passing the Puttiala Nullah, the line reaches the high watershed between it and the Cuggur, along which it will continue up to the point of divergence to the crossing of the latter; sand ridges lie more or less on this course which the line will skirt, with the exception of a narrow one on the edge of the Cuggur valley. Between the Cuggur and Sursoottee the soil is generally hard and clayey, and on account of the very small declivity of the surface, the ground is covered with water to a large extent in the rainy season, while in the dry hot season, on account of the deficiency of sand, it becomes so caked as to be almost useless for cultivation; the heat of this baked dark ground becomes sometimes so great, that even the villagers say they cannot leave the shelter of their houses from about 9 A.M. till 5 P.M. at that season; no wonder then that little or no cultivation is found along this tract. At the edge of the valley of the Sursoottee we come to the high land of the district of Nirwanah, and a soil very different from any we have hitherto met with, only limited in its capabilities for cultivation by the extent to which irrigation can be supplied. In spite of the deficiency of rain-fall and depth of the wells, large and populous villages are scattered over its surface; in many villages there are no wells, drainage water collected in large jheels or tanks supplying the necessities of the inhabitants and their cattle for about nine months in the year; in the hot winds they almost universally dry up, and the villages are deserted until the jheels are again filled by the rains. Our estimate provides for a channel through this district only as far as the town of Nirwanah, the limit of the last season's longitudinal levelling; here the line is on the watershed between the Cuggur and Chittung, and there is no doubt of the possibility of carrying the channel along it for some fifty miles further.

Sections of the defined channels of the three nullahs or rivers as well as of their inundated valleys, at the points where my levels crossed, will be found in the sheets of sections. The Puttiala Nullah, which has the best defined channel of the three, it is proposed to cross by an *Aqueduct*, with an aggregate waterway of 125 feet, divided into five arches of 25 feet span

each, for the passage of the floods of the Nullah, the Canal channel above being 58 feet wide, the mean width of the earthen channel up-stream; the arches are sprung from the level of the highest flood. Now, the area of flood stream in the defined channel is 656 superficial feet, that of the adjoining inundation 2746.5 superficial feet; the velocity of the current in the latter is very small. For the passage of the whole of this, the waterway provided is 1687.5 superficial feet up to the springings of the arches of the aqueduct, besides the spaces included between the chords and crowns of the five arches, which have a uniform rise of 8.35 feet. The details of the work are very similar to those of the Roopur aqueducts; the soil being firm hereabout and the bed of the Canal very little raised above the natural surface, the protective sand-cores in the embankments on either side have not been considered necessary.

The passage of the Cuggur is a more difficult business both on account of its greater volume and extensive inundation. The flood waterway where my levels crossed is 2725.5 superficial feet, the water rising 20.5 feet above the level of the bed, in a channel with a mean width of about 100 feet—the valley on the right bank is covered in floods to the extent of about $3\frac{1}{2}$ miles wide but how much of this is owing to natural inundation, and how much to badly constructed water-courses, which have been long in existence in this neighbourhood, I cannot say; one thing is certain, that the velocity over this flooded surface is very small indeed. For the passage of the deep channel an *Aqueduct* is proposed, similar to that for the Pattiala Nullah; but to carry the bed of the Canal at such a level that the flood mark of the river should not be above the level of the springings of the arches, it will be necessary to cross the Cuggur at same point lower down its course. I have designed the work on that supposition. On the present line the floods would rise to the crowns of the arches. The aggregate waterway given under the work is 150 feet divided into 5 spans of 30 feet each; the piers 16.5 feet up to the springings; the arches, segments of 60° ; the versed sine being 4.02. A thickness of 2.5 feet has been given to the arches, covered by half a foot of flooring; the Canal waterway above is 56 feet in clear width; the bed under the arches will be floored with a 2-foot layer of kunkur blocks, carried out to a length of 25 feet, up and down-stream. The inundation waters it is proposed to pass through the Canal by means of an Inlet and Outlet, similar to that described below for the Sursoottee; the waterway for both inlet and outlet

to be 100 feet, divided into ten bays of 10 feet wide each. The total superficial area of waterway thus provided would be:—

Under the aqueduct,	...	...	...	...	2,475 a. ft.
Through inlet and outlet,	...	...	...	...	400 "
Total, ...					2,875 "

Captain Cunningham, in his report, gives the flood section of the Cuggur after its junction with the Puttiala Nullah as $140 \times 29 = 4060$ superficial feet, at a point where it does not overflow its banks; so that assuming the waterway given for the Puttiala Nullah (1687 superficial feet) to be correct, I believe the waterway I have given to the Cuggur works will be ample for any demands that could be made on them.

Passage of the Sursoottee.—Between the 46th and 47th five thousands, the line reaches the edge of the inundated valley of the Sursoottee, which is here covered with water to a greater or less depth in the rains, for a width of nearly $5\frac{1}{2}$ miles, the central channel being only 50 feet wide by 8 feet deep; the low land on the right bank is covered for the greater part with "shora," or earth strongly impregnated with it, into which the foot sinks at every step except where overgrown with grass; this circumstance alone would tend to the supposition that the inundation in this valley was almost "still" water; the whole of the inundated space on the left bank is a sheet of rice fields. The works proposed here are an *Inlet* and *Outlet*, with a *Stop Dam bridge* to prevent flood water passing down the Canal. The aggregate waterway of Inlet as well as Outlet will be 200 feet, divided into twenty bays of 10 feet each, by piers $2\frac{1}{2}$ feet in thickness; a roadway of timber will be formed over both inlet and outlet. Masonry floorings are given to both; revetments on the Canal side are connected by curtains right across the bed; the foundations of all will be sunk to a uniform depth of 6 feet below the bed. The Stop Dam bridge will have a waterway of 52 feet (equal to the mean waterway of Canal channel) divided into three spans, two of 18 feet each, one of 16, wooden superstructure of the usual design, and tow-paths 8 feet wide under the side spans. The regulation will be effected in the inlet and outlet by sluice gates and windlasses, and in the stop dam bridge by horizontal sleepers. The data for the determination of waterway for the Sursoottee are imperfect. By referring again to Captain Cunningham's report, I find that the section at the broken bridge of Polur where apparently the river does not inundate its banks, is $70 \times 9 = 630$ superficial feet, but considering that

the depth of flood as well as velocity in the place where my levels crossed, are much less than could be the case in a confined channel, I have given more than double that amount of waterway to the work, viz., $200 \times 7 = 1400$ superficial feet, an allowance more than sufficient, I believe, for the highest flood. With such an outlet, the ordinary Canal embankment will be strong enough to resist the pressure of the inundation across the valley; these works would be constructed where the present defined channel of the Sursoottee crosses the Canal line.

Two Overfalls with a drop of 9 feet each will be required, to overcome the excessive slope between the Puttiala Nullah and Cuggur crossings; they will be identical in details of design, with those described before; the aggregate waterway for each 65 feet, divided into five bays of 13 feet each, with wooden bridges, having a 12 feet width of roadway.

Twenty-five Crossings are provided for along this line, or one in about three miles; two by the stop dam bridges at the Cuggur and Sursoottee; two by overfall bridges; the remaining twenty-one by timber bridges of the usual design, the width of roadway being either 12 feet or 20 feet, giving a clear passage of 10 or 18 feet wide inside the railings, for single or double traffic; it may be found necessary hereafter to construct a masonry arched bridge on the line of the Puttiala and Umballa road, but at first the temporary structure will answer.

No separate escape channels will be necessary on this line—the outlets at the Cuggur and Sursoottee being sufficient for the purposes of regulation.

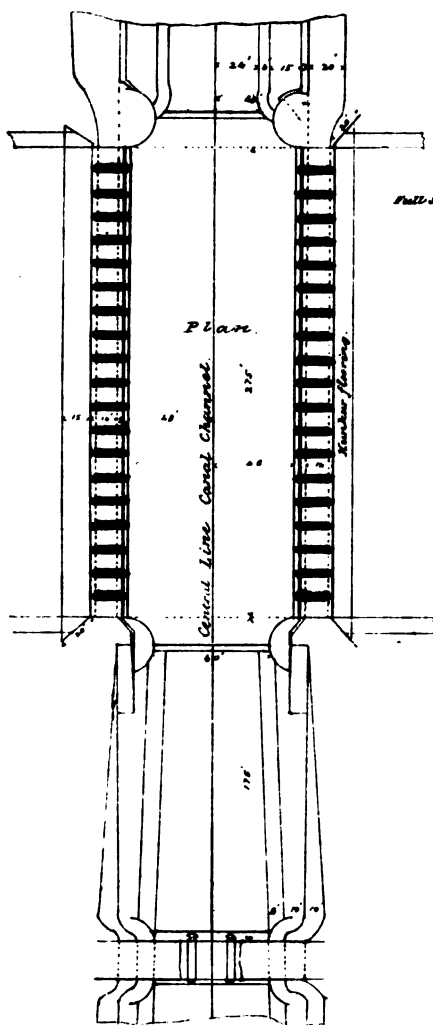
Six 1st class and ten 2nd class *Chokies* will be required. I have given one 1st class in addition to the number required by the limit of one in every fifteen miles, in consideration of the number of heavy works between the Puttiala Nullah and the Cuggur.

RATES OF LABOR, MATERIALS, &c.

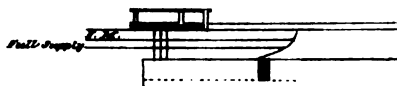
The rates of the different descriptions of work as well as the cost of bricks have been mainly taken from those ultimately obtained on the Baree Doab Canal, the circumstances of the two works being to a great degree similar; the demands of a new work on an extensive scale so alter the existing market prices of everything that it would be useless to base any

SUTLEJ CANAL PROJECT.

Inlet und Outlet for Sursootlee-Nirwanah Branch.



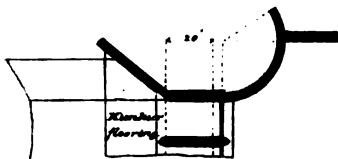
Part Elevation of Outlet.



Half Section Dam Bridge.



Part Plan of Outlet.



Puro Plan Dam Bridge



Cross Section Outlet



estimate on them. The cost of the *groined spurs* of open piling is taken from a statement of actual expenditure on the Western Jumna Canal; the rate of kunkur masonry from the Ganges Canal Works. *Limestone* is procurable from the beds of most of the torrents above Roopur, at no great distance from the Canal line; *jungle wood* for burning it is scarce on the low hills close to the line, but is said to be in abundance higher up in the districts of Hindour and Nalaghour, also in the Hoshyarpoor district on the right bank of the Sutlej; which, however, I had no leisure to examine personally. *Kunkur*, fit for burning into lime, is found from Roopur downwards. "*Oopla*," for fuel is as usual scarce and dear near the foot of the hills; in the pastoral districts below it appears to be in abundance. *Brick* buildings abound all over the Sutlej valley, and in the villages along the branch canals, many of which, old and tumble-down forts, and the like, will, I have no doubt, supply a good quantity of ready made material; in some of the lower districts where villages are more thinly scattered and cattle few in number, "*koora*," (the village refuse,) the usual material for burning bricks, and the best, will be deficient; here, however, the number required will be small. Blocks of hard *kunkur* and *conglomerate* are to be found all over the ravines in the low hills below the Sursa Rao; and as I have mentioned before, when describing the works in the neighbourhood, *boulders* of all sizes are procurable from the beds of the Sutlej, Lohund, Kalee Koondwalee, and Sursa, besides other small hill torrents. On the promontory of the bangur, two miles below Roopur and close to the Canal line, a very extensive bed of first-rate block kunkur exists, visible above the surface in many places, but nowhere, as far as I could ascertain from villagers on the spot, deeper than 2 or 3 feet, varying in thickness from 1 to 4 feet; judging from the specimens of it in numerous buildings and wells in the neighbourhood, it seems fit for any kind of masonry. The roadway over the old bridge at Sirhind is floored with similar material, said to have been brought from Roopur, and appears to have stood the wear and tear of the traffic, for, we might say, centuries, better than any other material used for that purpose in these provinces. The existence of such a quantity of it in its present locality is a fortunate circumstance for these works if they be carried out, for, independently of its value in the construction of the heavy masses of masonry, it affords us the means of covering the more exposed portions of our works, such as crests of falls, &c., with a cheap and efficient substitute for stone. Experience has fully proved that, where

there is little extraneous pressure, if the facing of the masonry work exposed to the violent action of water (especially when loaded with silt) be of some hard material, it matters comparatively little what the body of the work may be composed of, provided it be some substance unaffected by the presence of mere humidity; were such a material everywhere available, the thickness usually given to many parts of our works might be much reduced. Where bricks only are used the facing is necessarily expensive; only those semi-vitrified and laid with the finest possible joints, will at all stand the continued action of water running at a high velocity; plaster is certain to be washed off—and even with the best bricks and finest workmanship deep furrows may often be seen ploughed into the masonry. *Black kunkur* is found in places along the course of the Cuggur, and in the Hissar district. *Deodar timber* is procurable now at the Roopur Ghât at the rate of two cubic feet for the rupee, but as yet only a small quantity comes down the river annually; common *fir* (cheer) is in abundance at the rate of four cubic feet for the rupee; what quantity the forests up the Sutlej can supply of either, I cannot say. Along the banks of the Cuggur, between the hills and its entry into the Thanesur district, extensive groves of *beelar* are found here and there, some of very large dimensions, admirably suited for bridging purposes—the Nirwanah branch lies for miles together through uncultivated tracts covered with jungle shrubs and trees, some of very large size, chiefly in the vicinity of the Cuggur and Sursoottee.

The allowance for *Contingencies*, 10 per cent. on the cost of the works added to the estimates, is intended to cover all expenditure on such items as “compensation for trees, wells, &c., &c.,” taken up with the land, “conservancy arrangements,” “office contingencies,” “temporary shelter for workpeople, &c.,” “survey and lining out,” and “tools;” it is the proportion of expenditure found necessary for those purposes on the works of the Baree Doab Canal. The per centage for *Establishment* on total cost of works, including contingencies, on those works, was 10·6. I have increased this in the present estimate to 12 per cent. to allow of additional supervising establishment; there were few of the officers employed on the Baree Doab Canal who were not more or less injured by the incessant toil both mental and bodily. It will hardly be considered advisable to repeat the experiment.

PROBABLE COST OF ENTIRE PROJECT.

The possible prolongation of the Kotluh and Nirwanah branches, with a proposed branch through the Loodiana and Ferozepoor districts down to Bhuttiana, have been elsewhere described, and are sketched into the general map; it only remains to show their probable cost, for which we have very fair data from the estimate now submitted. Taking the last 15 five thousands of the Nirwanah and Kotluh branches, as now estimated, the average cost per *five thousand*, comprising excavation of channel, chokies, rajbaha heads, and bridges, (the last bridge on each being taken as the basis of calculation,) with percentage for contingencies and establishment, is Rs. 7,426 for the former, Rs. 10,690 for the latter; this, it is evident, is a very safe estimate; the channels, and consequently the contents of the excavation, and length of bridges decreasing inversely as the distance from the head. The proposed extension to the Nirwanah branch being 61 five thousands, and for the Kotluh branch 40 five thousands; we have the total cost if completed of the

Nirwanah branch, Rs. $7,69,236 + (51 \times 7,426) = \text{Rs. } 11,47,954$

Kotluh branch, " $14,51,836 + (40 \times 10,690) = \text{" } 18,79,436$

For the *Loodiana branch* this estimate of cost of the Kotluh line may be safely taken, the circumstances of both being very similar; the declivity of the country surface must evidently be very nearly the same on the two lines, and there will be deep excavation, about 22 five thousands, immediately below the head of the Loodiana branch; the irrigating length of the latter, I have shown elsewhere, may be 147 five thousands; the total length, if the head be near Surranah would therefore be $147 + 22 = 169$ five thousands; we have then

Kotluh Loodiana Rupees
141 : 169 : : 18,79,436 : $\frac{169}{141} \times 18,79,436$

Cost of *Loodiana branch*, = Rs. 22,52,657.

The cost of the project, therefore, if fully carried out would be—

	Ra.
<i>Central line</i> , through the Sutlej Khadir to head of irrigation,	37,52,076-70
<i>Central line</i> through the Sutlej Khadir below head of irrigation,	18,26,499-17
<i>Nirwanah branch</i> , 	11,47,954-24
<i>Kotluh</i> , " 	18,79,436-56
<i>Loodiana</i> " 	22,52,657-00
Grand Total, 	1,06,96,633-67

The total is somewhat in excess, as the Loodiana branch would probably be taken off from the Kotluh line a few miles below the Surranah head, the intervening portion of channel being widened to receive the supply for both branches.

The above estimate does *not* include *Lockage*. If it be considered advisable to render the branches navigable throughout, and the design above described for a single lock chamber attached to each overfall be approved of, the additional expense would be as follows :—

	Rs.
Cost of the Barah Overfall, Estimate No. 19,	18,475-94
" with Lock, " " 20,	34,074-18
Difference due to lock,	15,598-19

Now the cost of a lock chamber varies comparatively little with the depth of drop, we may therefore very safely assume Rs. 15,000 as the excess on each overfall, or 2,40,000 Rs. extra on the whole line for *single* lockage. Double lock chambers might be necessary on the Loodiana and Nirwanah branches; not, I think, elsewhere. All the other works on the lines included in the present estimate are designed to allow of the free passage of boats and rafts, so that no alterations to them will be necessary, to allow of uninterrupted navigable communication; this, of course, adds materially to the estimate, but alterations after the admission of water into the canal would involve a very much larger outlay; and in some cases, as in superpassages, &c., an almost total reconstruction of the works.

The lengths of the several lines in miles (of 5,280 feet each) are as follows :—

	Miles.
Central line through Khadir, &c.,	27-76
" remainder,	85-87
Nirwanah branch,	121-21
Kotluh "	185-64
Loodiana "	160-08
Grand Total,	530-51

Mills are not estimated for in connection with the works; past experience has fully proved that they will always give a remunerative return when constructed in favorable localities.

I have not considered it necessary here to estimate for *Rajbhuas*. Rs. 1,000 per mile may be assumed as the probable cost, and three miles of rajbhuha to one mile of irrigating canal channel. The rate of water-tax I have elsewhere assumed in calculating the profits of the project, is taken from a canal where the cost of rajbhuas has hitherto been defrayed by the cultivators themselves; if constructed by the Government, a corresponding increase would of course be made to the water-rate.

INCOME, EXPENDITURE, AND PROFITS.

From the report of the Superintendent General of Irrigation in the North-Western Provinces, for the year 1860-61, it appears that the returns of the Eastern Jumna Canal for that year, show a rate of Rs. 286 per cubic foot of discharge at the heads. It is not likely that the duty done by the water in one of the driest years on record will be less in years of average rain-fall; I think, therefore, we may with safety assume Rs. 280, as the yearly value of a cubic foot of discharge at the head of irrigation. By the same returns, one cubic foot of discharge is sufficient for the irrigation of 296 acres, and the rate of current expenditure (for maintenance and repairs) was Rs. 120 per cubic foot of discharge per annum. The increase of land revenue from the introduction of canal irrigation we may take at the very low rate of Rs. $1\frac{1}{2}$ per acre per annum; I believe it to be far below the mark, but it is as well to show only the minimum rate of profit. As to the present rate of land-tax, over by far the largest proportion of the country which will come under the influence of these Canals, Rs. 1 per acre, per annum, may, I believe, be taken as the outside average. The quantity of land required for the canal channels now estimated for is 12,928 acres. For the Loodiana branch and the prolongations of the Kotluh and Nirwanah branches, 9,549 acres will probably be required; we have therefore a total of land occupied by the canal works = 22,477 acres. Now if we take the full annual rates for 3,000 cubic feet, and half rates for the extra 500 cubic feet, available for the Khureef crop only; supposing also that the works may be completed in six years, we have—

			Rs.
Water-rent,	3000 × 290	=	8,40,000
"	500 × 140	=	70,000
Increase of land revenue,	3000 × 290 × 1·5	=	13,05,000
" "	500 × 145 × 0·75	=	54,375
Total Income,			<u>22,69,375</u>
<i>Deduct.</i>			
Annual current expenditure,	3000 × 120	=	3,60,000
" " "	500 × 60	=	30,000
Loss of land-tax, annually, on 22,477 acres, about,			<u>35,000</u>
Total, . . .			<u>4,25,000</u>
Nett Income, Rs.,			<u>18,44,375</u>

	Total of present Estimate, 1,05,98,623
Add compensation for 22,477 acres taken up at 6 years purchase,	2,10,000
Ditto loss of land-tax for 6 years on 22,477 acres,	<u>2,10,000</u>
Grand Total Expenditure, Rs.,	<u>1,10,18,623</u>

From which we obtain a probable return of 16·7 per cent. per annum from water-rent and increase of land-tax *alone*; navigation returns I have not estimated, as the cost of lockage is not included in the estimate; from the returns of the Ganges Canal even up to the present time, Rs. 50,000 per annum would be the minimum of transit dues.

Though temporary expedients have been adopted in so many instances in this project, showing consequently a less outlay in original construction, it may be useful to compare its cost with that of other similar works. Taking the ultimate original cost of the Ganges Canal works at Rs. 2,00,00,000, and its discharge at 6,750 cubic feet per second; that of the Baree Doab Canal at Rs. 1,35,09,491; and its discharge 3,000 cubic feet per second; we have for the

<i>Ganges Canal,</i>	Rs. 2,963 per cubic foot of discharge.
<i>Baree Doab Canal,</i>	Rs. 4,508 " "

These rates include cost of lockage throughout. For the present project without lockage—*Sutlej Canal*—Rs. 3,261 per cubic foot of discharge. Nothing has been included in our estimate except what appeared absolutely necessary to the efficiency of the works, not even a single ghât. An Abstract Statement showing the cost of different divisions of the project is given further on.

The heavy outlay on the original construction of Irrigation works in these provinces has been ere this attributed in great measure to useless expenditure on ornament, "bridges with expensive ghâts," &c., and been contrasted unfavorably with the cost of works for like purposes in other parts of India. I leave the abstract of this project to speak for itself; the figures will show how small a proportion of the entire cost is devoted to works in which ornament is *possible*. A like result would, I have little doubt, be obtained from the Statements of Expenditure on other similar works. The excavation of the Canal channels, and the works connected with the natural drainage lines of the country, have always comprised by far the largest proportion of the original outlay on any irrigation project, and so far from these having been reduced in size or cost by the growth of experience, they have hitherto been steadily added to, because of the serious evils attending the adoption of temporary or inefficient expedients, which year by year become more manifest. That irrigation, without the exercise of due precautions against intercepting the natural surface drainage, is anything but a blessing to the country, no one practically acquainted with the irrigated districts of India, will I think, deny. The cost of these precautionary measures will vary of course with the physical features of the country. If it be asked why the Madras Irrigation works cost less in proportion to the income derived from them, than those in Northern India, the difference in the declivities of the country traversed by the canal channels, is sufficient to account for a large proportion of the difference in cost. Other valid causes might be adduced were this the proper occasion to enter into the question fully.

One other source of increase of cost in the Canal projects of late years in these provinces, is the necessity of providing for a navigable communication throughout, which involves, besides lockage at the overfalls, increase of excavation in the formation of tow-paths, and considerable additions to every bridge to give towing passages on either side, as well as extra height to afford headway for laden boats. Navigation appears to be satisfactorily combined with irrigation on the Madras canals, and here again the small declivities come in to their aid. In a Report of Col. Sir A. Cotton's, dated the 16th June 1852, on some of the Godavery irrigation channels, he mentions a mile an hour (or 1.47 feet per second) as the maximum velocity which ought to be allowed in the current of a navigable channel; were this to be taken as the basis of our calculations, the cost of our works in

excavation, and overfalls to overcome the superfluous surface slope, would be well nigh doubled. It would probably be a cheaper and more efficient plan to construct an entirely separate channel for navigation alongside the Canal, to which the latter would act as a feeder; the cost of the irrigating channel might then be considerably lessened by the diminution of the excavation for berms (or tow-paths) and the reduction of the width of, and headway under, the bridges to that necessary for the mere passage of the water supply. That navigation is practicable, however, with higher velocities than this, the experience on the Ganges Canal works seems to prove; for with all its faults of excessive velocity of current in the upper divisions, want of towing passages under the bridges, and irregularity of height of tow-paths, the navigation returns are already more than Sir P. T. Cantley estimated them at.

As to the *time* which will probably be required for the construction of the works so far as to commence irrigation, it obviously depends on the speed with which the heavy masonry works in the Khadir, and the deep excavation in the high land can be pushed on; no water can be delivered at the heads of the irrigating branches till these are completed. If funds and *trained* officers are available as required, six years will I believe suffice for the completion of this section; the irrigating lines below could of course be finished simultaneously if deemed advisable.

The possibility of drawing the supply from the Sutlej below the mouths of, at least, some of the formidable torrents which intersect the Khadir, by means of an *Anicut*, the method so successfully practised in Madras, was suggested to me by Colonel Yule; the height of the surface of the Bangur, where the water must be delivered, puts it however out of the question.

CALCULATIONS FOR DISCHARGE, &c.

The formulæ used for calculating the velocities in the various channels are as follows:—

For the canal channels, and others where the mean velocities are not above 4 feet per second.

$$V = 90 \sqrt{\frac{R}{S}}$$

For high velocities, such as obtained in hill torrents, &c.

$$V = 93 \sqrt{\frac{R}{S}}$$

where—

V = mean velocity in feet per second.

R = hydraulic mean depth in feet.

S = denominator of fraction denoting declivity of bed, the numerator being unity.

They were taken originally from Neville's work on Hydraulics; equations of this form with a co-efficient suited to each particular case, give I believe, quite as good approximations (they are but approximations at best) as the more elaborate formulæ of Dubuat and others. The equation for discharge over "complete" overfalls is—

$$D = \frac{2}{3} c_d l \sqrt{2g} \left\{ (d + h_a)^{\frac{3}{2}} - h_a^{\frac{3}{2}} \right\}$$

where—

D = discharge cubic feet per second.

l = width of waterway.

$$\sqrt{2g} = 8.025.$$

d = depth of water in channel above.

h_a = head due to velocity of approach.

c_d; the co-efficient has been generally taken = .628, in some cases = .8.

For discharge over "incomplete" overfalls the equation is:—

$$D = c_d l \sqrt{2g} \left\{ d_1 \sqrt{d_1 + h_a} + \frac{2}{3} (d_1 + h_a)^{\frac{3}{2}} - h_a^{\frac{3}{2}} \right\}$$

in which d₁ = difference of level between crest of overfall and surface of stream in lower channel.

d₁ = height of drop,—the others having the same signification as in the last equation.

As the declivities are expressed in this report, in terms slightly differing from those ordinarily employed, the following table may perhaps facilitate comparisons.

1 in 6,000 or .88 feet per mile (5,280 feet.)

1	„	4,800	„	1.10	„	„	„
1	„	4,700	„	1.12	„	„	„
1	„	4,000	„	1.32	„	„	„

1 in 3,500 „ 1.51 feet per mile (5,280 feet.)

1 „ 3,000 „ 1.76 „ „ „

1 „ 2,500 „ 2.11 „ „ „

LIST OF RATES ADOPTED IN THE ESTIMATES.

Description.	At	Per
	RS.	
Excavation, canal channel,	2 to 4	1,000 c. ft.
„ in boulders, shingle and water,	12	1,000 „
Embanking,	5 to 6	1,000 „
Puddling,	5	1,000 „
Sand cores,	6	1,000 „
Shingle work in bunds,	10	1,000 „
Boulder and crib-work in spurs and bunds,	12	1,000 „
Dry boulder work (filling),	15	1,000 „
Masonry, brick-work in lime cement,	16 and	25
„ boulder in lime cement,	14	100 „
„ mud-work,	8	100 „
„ arching,	28 and	35
„ in wells,	20	100 c. ft.
Stone grooves,	2	per l. ft.
Box-work,	50	100 a. ft.
Crib-work revetment,	10	100 c. ft.
Under-sinking, large wells,	15	„
„ small wells,	8	„
Curb frames, large,	25	each.
„ small,	15	„
Paved slopes,	3	100 a. ft.
Metalling in roadway,	5	100 c. ft.
Flooring, terras,	5	100 a. ft.
„ kunkur, up and down-stream,	6	100 c. ft.
„ brick-on-edge, over arches,	28	100 „
„ dry boulder work,	6	100 „
Roofing, in timber,	875	per c. ft.
„ on beams and kurries,	30	100 a. ft.
„ flat without beams,	16	100 „
„ „ with beams,	25	100 „
„ thatched,	7	100 „
Timber work,	625	per c. ft.
Doors, two-third glazed, 6' x 5',	25	each.
Falling gates, 11' x 6', with iron-work complete,	1-5	per a. ft.
Planks, 11' x 1'0' x 0.25',	12	each.
Gates,	1	per a. ft.
Lock gates,	8	„
Sleepers, 12' x 0.5' x 0.5',	12	each.
Piling at foot of slope,	4	per l. ft.
Piles,	1.5	each.
Groined spurs,	4	per l. ft.
Windlasses,	50	each.
Bitt heads,	10	„
Bar chain, small,	4	per l. ft.
Iron work,	0.5	per seer.

ABSTRACT OF GENERAL ESTIMATE.

Description.	Central line in Khadr.	Central line be- low Khadr.	Kodinh branch.	Nirvanah branch.	Total.
Excavation of channel,	19,00,047-08	8,78,177-61	9,69,908-28	8,89,000-78	41,37,133-75
Drainage works, including head works,* ...	10,86,384-89	...	...	1,27,633-70	12,14,018-59
Overfalls,	...	37,620-76	50,118-47	21,888-56	1,09,622-79
Escapes, including heads,	...	67,813-48	61,418-05	...	1,29,331-53
Bridges and branch heads, and fords,	39,155-79	29,069-70	29,469-00	25,088-00	1,15,727-49
Accommodation for establishment,	13,255-04	20,686-33	25,529-96	21,417-53	80,888-85
Roads,	6,674-00	18,136-00	20,200-00	15,400-00	60,410-00
Irrigation outlets,	...	25,200-00	28,800-00	24,000-00	78,000-00
Contingencies at 10 per cent.,	3,04,561-68	1,07,670-39	1,17,943-88	62,437-86	5,92,508-31
Establishment at 12 per cent.,	4,02,008-22	1,42,124-91	1,55,553-92	82,417-31	7,82,104-36
Totals, Rupees,	87,52,076-70	18,26,499-17	14,51,886-56	7,69,228-24	72,99,640-67

* Drainage works include dams, aqueducts, superpassages, inlets, outlets, excavations for drainage cuts, and bunds and spurs connected with hill torrents.

J. CROFTON, CAPT., R.E.

No. LXXIII.

JUMNA FLOODS DIAGRAM.

Communicated by GEORGE SIBLEY ESQ., C.E., *Chief Engineer, E. I. Railway, N. W. P.*

THIS diagram commences from 1st January 1861, and is plotted up to the end of April 1865. The records for 1860 were unfortunately lost.

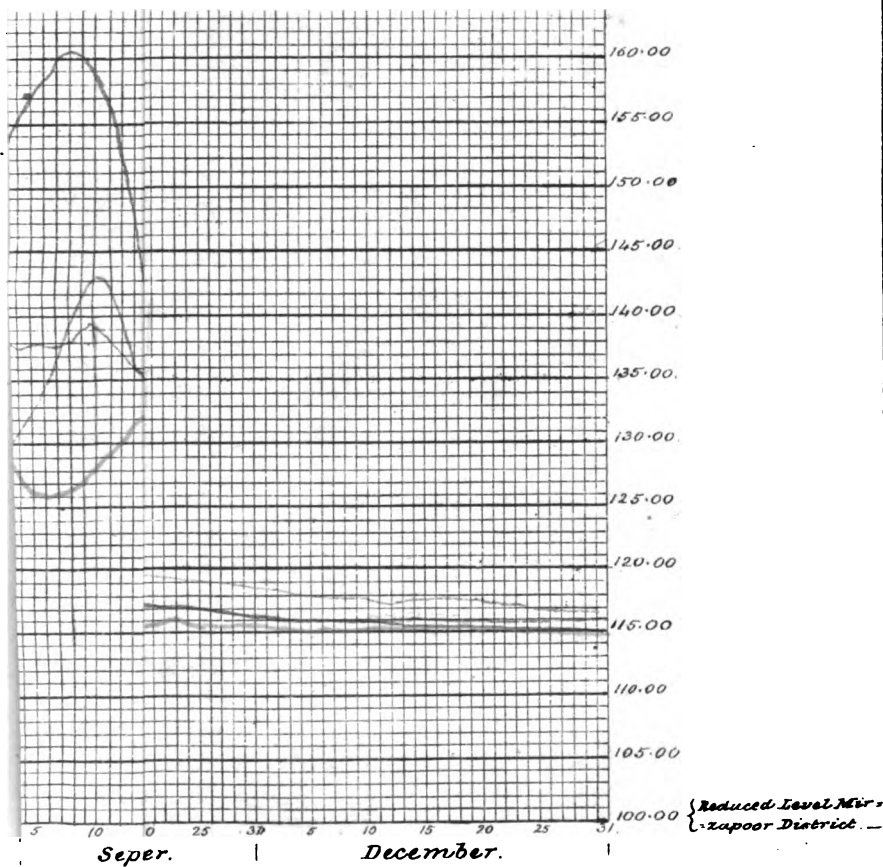
The horizontal divisions represent feet, and the vertical lines twenty-four hours interval, but the record has been taken twice daily, viz., at 6 A.M. and 6 P.M.

It will be observed that the extreme variations of level between the five years on the 1st January, is less than 2 feet; also that (excluding the present year, which is entirely abnormal) the extreme variation of lowest low water level is 2 feet.

The date of lowest level was for the several years, in their order, as follows:—19th April, 26th April, 21st May, 28th April, 11th February. Thus, for three years out of the five, the date of lowest low water fell between 19th and 28th April, and this may be taken to be the normal average; at that date begins the slight rise due to snow melting. In 1863, this slight rise was more than counteracted by the continued prevalence of strong westerly winds, and the dates of lowest level was protracted till 21st May.

In this year the period of lowest water was reached on 11th February, at which date a slight rise, extending to 1 foot, occurred, and was maintained until 12th March, when the (at that season) extraordinary rise of 3 feet further took place, making the river 3·6 feet higher than the average at that period, and 6 feet higher than the lowest recorded level of that date.

It will be seen that in three years out of four, the great rise due to



the periodical rains commenced on the 19th or 20th June. Last year was one of exceptional drought, and the rise was deferred till 15th July.

In three years out of four, the period of highest flood fell between the 22nd and 26th August, but the highest flood of all, that of 1861, fell so late as 10th September.

The reduced level of highest floods in the several years, consecutively, were as follows:—

In 1861,	...	...	...	...	161·60
„ 1862,	...	...	...	...	144·50
„ 1863,	...	...	...	...	155·00
„ 1864,	...	...	...	...	152·50

The highest flood, 1861, is very nearly the same as that of 1832, the highest recorded; and the flood of 1862 is nearly the lowest recorded; so it may be taken, roughly, that the lowest recorded flood rises 30 feet above low water, that an average flood rises 40 feet, and a maximum flood rises 50 feet, above the same level.

The year 1861 was remarkable, not merely from the exceptional height, but also for the long duration of the floods. The river ran for eight days over 155·00, and for four days over 160·00.

The maximum rate measured was rather more than eight miles an hour, or about 12 feet per second (accurately, 950 feet in 81 seconds); for twelve days it ran over 10 feet per second.

At the period of greatest discharge, the mean surface velocity must have been 10 feet per second, and mean velocity of the whole stream upwards of 9 feet per second; the sectional area at that level being about 145,000 feet, it follows that the discharge per second must have reached the enormous amount of nearly $1\frac{1}{2}$ million cubic feet.

G. SIBLEY.

No. LXXIV.

PUNJAB RAILWAY INSTITUTE.

Designed and Built by EDWIN E. BAINES, Esq., *District Engineer.*

THE Chief Engineer (J. Harrison, Esq.) and the late lamented Agent, R. W. Stevens, Esq., of the Punjab Railway, in April 1863, taking into consideration the rapid increase of European employés on the Company's works at Nowlukha, Lahore, deemed it advisable that some rational place of amusement and instruction should be formed; accordingly, instructions were given to Mr. E. C. Baines, the Engineer of the district, to prepare a design and estimate, and these having received sanction, the works were commenced in the autumn of 1863, and were available for the members' accommodation at the commencement of the ensuing hot season.

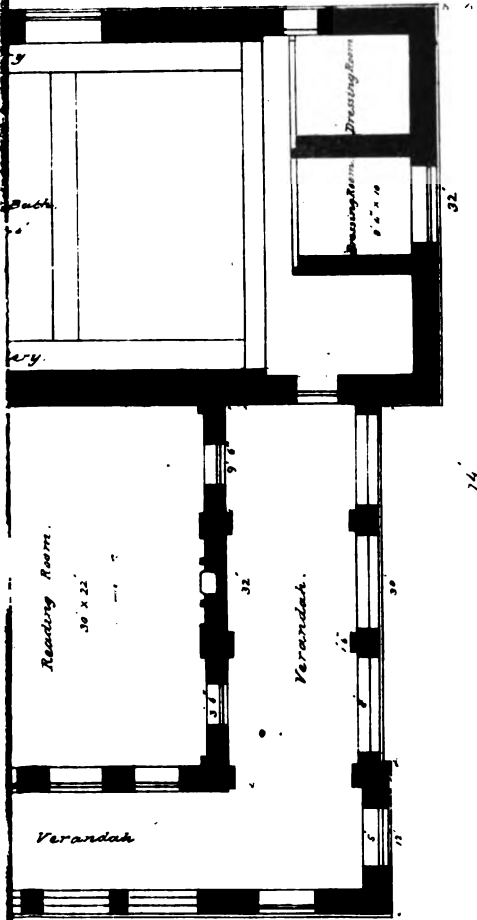
The arrangements consist of a Reading-room, 30 × 21 feet, with small Book-room, and Khansamah's room attached, surrounded with a verandah 8 feet in width; in the rear is a commodious Swimming Bath, 44 × 27 feet, provided with two small dressing-rooms.

The bath gives a depth of 10 feet of water, one half of which will be supplied from the adjacent rajbaha naturally, and the remainder from a well. The bath can easily be flushed out, being connected by a sluice with the Company's culvert.

The Institution is supported by about eighty members. The table is well supplied with books and periodicals. The estimated cost was Rs. 12,571-3-3. The executed cost, Rs. 11,352-6-3.

E. B.

PUNJAB RAILWAY INSTITUTE.



3 .

4

LAYING OUT CURVES.

BY R. MCKENNIE, Esq., *Assistant Engineer, Mysore.*

FIG. 1.—PX is any right line; it is required to diverge from it at the point A, into a Curve of any Radius, such that the line PX shall be a tangent to the curve at that point.

(1°). Proceeding to the point A, and adjusting the theodolite over it, lay out any angle XAQ that is contained in the Tables, such that there may be no obstruction in the line AQ; and set up a pole in that direction. For example, let us suppose the angle XAQ = 20°, and the radius of the curve six chains.

(2°). Multiply the *Tabular Semi-Abscissa** and Ordinates (which are entered in the Tables as decimals of one chain, or any other unit, *vide* Formulæ), opposite the angle selected (20° in this instance), by given Radius, for *new* Semi-Abscissa and Ordinates corresponding to the given radius. In the above example:—

				CH. LKS.
Tabular semi-abscissa,	$\times r =$	$\cdot 342020 \times 6 = 2\cdot 052$	$= 2$	5
1st tabular ordinate,	$\times r =$	$\cdot 011752 \times 6 = 0\cdot 070$	$= 0$	7
2nd	„	$\times r = \cdot 022146 \times 6 = 0\cdot 132$	$= 0$	13
3rd	„	$\times r = \cdot 031224 \times 6 = 0\cdot 187$	$= 0$	18 $\frac{1}{2}$
9th	„	$\times r = \cdot 059722 \times 6 = 0\cdot 358$	$= 0$	35 $\frac{1}{2}$
10th	„	$\times r = \cdot 060307 \times 6 = 0\cdot 361$	$= 0$	36

FIG. 2.—(3°). Then from A chain towards Q, to length of new semi-

* Semi-chord ?—[Ed.]

abscissa, or 2 chains 5 links, and let B be the point arrived at, where place a staff.

(4°). Divide the semi-abscissa corresponding to given radius into ten parts, which is at once done by shifting the decimal point one place to the left, and the result for radius of six chains, is $20\frac{1}{2}$ links. We thus get the interval between each ordinate, or space intercepted between each offset from the line AQ.

(5°). Now commence at A, and $20\frac{1}{2}$ links from it on the line AB stick down a peg corresponding to the point *a*, Fig. 1. $20\frac{1}{2}$ links from that again, on the same line, place another, corresponding to *b*, and so on, till finally you arrive at B, where a staff has already been placed, and which ought to be $20\frac{1}{2}$ links from the point *i*, or 9th peg from A.

(6°). Then, from the points *a*, *b*, *c*, &c., *h*, *i*, and B, lay off at right angles to AB, the calculated 1st, 2nd, 3rd, &c., 8th, 9th, and 10th ordinates, respectively, that at *a* being 7 links, at *b* 13 links, and so on, these extremities being connected will give the required curve.

(7°). To complete the curve, produce the line AB till $BC = AB = 2$ chains 5 links. On this line place a peg, $20\frac{1}{2}$ links from B, corresponding to point *i'*, Fig. 1, and so on, placing pegs in succession till C is reached, which ought to be $20\frac{1}{2}$ links from the last peg, *a'*, placed.

(8°). Then, from the points *i'*, *h'*, &c., lay off the 9th, 8th, &c., ordinates just used, i. e., $35\frac{1}{2}$ links at *i'*, $34\frac{1}{2}$ links at *h'*, &c., and 7 links at *a'*.

(9°). Should it be desirable to continue the curve, remove the theodolite to C, and make an angle $ACY = 180^\circ - 2X\angle A$, which will be in this case $180^\circ - 40^\circ = 140^\circ$. Set up a pole in the line CY, and proceed precisely as before, the calculations being the same, as will be at once seen from the construction; so that instead of finding the tangent at the point C, and laying off the abscissa from it, we lay off the abscissa from the last one, thus saving time. Thus the curve will be continued from C to D, $CD \text{ being} = AC$.

(10°). By continually proceeding in this way we may complete the circle, and the several abscissæ will be the sides of a regular polygon inscribed in a circle.

Sometimes, however, rule 9°, is not applicable, from trees or other obstructions in the line of the abscissa, in which case—

Fig. 2.—(11°). Set the theodolite at C, and make an angle ACX'

RAILWAY CURVES.

Fig. 1

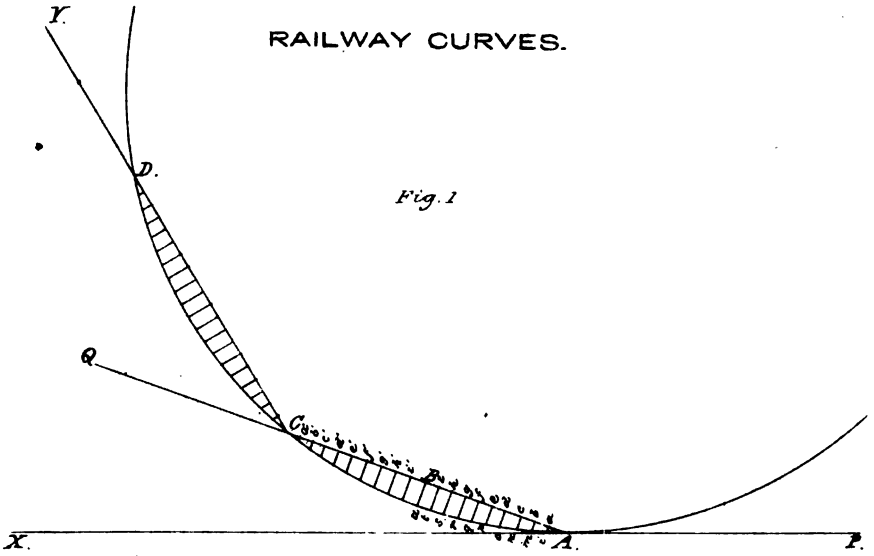
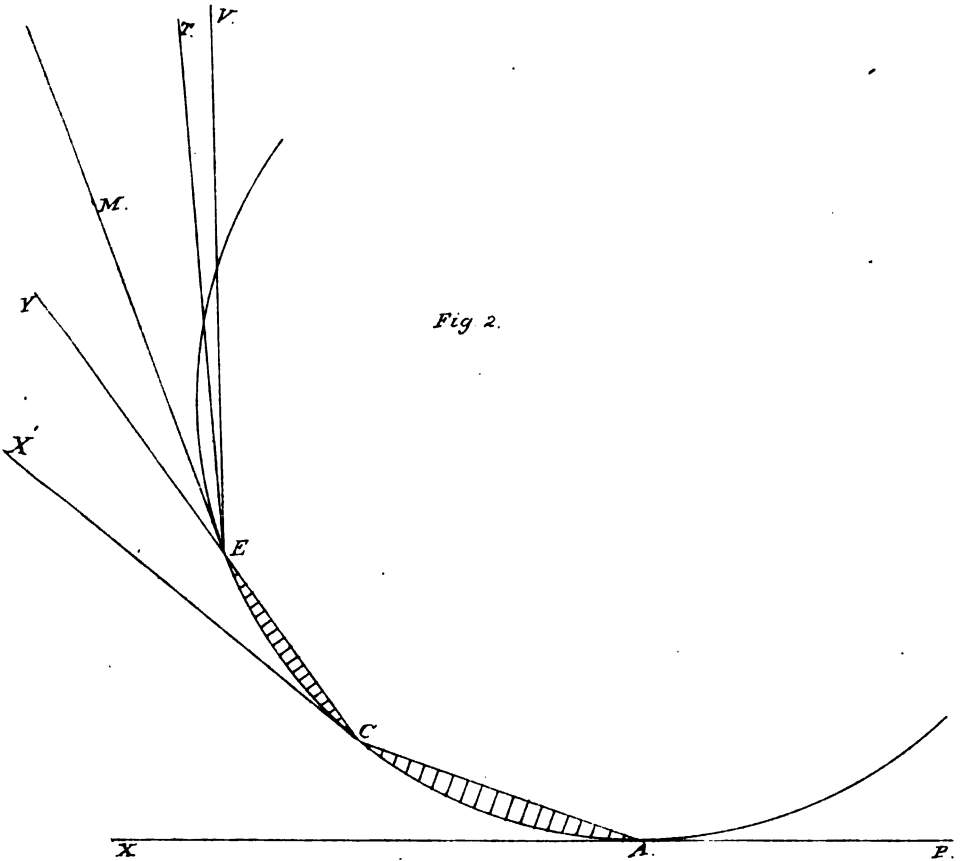


Fig. 2.



$= 180 - XAQ = 180^\circ - 20^\circ = 160^\circ$, and set up a pole in the line CX' which will be a tangent to the curve at the point C , and use any other tabular angle $X'CY'$ applying the previous rules; thus the curve will be traced from C to E , or end of abscissa corresponding to tabular angle $X'CY'$. Rule 9° can now be applied for the continuation of the curve by making an angle at E , $CET = 180^\circ - 2X'CY'$, and so on, provided no obstacle prevents the measurement of the abscissa; thus avoiding new calculations so long as the same angle, $180^\circ - 2X'CY'$ is used.

Should it not be desirable to continue using the same angle, we can set the instrument at E , and apply rule 11°, thus finding the tangent ME at that point, and using some other tabular angle, continue the curve in spite of all obstructions.

If the reverting point happened to be at C (the end of the abscissa), we could revert into a tangent by making $ACX' = 180^\circ - XAQ$, as in rule 11°; and so on for the tangent at the end of any abscissa. The general case, however, is, to suppose the reverting point to be situated anywhere in the curve.

Fig. 3.—(12°). Set the Theodolite at C , or end of abscissa, and find the angle δCA ; then convey the instrument to δ and make an angle $C\delta Z = XAC - \delta CA$, then the line δZ will be a tangent to the curve at that point; and so on in similar cases.

Fig. 4.—(13°). To construct the S curve, the point of contact of curves being the point δ , find a tangent to the curve at that point; and using any tabular angle, proceed as before, the ordinates and abscissa being on the opposite side to the first curve; by the same means any number of reversed curves can be laid out.

When the radius of the curve is large, a small tabular angle should be used, and *vice versa*, so that in no case need the abscissa and ordinates be of inconvenient dimensions. The tabular angles from 1° to 20° , at intervals of $15'$, are found to answer all practical purposes.

These Tables have been computed from the formulæ appended, with great exactness, and having been tested by the Differential method, have been found to be very accurate, so that they may be relied on. The tabular values have been carried to six places of decimals: any number of places, however, may be used in practice, according to the degree of accuracy demanded.

Though these Tables, with the method of using them, may appear

troublesome, their extreme accuracy on the ground compensates in a great measure for any extra work they may give; and I question if they may not be on the whole quite as expeditiously used as any other instrumental method.

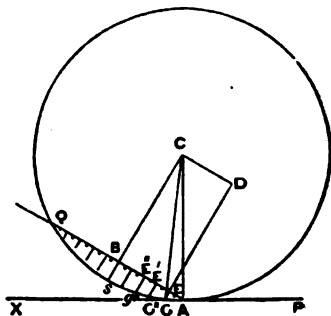
I am aware that there is one method by the chain alone which is very expeditious, and which I invariably use myself extensively when great accuracy is not wanted; this, as well as many useful problems will be found treated in full in "Henck's Field-Book for Railway Engineers," a work which at once recommends itself on perusal.

In conclusion, I in no way claim to be the investigator or calculator of these Tables, but beg to give the whole credit to Mr. William Gartland, C.E., Dublin, to whom I am indebted for many miscellaneous and valuable mathematical investigations in manuscript; and trust they may be found as valuable to others as to myself. I am not aware either that they have ever been printed, or are in any way generally known; indeed I have reason to think they are not, but should they be, my apology must be that they may be useful to men who are not likely to have met with them.

Investigation of formulæ.—Let PX be a tangent to a circle at the point A; draw any line AQ, making an angle with XP at A = θ .

Draw CS perpendicular to AQ, it will also bisect it; and it is evident that $\angle SCA = \angle QAX = \theta$.

Let $AE = \frac{1}{10} AB$, and draw GD at right angles to AB at E.



$$\text{Now, } AB = r \sin \theta, \text{ but } AE = \frac{1}{10} AB \therefore = \frac{r \sin \theta}{10}.$$

$$\text{also } BE = CD = 9 AE = \frac{9 r \sin \theta}{10} \dots\dots\dots (a).$$

$$BC = ED = r \cos \theta \dots\dots\dots (\beta).$$

$$GD = \sqrt{r^2 - CD^2} = \sqrt{r^2 - \left(\frac{9 r \sin \theta}{10}\right)^2} \dots\dots\dots (a).$$

GARTLAND'S RAILWAY CURVE TABLE.

Tangential												Deg. Min.	
		1st Ordinate.	2nd Ordinate.	3rd Ordinate.	4th Ordinate.	5th Ordinate.	6th Ordinate.	7th Ordinate.	8th Ordinate.	9th Ordinate.	10th Ordinate.	Semi-Abscissa.	Tangential Angle.
14	0	-005713	-010797	-015261	-019113	-023261	-025011	-027067	-028533	-029411	-028008	-251080	13 40
14	15	-005921	-011189	-015812	-019802	-023166	-025011	-027067	-028533	-029411	-029704	-241922	14 0
14	30	-006132	-011586	-016372	-020503	-023985	-026824	-029027	-030598	-031538	-031852	-246153	14 15
14	45	-006347	-011992	-016944	-021217	-024818	-027755	-030032	-031657	-032629	-032954	-250380	14 30
15	0	-006566	-012403	-017525	-021943	-025665	-028701	-031055	-032733	-033739	-034074	-254602	14 45
15	15	-006790	-012834	-018117	-022682	-026527	-029663	-032094	-033828	-034867	-035213	-258819	15 0
15	30	-007017	-013250	-018718	-023432	-027403	-030641	-033151	-034941	-036013	-036370	-263031	15 15
15	45	-007246	-013684	-019328	-024194	-028292	-031663	-034223	-036070	-037177	-037545	-267238	15 30
16	0	-007479	-014123	-019947	-024968	-029195	-032641	-035313	-037217	-038358	-038738	-271440	15 45
16	15	-007717	-014572	-020257	-025278	-029575	-033666	-036424	-038382	-039558	-039950	-275637	16 0
16	30	-007959	-015026	-021218	-026553	-031046	-034706	-037544	-039565	-040776	-041180	-279829	16 15
16	45	-008205	-015488	-021868	-027365	-031992	-035762	-038684	-040766	-042013	-042429	-284015	16 30
17	0	-008454	-015956	-022527	-028188	-032952	-036833	-039841	-041984	-043267	-043695	-288196	16 45
17	15	-008708	-016433	-023198	-029024	-033927	-037920	-041014	-043220	-044540	-044980	-292372	17 0
17	30	-008966	-016916	-023879	-029872	-034916	-039023	-042205	-044473	-045831	-046283	-296542	17 15
17	45	-009227	-017407	-024568	-030732	-035918	-040141	-043412	-045743	-047139	-047604	-300706	17 30
18	0	-009491	-017904	-025267	-031604	-036934	-041274	-044637	-047031	-048465	-048943	-304864	17 45
18	15	-009760	-018410	-025977	-032489	-037966	-042424	-045877	-048337	-049810	-050360	-309017	18 0
18	30	-010033	-018922	-026696	-033386	-039011	-043589	-047135	-049661	-051172	-051676	-313164	18 15
18	45	-010310	-019442	-027426	-034295	-040070	-044769	-048409	-051001	-052553	-053070	-317305	18 30
19	0	-010590	-019967	-028166	-035216	-041143	-045964	-049700	-052359	-053951	-054481	-321439	18 45
19	15	-010875	-020501	-028916	-036151	-042231	-047177	-051007	-053735	-055368	-055911	-325568	19 0
19	30	-011163	-021041	-029676	-037097	-043333	-048405	-052332	-055128	-056802	-057359	-329691	19 15
19	45	-011456	-021590	-030445	-038055	-044448	-049647	-053672	-056538	-058253	-058824	-333807	19 30
20	0	-011752	-022146	-031224	-039024	-045576	-050905	-055029	-057965	-059722	-060307	-337917	19 45
												-342022	20 0



$$\begin{aligned}
 GE &= GD - ED = \sqrt{r^2 - \left(\frac{9r \sin \theta}{10}\right)^2} - r \cos \theta \quad \dots (\beta). \\
 &= \sqrt{r^2 \left\{ 1 - \left(\frac{9 \sin \theta}{10}\right)^2 \right\}} - r \cos \theta. \\
 &= r \left\{ \sqrt{1 - \left(\frac{9 \sin \theta}{10}\right)^2} - \cos \theta \right\}
 \end{aligned}$$

Let $\frac{9 \sin \theta}{10} = \sin x$ from which x can be got

$$\therefore GE = r \left\{ \sqrt{1 - \sin^2 x} - \cos \theta \right\} = r \left\{ \cos x - \cos \theta \right\}$$

Similarly, values for $E'G'$, $E''G''$, &c., can be found, each being at a distance from one another $= AE = \frac{1}{10} AB$.

Also $BS = r - BC = r - r \cos \theta = r(1 - \cos \theta)$.

Now, calling AB , the semi-abcissa, and EG , $E'G'$, $E''G''$, &c., the 1st, 2nd, 3rd, &c., ordinates, we enter their values, under their respective heads in the tables.

The rules for diverting the line from curve to tangent, &c., are so simple of geometrical proof as to require no demonstration.

R. McKENNIE.

No. LXXVI.

ROADS AND RAILWAYS IN INDIA.

*Re-printed, by permission, from a pamphlet by SIR WILLIAM DENISON,
K.C.B., Colonel, Royal Engineers.*

LOOKING to the fact that the Government of India, although it has expended large sums upon roads and railways, as well as upon canals, when opportunities of constructing these were afforded, has yet many thousand miles of road to make, and fresh lines of communication to open, I cannot but think that an enquiry into the circumstances which influence the cost of transport in India, and a comparison of the advantages presented by different modes of communication, would be useful, not merely to the Government, but to the capitalists who may be disposed to invest money in works of this kind, and who, of course, would wish to derive from such investment the largest returns.

Such an enquiry, will, I think, tend to prove that the local features of the country, the character of its climate, the peculiarities of the people, and the nature of their industrial system, influence, far more largely than many are apt to think, the discussion of questions which would seem, to most, to be simple matters of engineering experience.

Before, however, I enter upon this enquiry and comparison, I must premise that the facts which I propose to classify and arrange, as the basis of any inferences I may draw, have reference to the Presidency of Madras, which occupies by far the largest portion of the southern extremity of the Peninsula of India. There is, however, a marked similarity between the state of things in the different Presidencies; and, with some trifling allowances for local peculiarities, I think that what I have to say about railroads in Madras, will be found applicable to the whole of India.

General aspect of the Country.—The Peninsula of India extends from

Cape Comorin in latitude 8° N. to latitude 20° or 21° W., at which point its width is about 14° of longitude or 800 miles or thereabouts.

A range of mountains from 6 to 8000 feet high runs parallel to the Western Coast at a distance of about 50 or 60 miles from the sea. This range is broken through at one point where there is a gap of about 40 miles in width, the height of which is not more than 1,200 feet above the sea. The fall of the ground to the westward is therefore rapid, while speaking generally, there is a gradual and much more gentle slope to the eastward, which is interrupted, occasionally, by abrupt secondary ridges rising to a height of 2 or 3000 feet. Nearer the East Coast the land slopes gradually towards the sea, at the rate of about 4 feet per mile, in great plains, where there is but little to catch the eye, or to relieve the monotony of the landscape. It follows, from what has been said above, that the rivers flowing to the West Coast have short and rapid courses; though, as they flow through a narrow belt of alluvial soil near the sea, they are often navigable for small craft for some miles from the mouth. Those that flow to the eastward have a much longer course, and, as they drain a much larger area of country, they bring down, during the rainy season, a very heavy body of water; as, however, the supply is but temporary, as will be seen when I speak of the climate, these rivers do not afford any facilities for water communication in their unimproved state.

Climate.—The position of the Peninsula, within the northern tropic, exposes it to the action of the periodical rains. These are modified in their action by the relation of the Peninsula to the great mass of the continent from which it projects, and assume the form of two distinct monsoons. The south-western, which is by far the most extensive in its action, commences about the middle of May, and, so far as the Peninsula of India is concerned, expends its force principally upon the West Coast, and the range of mountains paralld to it, where during the months of June, July, August, and part of September, there is a steady down-pour with an occasional break; the average rainfall may be put at 180 inches.

Of course a large proportion of this water returns rapidly to the sea on the West Coast; the effect being to lessen the saltness of the sea to such an extent as to kill the fish and all the plants which are naturalized in salt water, for several miles from the coast, and to cause thereby a most disagreeable putrescent effluvium along the coast, and for three or four miles out to sea.

A portion of the rain of the south-west monsoon is discharged upon the eastern slopes of the mountain range, and drains into the water-courses which form the heads of the large rivers, such as the Godavery, Kistaah, and Cauvery, which discharge themselves into the Bay of Bengal; causing heavy floods in the lower portions of these rivers. In October the wind veers to the northward of east, and is called the north-east monsoon. It brings with it the rain which it has sucked up in the Bay of Bengal, and discharges it upon the eastern slopes of the Peninsula. The amount, however, of this discharge, which continues at irregular intervals through November and December, is not nearly so great as that of the south-west monsoon. The average of twenty years gives thirty-one* inches as the amount of rain at Madras during the north-east monsoon, and further inland the average is much less, not exceeding thirteen inches.

Rain may be said to fall from May to December in some part or other of the Peninsula; but the $4\frac{1}{2}$ or 5 months from January towards the end of May, may be termed emphatically the dry season. No vegetation takes place, except in situations where water can be found to irrigate the soil; the sky is cloudless, there is nothing to impede the action of the sun upon the ground, which is baked to the hardness of a brick where the aluminous element prevails, and is reduced to a dust where its consistency is less compact.

Cultivation.—From the foregoing description of the climate, it may be inferred that the productiveness of the country depends altogether upon the periodical rains. Should nature pause in her action for a single season, the result of this short cessation would be such a wide-spread famine as would destroy millions upon millions of people, and reduce the country to a desert.

On the West Coast the rain falls with such regularity, and the atmosphere generally is so moist, that few or no attempts are made to retain the water discharged upon the range of mountains bordering the coast. On the east side of these mountains, however, the case is very different. Here the rain is scanty and irregular, and care is taken to secure as much as possible of the drainage of the country. In every water-course, or line of drainage, dams will be seen following each other in regular succession, till all, or nearly all of the drainage water is caught, and retained for agricultural purposes; the surplus, which finds its way into the rivers, is again stopped by *anicuts* or dams constructed across them, from distance to

* Being rather less than the *total* annual rainfall of the Punjab, where the cold weather rains of January and February average from 2 to 5 inches only.—[ED.]

distance, and channels are taken from above these dams by which the water of the river is distributed as extensively as possible. When all this has been done, there is but a small proportion of the cultivated land which is susceptible of irrigation; the remainder is dependent upon the ordinary action of the rains, and is sown with what are termed "dry crops;" namely, various kinds of millet and raghi, and also with oil seeds, gram, and other leguminous plants. This dry cultivation imposes upon the farmer the obligation of completing his agricultural operations rapidly; he cannot plough before the first rains have softened the ground; he cannot sow till he is pretty certain of continual showers of rain. The result is that he is compelled to maintain, or at all events to employ, a pair of bullocks for every five, or at least, for every eight acres of land which he cultivates, as he would not be able, with less animal power, to carry through the various ploughings and hoeings which the land demands. The crop springs up rapidly under the influence of rain, and of a sun nearly vertical, and is ready for reaping in four or five months. It is then reaped, trodden out by bullocks, as was done in the time of Moses, and winnowed by the wind in a manner as old-fashioned as the threshing. When all this has been done, the farmer, unless he has land which he can irrigate, and from which he can get a second crop, has no work for his bullocks during the five or six months of the dry season; they are, consequently, employed in conveying produce to market, and the farmer or cultivator, leaving his land to take care of itself (which it does by producing a plentiful crop of coarse grass and weeds) attaches his bullocks to a light cart or bandy, and becomes a common carrier, being satisfied, of course, with very small profits, as every penny which he receives, in addition to the amount required to maintain his bullocks, is clear gain.

Population.—The population of the Madras Presidency may be put at 24,500,000, of which about 16,800,000 are employed in agriculture. About 450,000 are congregated in Madras and its suburbs. There are, however, few large towns, though in each district there are three or four towns, about which the population congregates more densely than in the rural districts. As a general rule, the population is more generally diffused over the face of the country than is the case in England, where the agricultural portion of the community forms a much smaller portion of the whole than is the case in India.

Wages.—A necessary result of this dissemination of the people, and of

their employment in the rude processes of agriculture, is that wages are low every where. The capital expended by the different Companies upon Railways and Irrigation Works, has, by increasing the demand for labor, raised *locally*, the rate of wages; but, even now, in parts of the country a little distant from the lines of Railway, from Rs. $2\frac{1}{2}$ to Rs. 4 per month or from $2\frac{1}{2}d.$ to $8d.$ per day, may be considered as the ordinary and average rate of wages; while, generally speaking, the whole of the agricultural labor is paid for in kind. The hire of a pair of bullocks and a man to drive them, and to plough at the same time, is 5 annas or $7\frac{1}{2}d.$ per day.

Roads.—Though men and cattle may be hired at a very low rate, as shown above, yet the cost of transporting commodities must depend very much upon the character of the road over which the traffic is to pass. The main lines of road throughout the Presidency are, generally speaking, in a fair state of repair, much money having been spent upon them. The principal obstacles to ready communications are the nullahs and water-courses, many of which are not bridged; during the rainy season these are torrents altogether impassable; while in the dry season, the river beds are filled with a loose drifting sand across which the ordinary carts or bandies, carrying about half a ton, require to be assisted by many men. The cross roads are in pretty good order for the character of the traffic which passes along them; indeed, during the dry season, roads though deep in dust, do not oppose any great obstacle to the movement of goods or produce. A great proportion of the work of transport is accordingly done in that season; the cost of conveyance being about $2\frac{1}{2}$ annas, or $3\frac{3}{4}d.$ per ton per mile.

During the rainy season the cost of conveyance is much enhanced: in the first place, the roads are soft and damaged by the rain; the bridges are carried away by floods, culverts blown up, &c. The actual labor and risk of conveyance is therefore much greater. In the second place, the rainy season being the working period of the agriculturists, the whole of the animal power of the ryot is expended upon his cultivation, and he cannot spare any to be employed upon road traffic, and there is, therefore, less competition. To set against this, however, there is less traffic at that time of the year, and I am disposed to consider the figures above given as the cost of conveyance, and which were taken from a return furnished by the Commissary General, of the contract price for Government transport, to be a fair average for the whole year.

Railroads.—Of these, the Madras, or South Western line, is completed

from coast to coast, a distance of 406 miles. The North Western, which is eventually to communicate with Bombay, is open for a distance of 41 miles from its junction with the Madras line. The Great Southern of India line, is finished from Negapatam to Trichinopoly, a distance of about 80 miles, but it has yet to be connected with the Madras line by an extension of about 80 miles, which will meet the South West line at a point about 250 miles from Madras. A branch from the Madras line, about 80 miles in length leads to the Military station of Bangalore: this is just completed. When the whole of these lines are finished, there will be a complete chain of Railway communication connecting the principal Military stations in this Presidency with the great depôt at Madras; and this latter will communicate directly with Bombay.

Canals.—Of these there are but few. The Irrigation channels in the deltas of the Kistnah and Godavery are used with great advantage for local traffic; and there is a coast canal, connecting the backwaters of some of the rivers to the north and south of Madras; while the Irrigation Company has on hand a project for completing a line of water communication between Kurnool on the Toombuddra, and the sea on the East Coast.

As a general rule, however, the country is altogether unfitted for this kind of communication, owing to the difficulty of securing, either at or below the summit levels, a sufficient supply of water to furnish the lockage and to meet the very large demand on account of evaporation.

I have given this short sketch of the Madras Presidency, and of the existing means of communication, in order to facilitate the comparison which it will be necessary to make between the result of the Railway system here and elsewhere.

In England and Australia, the *indirect* benefits arising out of the Railway system, afford a full compensation to the country at large for the capital sunk in the Railway. The holders of the Railway shares are losers, of course, to the extent of the difference between the dividend paid, and the ordinary interest upon the capital invested; but every man who travels by rail, and every man who has goods to send to market saves a very large percentage of the amount he would have had to pay, had his means of communication been limited to turnpike roads.

In India, however, so far as the conveyance of goods is concerned, the *indirect* benefit is by no means so great as that which is enjoyed by Eng-

lish or Australian merchants. Here the cost of moving goods is about 2½d. per ton per mile on the road, while on the rail it may be put at 1½d; that is the cost per rail is to that per road as 2 to 5, while in New South Wales it is as 1 to 4, and in England 1 to 5.

The benefit to travellers in India is very great; the facilities afforded by the Railway have made thousands travel, who in former times never dreamed of moving from their homes. Still, however, the poverty of the people, the very low wages which they receive, taken in connection with the fact that a very large proportion of such wages is paid in kind, would seem to point to the conclusion that years must elapse before any very great extension of passenger traffic will take place, except in the vicinity of large towns. At the present low fare of ⅔ths of a penny per mile for 3rd-class passengers, the Madras cooly would only be able to travel 9½ miles for his daily wages; while an English laborer would earn enough in one day to carry him 80 miles. A reduction in the Madras rates would, I have no doubt, increase the number of passengers; but it is very questionable whether it would increase the net receipts. If, indeed, the cost of working the Railway in India bore the same ratio to the cost of working in England, as the rate of wages in India does to that in England, the lowness of the Madras rate would not have much influence on its net receipts. But in India the cost of freight has to be added to that of the coal or coke used; the wages of skilled labor, as Engine Drivers, &c., are higher than in England, and though the ordinary labor employed about the stations, and on the maintenance of way, is cheaper than in England, it is not cheaper in proportion to the difference of wages, for one Englishman will probably do the work of *at least* three Natives. On the whole, it will, I think, hardly admit of a doubt that the amount of traffic required to pay the interest of the capital expended upon the construction of the Railway, as well as to defray the costs and charges of maintenance of way, and of locomotive power, must be far greater in India than in England and elsewhere.

Now the interest of capital is one of the heaviest charges against the proceeds of Railway traffic, and when the traffic is comparatively light, and not likely to increase to any great extent, it may be more to the advantage of the Government, and of the country generally, that a description of road should be constructed which involving a smaller outlay of capital, but requiring a somewhat more costly description of locomotive power, would, at a charge little, if at all, in excess of that of the Railway, furnish a return

sufficient to keep the road in thorough repair, pay the interest of the capital expended upon its construction, and provide an amount of tractive power fully adequate to the wants of the people, though the time expended would, of course, be very much in excess of that required by the locomotive line.

I propose, then, in the remainder of this article to investigate carefully the relation between the outlay and the returns upon various kinds of roads in the Presidency of Madras; namely, the Railway worked by the Locomotive engines; the Railway worked by Animal Power; and the Macadamized Road. The first step towards this comparison must be the determination of the amount of passenger and goods traffic which is to be taken as a standard quantity, and in order to simplify the calculations, and, indeed, to substitute matter of fact for matter of inference, I propose to take the amount of traffic upon some given line, or portion of a line of existing Railway, as this standard.

The Madras or South West line of Railway, extending from Madras to Beypore, a distance of 406 miles, partakes too much of the character of a great Trunk line to justify the adoption of the whole or of any portion of it, as a standard of comparison, whether as to outlay or as to the amount of traffic; but the North West line, or the portion of it already completed, viz., 41 miles, may be fairly looked upon, at present, in the light of a branch; and an enquiry into the cost of moving the passengers and goods, stated to have passed over this line, by some more simple system of conveyance, will afford satisfactory data as to the relative advantages of Railways or other roads.

I may observe that the Madras Railway, though it only paid, during the first half of 1868, interest to the amount of $\cdot 66$ per cent. or 13s. 7d. per hundred pounds of capital expended upon *the whole line*, did, I have no doubt, pay the full interest of five per cent. upon the cost of the 40 or 50 miles nearest to Madras; but it would be difficult, if not impossible, to attempt to deal with the line in sections, and to attribute to each its fair share of expenditure and receipts. It is only necessary to say that, with an amount of traffic equal to 595,000 passengers, and 960,000 tons of goods in the half-year, the amount of interest was only, as stated above, $\cdot 66$ per cent. for the half-year, so that 1,200,000 passengers and about 200,000 tons of goods would only pay the cost of traction, of maintenance of way, and $1\frac{1}{2}$ per cent. upon the outlay of capital.

The following is an abstract of the nature and amount of the traffic on the North West line, for the half-year ending 20th June 1863; and the numbers given will, when doubled, form the standard amount of traffic upon which the calculation of the cost of conveyance on the different kinds of roads will be based; the actual cost of the working of the Railway being taken.

<i>Passengers.</i>			
1st-Class,		194 × 2 =	388
2nd "		1,411 =	2,822
3rd "		75,999 =	151,998
<i>Goods.</i>			
Tons,		15,711 × 2 =	31,422

The 1st and 2nd-class passengers will be merged into one of say 3,220. The second-class of passengers will consist of 152,000, and the goods will be taken as 32,000 tons. I will now proceed to enter upon a detailed examination of the cost of *Construction*, of *Maintenance of way*, and of *Locomotive power* upon the Macadamized road, upon the Railway for Animal power, and upon the Railway for Locomotive power, with reference to the above amount of traffic.

CONSTRUCTION.

1st. *Macadamized Road*.—The data as to the cost of constructing such a road as this have been furnished by the Public Works Department, and the amount given below may be considered a fair average of the cost of such roads throughout the principal parts of the Presidency.

Width of road,		30 feet.
Width of metalling,		24 "
		£ s. d.
Cost of earthwork,		166 14 0
Do. of metalling,		168 16 0
Bridges and Culverts,		302 14 0
Sundries,		40 0 0
		<hr/>
		£673 4 0

If an addition be made to this sum for the cost of superintendence, &c., bringing it up to £750 per mile run, this will be an ample allowance for any contingency.

2nd. *Railway for Horse-power*.—The cost of the earthwork, and of the bridges and culverts, would be rather less on the railroad than on the macadamized road; for, while it is not intended to modify the gradients in

any way, or to add to the cuttings and embankments, except on very special occasions, the width of the road may be less. I do not, however, propose to make any deductions on this account, but shall assume the cost of the earthwork and bridges and ballasting, at the same sum as given for the macadamized road, viz., £750 per mile; setting the metalling against the ballast of the Railway. The cost therefore, of a railroad will be found by adding to the cost of the macadamized road, that of the purchase of rails, chairs, and sleepers, and that of the labor of fixing them.

The weight of the rail used at first on the Manchester and Liverpool line, was 35 lbs. to the yard, and it seems to me that, for horse traction, a rail 28 lbs. to the yard would be amply strong enough; and as 2,000 yards, or an addition of 240 yards to the mile, will be sufficient to cover all sidings, &c., $2 \times 28 \times 2,000 = 112,000$ lbs., or 50 tons per mile, will be the weight of the rails. These can be delivered at Madras at £8 10s. per ton, and an additional 80s. per ton, making a total of £10 per ton, will cover the charge for conveyance, so that £500 will be the cost per mile of the rails delivered upon the road. Timber sleepers have been found to decay rapidly in this climate; I should therefore be inclined to recommend the employment of stone blocks as supports for the rail: in many parts of this Presidency, where the gneiss crops out on the surface, the stone block would be far cheaper in first cost, and far more durable than any other description of sleeper; but, as these may not be attainable generally, I propose to allow for the use of the iron pot sleepers, which have been employed on the Railway. For the horse traction line these may be made lighter than for the locomotive line, but I propose to allow for the same weight and price, that is £1 per pair of sleepers with the connecting tie-rod. I shall allow, however, for a bearing of five, instead of four feet: the cost, under these conditions, of chairs and sleepers will be £1,200 per mile.

The cost of laying the railway may be put as on the Locomotive line, at $4\frac{1}{2}$ d. per yard run, the cost for 2,000 yards would therefore be £37 10s.

In order to make the action of this railroad perfect, it should be provided with a line of Telegraph; and the cost of this, judging from the amount expended upon that on the Madras line of railroad will be £90 per mile.

The whole cost of this railroad for animal power per mile will then be as follows:—

	£	s.	d.
Earthwork, including Ballast or Metal,	830	10	0
Bridges, Culverts, &c.,	302	10	0
Rails,	500	0	0
Chairs and Sleepers,	1,200	0	0
Fixing Rails,	87	10	0
Telegraph,	90	0	0
Stables and Rest Houses,	50	0	0
Sundries,	40	0	0
Superintendence, &c.,	76	0	0
	<u>£2,627</u>	<u>0</u>	<u>0*</u>

Locomotive Railway.—The cost of this may fairly be put at the same rate £12,000 per mile: this has been the cost of the South West line, and it will in this case, include the cost of the rolling stock required to work the amount of traffic taken as the standard. The comparison, therefore between the capital expended per mile upon the different kinds of roads, and the annual charge on account of interest at 5 per cent. will be as follows:—

	Cost per mile.	Interest.
	£ s. d.	£ s. d.
Macadamized road,	750 0 0	37 10 0
Railroad for Animal power,	2,627 0 0	131 7 0
Railroad for Steam power,	12,000 0 0	600 0 0

MAINTENANCE.

The next matter for consideration will be the cost of the maintenance of way, that is, the annual outlay required to maintain the road in a state of thorough repair.

This must, of course, so far as the *Macadamized Road* is concerned, depend upon the amount of traffic, while the quality of the materials employed will have some action upon the annual charge. A fair approximation, however, may be arrived at by a reference to the amount commonly allowed for maintenance upon the great trunk lines of road in this Presidency, and Rs. 300, or £30 per mile, would be considered sufficient for a road upon

* This estimate agrees closely with Captain Yule's careful estimate, in his project for a Railway in Rohilkund, of a Cattle Draught line, at Rs. 26,500 per mile; but this includes Rs. 2,562 for plant and wagons, which are chargeable to draught rather than construction. It is considerably higher than Mr. Wilson's estimate for a light Railway to be worked by locomotives.—[Ed.]

which the standard amount of traffic is conveyed. The cost of repairs upon a road over which 1,872 vehicles pass per day, has, in an average of five years, amounted to £119 14s. 9d. In order to be on the safe side therefore, I propose to allow £55 per mile for the maintenance of the macadamized line of road in thorough repair.

On the *Railway for Animal power*, an allowance must be made for the wear and tear of rails and sleepers. The actual wear of the road itself will be very much less of course than that of the macadamized road, for the iron rail takes the action of the wheel; if, then, the rails and sleepers are renewed in twenty years, one-twentieth of the whole cost may be provided as an annual charge; and as this cost is £1,700, one-twentieth of that sum will be £85. One-half of the ordinary sum of £30 will be sufficient to cover the cost of other repairs; so that $85 + 15 = £100$ will cover the cost of the maintenance of the Railway for animal power.

The maintenance of way upon the *Railway for Steam power* must necessarily include an allowance for the renewal of rails, chairs, &c., and by taking the duration of these at twenty years, as in the Railway for animal power, an advantage will be given to the locomotive line; as the action of the heavy engine, going at the rate of from 20 to 30 miles per hour, must wear away the rail much more rapidly than the light and slow action of the animal power. Assuming then, 5 per cent. to be the annual deterioration of the rail and sleepers, and the cost, as on the Madras line, to be £3000 per mile, the annual charge for renewal of rails and chairs will be £150.

The other items under the head of maintenance are grouped together in the returns, and the cost may be put on an average at about £100 per annum per mile, while the charge for superintendence may be put at £5. The cost of maintenance of way on the steam power line will therefore be as follows:—

	£	s.	d.
Renewal of Rails and Sleepers,	150	0	0
Labor, Ballast, &c.,	100	0	0
Superintendence,	5	0	0
	<hr/>		
	£225	0	0

The annual charge upon the three descriptions of road under the head of interest of capital, and maintenance of way, will be as shown in the accompanying table:—

	Macadamised Road.	Railroad, Animal power.	Railroad, Steam power.
	£ s. d.	£ s. d.	£ s. d.
Interest,	37 10 0	131 7 0	600 0 0
Maintenance, . .	55 0 0	100 0 0	255 0 0
Total, ..	92 10 0	231 7 0	855 0 0

TRACTION.

Having thus arrived at the cost of constructing the different lines of road, as well as at that of maintaining them in a good state of repair; all that remains to be done is to determine the actual cost of traction upon each. To do this, however, would involve the solution of a variety of very complicated questions. It will be far more simple, therefore, to show, for the ordinary roads and for the existing railroad, the actual charge for the conveyance of passengers and goods. In the case of the *Railway*, the returns show the actual charge for locomotive power under several different heads; while on the *Macadamized Road*, the contract price per passenger or per ton of goods, includes not only the charge for power, but a variety of other items to which I shall allude hereafter.

With reference to the *Railway for Animal power*, I propose to submit a detailed estimate, on a liberal scale, of the cost of working it, as, in this country, I cannot obtain any direct information to guide me.

The cost of conveying goods upon the *ordinary Roads* has been shown to be 3½d. per ton per mile. This sum includes the interest upon the first cost of the vehicle and the cattle; the maintenance in repair of the vehicle; the maintenance of the cattle, and the hire of the persons employed to drive them; it will also include a premium of insurance upon the carriages and cattle, so that they may be replaced in case of destruction or death, by accident or disease. It also includes or should include, some premium of assurance against the risk incurred as a carrier, who is responsible for the goods under his charge. In addition to all these, it must include such a fair amount of profit as the contractor has a right to expect, besides the simple interest on his capital.

The charge of conveying 1st-class passengers may be put at 6d. per mile. This is arrived at by taking the cost of conveyance, by the Transit

Company, from Tripatore to Bangalore, a distance of 80 miles; the transit is capable of accommodating two persons inside, and a servant on the box by the driver. Each person may take 40 lbs. of baggage, and the total charge by the Company is Rs. 40 or 80s., that is 1s. per mile, or 6d. per each passenger.

A class of passengers analogous to the third-class on the Railway is conveyed to and from places in the vicinity of Madras, at a reasonably rapid rate, in vehicles drawn by bullocks or ponies; each of these vehicles is capable of containing four people, and the rate of charge varies from 2½d. to 3d. per mile for the whole vehicle; taking the largest sum, the cost per mile for each passenger would be ¾d.; but it would be safer to estimate the average cost at 1d. per mile per passenger, and this may be taken as a fair charge for such work in any part of the Presidency; as the Madras prices are probably in excess of those of the country districts. The cost then of conveying 3,220 first-class and 152,000 second-class passengers, and 32,000 tons of goods, will be as follows:—

	£	s.	d.
3,220 at 6d. =	80	10	0
152,000 at 1d. =	638	6	0
32,000 at 3¼d. =	600	0	0
Total, ..	£1,818	16	0

The returns for the *North West Railway*, for the same amount of traffic exhibit the expenditure under the various heads of classification, as shown in the following table:—

	£	s.	d.
Locomotive Department,	1,906	5	2½
Fuel,	3,054	12	0
Coaching,	1,259	1	0½
Tickets,	12	2	4½
Repair of vehicles,	116	2	5½
Electric Telegraph,	11	9	0
General charges,	117	6	6
Total, ...	6,476	18	6½

This sum, divided by 41·25, the length of the line, will give £157 0s. 3¼d. as the cost of conveying the whole of this traffic over one mile of Railway. No attempt is made to distinguish the actual cost of conveying

the different classes of passengers or of goods; in fact any attempt of the kind would merely be a matter of guess work. The above may be taken as *facts*, which do not involve any calculation.

I have now, however, to form an estimate of the cost of conveying the same quantity of goods, and the same number of passengers, along a *Rail-way* by means of *Animal power*.

The number of first-class passengers has been put at 8,220, or roughly, 10 per day, or 5 each way. To convey these, one first-class carriage would be required, which would travel at the rate of 10 miles per hour. It would be drawn by two horses,* and would be capable of accommodating 16 passengers. The distance of 41·25 miles would be divided into five stages, each pair of horses going a stage out and a stage back, or about 16 miles per day; a spare carriage would be required and a spare pair of horses.

The capital expended would be—

		£	£	s.	d.
8 Carriages,		at 250 =	750	0	0
12 Horses,		at 45 =	540	0	0
10 Sets Harness,		at 10 =	100	0	0
		<hr/>			
Total, ...		£1,390	0	0	

152,000 second-class passengers divided by 365, will give 416 as the daily number conveyed both ways. It will, however, be necessary to reckon upon some extra pressure occasionally; and carriage accommodation must be provided for, say, 240 each way, or 480 altogether. Each carriage will contain 30 passengers, and will be drawn by two horses at the rate of about 6 miles per hour; travelling the same distance as the horses drawing the first-class carriages.

The total number of carriages and horses required for the actual work will, therefore, be 16 carriages, and 80 horses; but it may be as well to estimate for 20 carriages and 100 horses.

The capital expended, then, upon rolling stock and animal power will be—

* Capt. Yule says in his *Project, &c.*, "Draft horses for such a purpose can scarcely be said to exist in India, and we must therefore look to oxen." It would have been well perhaps if this objection so often stated, had been met in the present paper. In the Punjab the Cabul horses, though small are excellent for draught and could be procured well under the estimated price, probably for Rs. 300 each. But the supply is very limited, and in the N. W. Provinces, good draught horses, able to do hard work at a fair speed, are unknown. It is to be noted, however, that it is only the *Passenger* traffic which is to be conveyed by horses.—[Ed.]

	£	s.	d.
20 Carriages,	at 250 =	5,000	0 0
100 Horses,	at 40 =	4,000	0 0
16 Sets Harness,	at 10 =	160	0 0

Total, .. £9,160 0 0

32,000 tons of goods may be put at 100 tons per day, or 50 tons each way.

Three tons may be allowed for each truck, and 34, therefore, would be required; each would be drawn by 3 bullocks, 6 extra trucks might be allowed to meet casualties; and a few extra bullocks should be purchased. As the daily journey of a bullock may be put at ten miles, the distance of 41·25 would be divided into four stages; so that 12 bullocks would be required for each truck, $40 \times 12 = 480$, would be in daily use, or say 500 to cover contingencies.

The trucks ought not to cost more than £100 each, and the bullocks £15 the pair.

The capital, therefore, expended upon the rolling stock and animal power for the goods traffic will be—

	£	s.	d.	£	s.	d.
40 Carriages, at	100	0	0 =	4,000	0	0
500 Bullocks, at	7	10	0 =	3,250	0	0

Total, ... £7,250 0 0

The total amount of dead and live stock required for the conveyance of passengers and goods along a Railway worked by animal power would be as follows :—

	£	s.	d.
First-class passengers,	1,390	0	0
Second-class do.,	9,160	0	0
Goods,	7,250	0	0

Total, ... £17,800 0 0

Say £18,000.

The annual charge may be estimated as follows :—

	£	s.	d.
Interest upon £18,000 at 5 per cent.,	=	900	0 0
Wear and tear of carriages and repairs, 15 per cent., on	9,750 =	1,462	10 0
Cost of re-placing horses and bullocks, 15 per cent., on	7,790 =	1,168	19 0
Repairs and re-placing harness, 20 per cent., on	260 =	52	0 0

	£	£	s.	d.
Keep of 112 horses, at £24 each,	=	2,688	0	0
Keep of 500 bullocks, at £8 each,	=	4,000	0	0
Hire of 20 coachmen, at £50 each,	=	1,000	0	0
Hire of 166 bullock drivers, at £10 each,	=	1,660	0	0
Repairs of stables, at 5 per cent, on,	2,000 =	100	0	0
Telegraph, &c., charges as on locomotive line,	=	11	9	0
General charges, including Clerks, &c.,	=	442	11	0
Total, ...		£13,485	9	0

This sum, divided by the total distance 41·25 miles, will give the charge per mile for traction £302 12s. 10d.,* and the general comparison between the cost of conveying the standard number of passengers and tons of goods per mile, on the three kinds of road, will be as follows:—

	Macadamised Road.			Railroad, Animal power.			Railroad, Steam power.		
	£	s.	d.	£	s.	d.	£	s.	d.
Interest,	37	10	0	131	7	6	600	0	0
Maintenance,	55	0	0	100	0	0	255	0	0
Cost of working,	1,313	16	0	302	12	10	157	0	3½
Total,	1,406	6	0	534	0	0	1,012	0	3½

I have in calculating the cost of working the Animal power Railway, made allowances for a variety of extra expenses; and I feel confident that the sum shown in the above table will be ample to cover the whole cost of working the line, and of paying an interest of 5 per cent., upon the capital expended. Under these circumstances, it is evident that, until upon any given line of road the amount of traffic very far exceeds that which passed over the North West line of railroad in the first half of 1863, it will be

* Capt. Yule's estimate per mile for a Cattle Draught line, is only Rs. 1,317, of which Rs. 140 are charged to maintenance of way (not included above); Rs. 430, to wear and tear of rolling stock; Rs. 374 for hire of Cattle, and the same for Establishment; the cost per ton per mile being reckoned at 0·7 annas. Mr. Hardy Wells in his Report on the same line, estimated the Draught expenses per mile of a Horse Railway at Rs. 5,650, and of a Bullock line at Rs. 3,361.

The great difference in this last estimate is in the number of animals estimated for, 2,000 horses or 4,000 bullocks for a line of 110 miles in length, being double the number set down in the present estimate for a similar length. Mr. Wells' calculation is for 105,000 tons of goods, and 224,000 passengers, yearly; each passenger is reckoned at 3 mds. = 240 lbs., probably to include his baggage. The cost, therefore, of haulage per ton mile, would be 0·7 annas for horses, and 0·8 annas for bullocks. It is to be noted, however, that these estimates do not include any charge for the interest on the dead and live stock, which is probably considered to form a part of the whole capital sunk. In the present estimate, deducting this item, and dividing the annual cost by the traffic, the cost per ton mile will be 0·75 annas, showing a striking agreement between the three estimates, considering that all are worked out on totally different data.—[Ed.]

far cheaper to employ animal power than steam, in the movement of passengers and goods.

It remains to be seen what charge it will be necessary to impose upon the traffic, in order to cover the whole of the charges upon the road; namely, interest of capital, maintenance of way, and cost of transport. An analysis of the cost of conveying the different descriptions of traffic will show that the following is pretty nearly the ratio of the outlay upon each

First-class Passenger,		066
Second class do.		430
Goods,		504

and if the whole charge of £534 per mile be divided in these proportions between the different heads of traffic, the charge upon the first-class passenger must be such as would return £35 4s. 10½d.; that upon the second-class, such as would yield £229 12s. 4½d., and that upon goods such as would give £269 2s. 8½d. Now the charge of £35 4s. 10½d., divided by the number of first-class passengers, viz., 3,220, would give 2·6 pence as the charge per head per mile. In the same way, £229 12s. 4½d., divided by 152,000, the number of second-class passengers, would give 1·38 farthings, as the exact charge per head per mile; while £269 2s. 8½d., divided by 32,000, would give 2·018 pence as the charge per ton per mile. A first-class passenger, however, might very fairly be charged at the rate of 3 pence per mile, and a second-class at a half-penny, while the charge for goods might be put at 1½d. per ton per mile; at these rates, with the standard amount of traffic, the gross returns would be £556 18s. 4d., or £22 18s. in excess of the amount shown above to be sufficient to cover the interest of capital, maintenance of way, and cost of conveyance. Provision, however, has been made for the conveyance of upwards of 11,000 first-class passengers, 190,000 second-class, and 44,000 tons of goods without any extra charge; and should the traffic increase to this extent, the returns at the rates mentioned above, would be—

	£	s.	d.
First-class Passengers,		187	10 0
Second-class do.,		395	16 8
Goods,		275	0 0

Total, ... £808 6 8

And the profit upon the capital expended (which, at the rate of £2,627 per-mile of road for construction, and £18,000 ÷ 41·25 or £436 for live

and dead stock, would amount to £3,063), would not be less than 13 per cent.

The fair conclusion to be drawn from what has been stated is, that with an amount of traffic larger than that which is likely to pass over most of the feeders of the Railways now in progress, a Railway worked by Animal Power would be a much cheaper mode of communication than either a Macadamized Road, or a Railway worked by Steam Power.

If, however, this would be the case when the traffic is already heavy upon the line of road, the advantages of animal power over steam would be still more marked when the traffic is comparatively light, and requires to be developed gradually. A Railway worked by steam must be provided with engines of power sufficient to drag the largest train over the steepest gradient on a line: and though the consumption of fuel is, to a certain extent, proportioned to the load the engine has to convey, yet, as this load is in very great measure composed of the dead or unprofitable weight of engines and carriages, the saving of fuel is not very great; while the other items which make up the working expenses, are in great measure independent of the load, and form a mileage charge.

With a Railway worked by animal power the case is different; here the power required is strictly in proportion to the load; no more horses or bullocks are kept than will be sufficient to meet the demands of the public for conveyance; and if these demands are casual or intermittent, arrangements can easily be made to meet the casual portion of the demand without the expenditure of capital, or the imposition of a permanent charge upon the promoters of the line of Railway. Again, the power of a locomotive engine must be proportioned to the maximum effort it has to make; that is, it must be competent to overcome the steepest gradient in the line with a full train behind it; it must, therefore, have an amount of power more than sufficient to do the work of the more level portions of the line; in fact, it is necessary to have an engine of 100 horse power, which it might have to exert for a mile or two; while an engine of 50 horse power would be amply sufficient to do the remainder of the work.

This is not the case with a Railway worked by animal power. If there be a hill too steep to be surmounted by carriage drawn by the ordinary team of horses or bullocks, the simple plan is to have a spare pair at the bottom to help the carriages over the hill. This, however, will seldom be necessary with horse teams; for a horse has a reserve of muscular energy,

which enables him to exercise for a short time, a much greater amount of power than is wanted for his ordinary work.

It is not, of course, probable, that the ratio between the passengers and goods traffic, which I have assumed as the standard for calculation, will obtain upon ordinary branch lines. The passengers traffic will be less than the standard, while the goods traffic will exceed it; looking, however, to the fact that I have estimated the cost of the rolling stock and the animal power, at a high figure, and have been very easy in my demands upon the animal power, it is more than probable that, when worked by a Company or an individual, the charge of $1\frac{1}{2}d.$ per ton per mile will be found sufficient to cover all expenses, and to give an interest upon the capital expended of at least 5 per cent.

I think, then, that I am justified in applying to by far the larger number of branches from the main line of Railway in India, the following conclusions:—

1st. That the cost of transport upon a Macadamized Road is largely in excess of that upon a Railroad, whether such railroad be worked by Animal or Steam power.

2nd. That the actual cost of Steam power is much less than that of Animal power upon railroads, but that this cheapness is, with a limited amount of traffic, more than compensated for by the increased cost of construction and maintenance of the railroad worked by steam.

3rd. That the circumstances of the country are not such as to admit of so large a development of traffic upon the branch lines of railroad as would compensate, by the saving in the cost of motive power, for the increased charge under the heads of interest of capital, and maintenance of way, consequent upon the adaptation of the road for Steam power.

4th. That, as a general rule, it would be far cheaper, and, therefore, more advantageous in every respect to construct the branch lines of Railway with a view to their being worked by Animal power.

W. T. DENISON.

No. LXXVII.

DHARWAR BRIDGES.

By J. HART, Esq., C.E.

THE Yangul Bridge* is the last of several subscription Bridges constructed over the Bunnehulla; a river which runs through the centre of the chief black soil plain of the Dharwar district.

The characteristics of this river are peculiar. Rising in the west, within the range of the south-west monsoon, it is subject to high floods during the months of June, July, August, and September; while, being fed by large tributaries from the east, it is liable to considerable freshes during most of the other months in which thunder-storms prevail.

Its waters are brackish, but by sinking pits in its bed, fresh water is obtained within a few feet of the salt.

Its banks are of black soil, of the most unstable character, giving way with the slightest set of the current against them, and then presenting steep scarps, so that the road slopes at its crossings are most difficult to maintain.

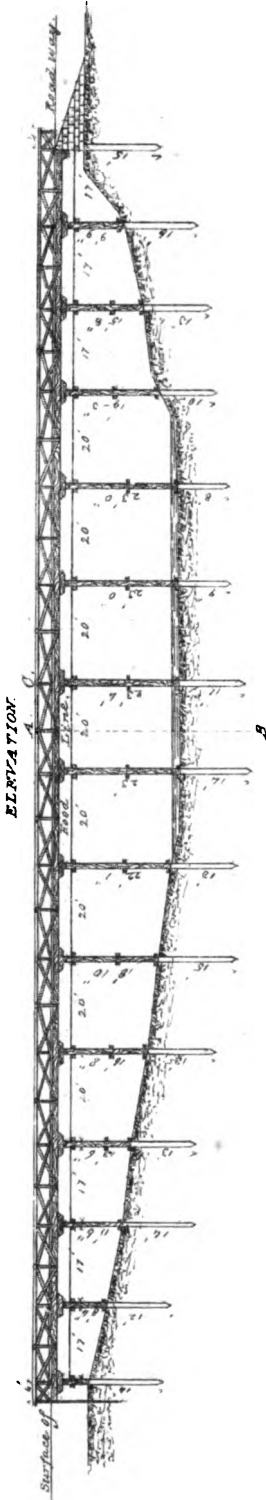
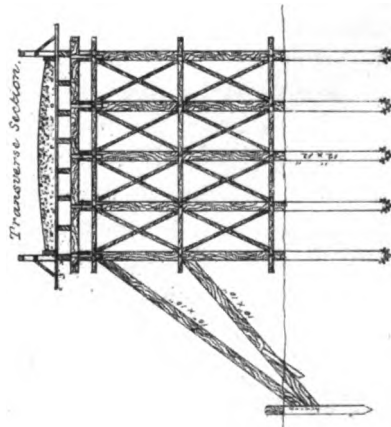
Its bed, consisting of silt and sand, overlying clay mixed with kunkur, abounds in quick sand during the rains; so that the crossing of this river was at all times a matter of anxiety to travellers.

This river, therefore, from several causes, formed a serious impediment to all communication between the villages on both sides for at least six months of the year; and this was so acutely felt that the inhabitants of the Hooble, Nowigoond, Dumbul, and Roan Talookas, subscribed to

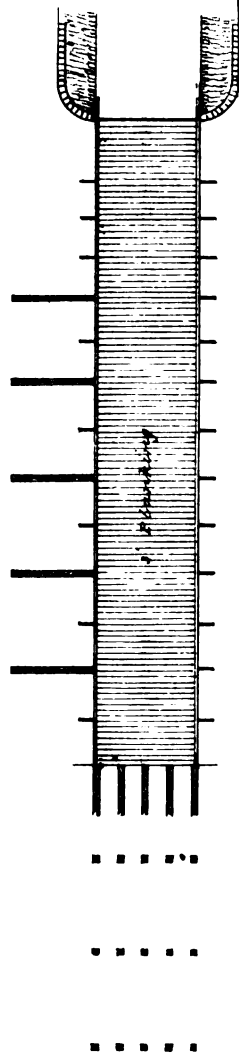
* This bridge (the Yangul) is distant from Dharwar 42 miles, being nearly double that of any of the other bridges.

YANGUL BRIDGE.

Constructed on the Benichalla River in 1864.



Half Plan of Superstructure.



Scale.

Scale.



build bridges along its course. In this they were assisted by Government, who supplemented their subscriptions by a "grant in aid." Bridges were thus built at Seergoopee, Hebsoor, Purdessoor, and Yangul.

The design of all these bridges is similar; being long timber piles driven into the river bed at short intervals to form the piers, on which whole logs are laid longitudinally as girders, and immediately on these, the road planking and material.

The piles of the bridges average 10 to 12 inches square, being hooped with a 28 lb ring, and shod or pointed, with a V shaped strap of, $3 \times \frac{1}{2}$ -inch, iron.

The nuts of the bolts used in these bridges are rivetted instead of being screwed on the shank, this former being found to be the more economical method.

The design adopted has been influenced by several considerations; the character of the bed and banks of the river; the ease with which large timber was procurable from the adjoining forests of North Canara, and the want of skilled labor and trained superintendence to carry out any very elaborate construction.

There is little to interest, therefore, in the structures themselves, but I venture to bring them forward for the purpose of giving some of the data connected with them, which may be of use to any one wishing to construct similar rude but effective bridges; and also, to enable me to describe the pile engine* used in building them. I am indebted to a drawing by Captain Playfair for the sketch of it, which I send; it will be of interest to those who do not know of the make-shifts to which Indian Engineers are often driven for plant.

The Pile Engine, which does not differ materially in principle from those ordinarily used, was constructed, I believe, by Captain Playfair, aided by Dr. Forbes, who had at his command the mechanical skill and resources of the Dharwar Cotton Gin Factory. It is roughly and economically built; and is well suited to the work it has to do, and to the workpeople for whose use it is intended.

Its chief features are an upright, or standard, formed by two vertical pieces, between the faces of which the monkey works, two longitudinal pieces, into which the foot of this standard is morticed, and to which it is stayed at the back; a frame, or platform, from which the above is hung,

* A working model of it was, I believe, sent to the Lahore Exhibition by Dr. Forbes.

and on which it runs transversely, motion being obtained by small rollers working on the upper side of the cross girders of the platform.

The Platform itself, on four large wheels, runs along a Tramway. The Ram is formed of an old gun, taken from the Fort of Noorgoond, after the capture of that place. The gun was sheared off at the breech, and a "lug" leaded into its muzzle, gives the means of lifting it by a pair of nippers.

These nippers, as well as the ram, slide in grooves in the faces of the standard, and on reaching the height of the jaws, the ram is released in the usual manner.

The weight of the ram is 680 lbs, and with the maximum fall of 18 feet, has a momentum of about 28,120 lbs or 10.3 tons. Five men are required to work the engine; viz., four at the winch, and one on the top, to facilitate the descent of the nipper after the ram; this is necessary on account of the friction of the rope in the two sets of blocks; besides these, four men are required for reliefs.

In constructing one of these timber bridges the first step is to erect a temporary scaffold, with a tramway for the pile engine to run on; and since the piles when driven are to be of the full height, in order that the girders of the bridge may rest immediately on their heads, the height of this scaffold must be fully as great as that of the intended bridge. It must also be somewhat wider to allow of the lateral motion of the standard, with ram, over the heads of the piles.

The scaffold is constructed with stout poles, fastened in old telegraph post sockets, or shoes. The sockets are screwed into the bed of the river as deep as they will readily go, a hole being first dug a few feet into the sand to receive them. On the top of these poles, which are in pairs, are fastened light cross pieces to carry the tramway girders, along which, guided by a slip of wood, run the wheels of the pile engine frame. Thus, the engine is enabled to command the whole length of the intended bridge, while the transverse motion of the standard of the engine on its own frame, serves the same end as regards the breadth of the structure.

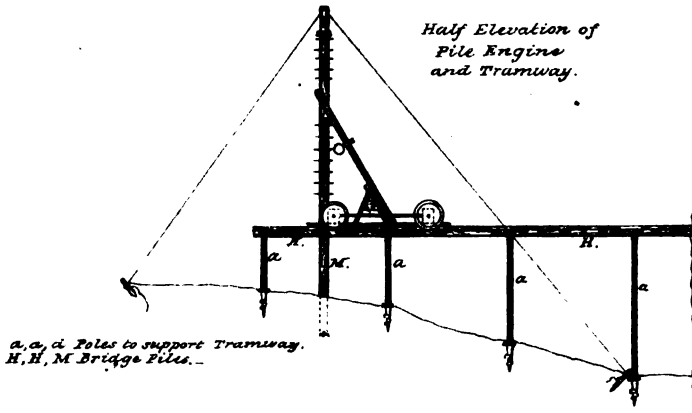
The Pile Engine being secured in position by wedges over the site of one of these piles, and a hole being dug to receive the point, the pile is raised into position by help of the windlass and blocks of the engine; and the operation of driving begins.

It is difficult to keep these very long piles from taking a set, or drift; this is prevented as much as possible by stay ropes run out, counter to any

PILE ENGINE.

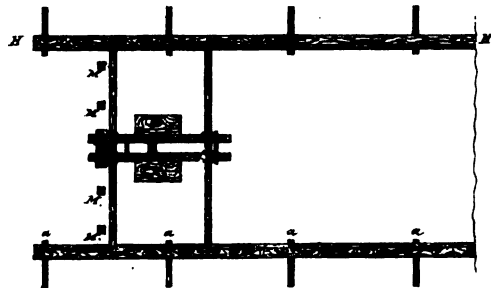
Scale $\frac{1}{100}$..

Half Elevation of
Pile Engine
and Tramway.

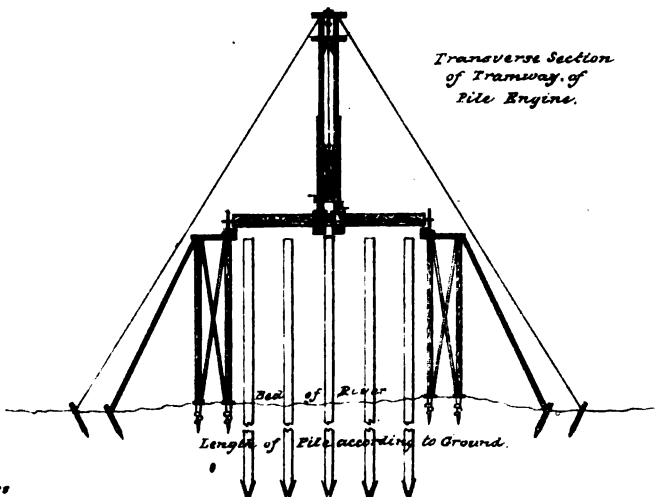


a, a, d Poles to support Tramway.
H, H, M Bridge Piles.

Half Plan of Pile Engine and Tramway.



Transverse Section
of Tramway of
Pile Engine.



such tendency which may appear while they are being driven; there are, however, few of the bridges in which some of the piles are not considerably out of plumb.

The piles receive, when nearly driven, a blow every four or five minutes, about one and a half minutes being consumed in raising the monkey, and the rest of the time in getting down the nippers. A pile is driven each day, which makes the calculated cost of driving one to be about Rs. 3 or 4.

The rule observed as to the depth to which the piles are to be driven seems rather indefinite, they are driven an average depth of 12 feet into the bed, or until they refuse to drive further, and begin to split at the head.*

Diagonal bracing, transversely between the piles, as shown in the section, is not always to be recommended, as it may cause the accumulation of great quantities of brushwood in the time of flood. Moorum covering is also objectionable, on account of the rapidity with which the planking under it decays. I observed the following instance of its effect the other day in the Hebsoor bridge. That bridge is covered with moorum, and I find by examination that its planking is quite rotten, while that of another timber bridge near it, not *moorumed*, is still quite sound. The age of the former is two years, of the latter four, which makes the comparison still more striking. This defective arrangement is avoided in the Yangul bridge.

It seems to me that the only disadvantages of bare planking are danger of fire, inconvenience to horsed vehicles from the noise, and to cattle, from its slipperiness in the rains; but, these are not worthy of being considered when the destruction of such an expensive item as planking is at stake. It is a question whether it would not be better, and also in the end cheaper, to use transverse joists laid over the longitudinal road girders, to carry the planking; the last might then be made a little lighter. This is a point however, which the experience of a few years will probably decide.

Slight improvements might also be made in the pile engine, the most obvious of which is the substitution of a crab winch with a single pulley at the top, for the wooden winch and two sets of blocks. This would effect a considerable saving, in *time*, because of the facility with which

* The mistic in charge says, that when this occurs, the pile sinks about $\frac{1}{2}$ to $\frac{3}{4}$ an inch with each blow.

the nippers would then follow the ram; in *labor*, because under this arrangement the man placed on the standard to free the ropes, would not be required; in *height* of standard, because the space taken up by the double blocks would be made available.

The ram might also be heavier, and the fall less, which would decrease somewhat the liability of the heads of the piles to split; and, I think, some of the scantlings of the frame might be reduced with advantage.

The quantities and cost of the Yangui bridge, taken from the work accounts are as follows:—

BRIDGE.				Rs.
r. ft.				
656	Erecting tramway for pile engine, nearly all labor, @ .75 each,			492
988	Piles driven into bed (labor), @ 1.69 each,			1,679
c. ft.				
1,861	Timber in piles, including all work except driving, @ 2.92 each, ...			5,452
8,290	" girders, planking, and standrail, @ 7.3 each, ...			24,020
Total, Bridge,				31,643

APPROACHES, &c.				
c. ft.				
6,320	Excavation of foundations, @ 1.0 per 100,			65
2,992	Dry stone rubble, @ 19.0 each,			588
2,78,099	Earthwork, @ .375 per 100,			1,172
11,014	Gravelling surface of road, @ 1.0 per 100,			126
Total, Approaches,				1,951
Grand Total,				33,594

If to the rate for driving piles, be added the contingent cost of the tramway, the cost of driving them per foot will be in these bridges, Rs. 2-2, and the cost of each pier be Rs. 508.

The following is a table of the principal dimensions, cost, &c., of the several timber bridges constructed in the Dharwar district, on the principle mentioned in the foregoing pages.

Name and Description of Bridges and date of Construction.	Length.	Breadth out to out.	Greatest over bed.	Cubic feet of Timber.	Cost of Timber.	Cost per Foot of Timber-work only.	Total Cost of Bridge.	Total rate per foot of Bridge.	Remarks.
SHEERGOOPER, 9 bays of 10 feet span, 1862.	144	22		4,230	2,248	15·5	7,116	49·4	Rates—Wood, 10 as. per c. ft.; coolie, 2 as. per day; carpenter, 8 as. per day.
HEBBOOR, 15 bays of 16 feet span, 1862.	240	22	21	6,083	3,508	14·6	11,440	47·6	Rates—Wood, 10 as. per c. ft.; coolie, 2 as. per day; carpenter, 8 as. per day.
PURDESSOOR, 15 bays of 16 feet span, 1862.	240	22	23	7,864	5,607	23·3	13,764	57·3	Rates—Wood, 10 as. per c. ft.; coolie, 2 as. per day; carpenter, 8 as. per day.
YANGUL, 8 bays of 20 and 6 bays of 17 ft. span, 1864.	263	22	24	6,174*	11,406	43·3	22,680	86·2	Rates—Wood, Rs. 2-8 to 3-8; coolie, 4½ as. per day; carpenter, 12 as. per day.

* Besides the timber shown in this item, there was some of that of the pile engine, tramway, used up in the bridge, which makes a slight confusion in the timber accounts.

J. HART, DHARWAR.

No. LXXVIII.

KOORUM FRONTIER OUTPOST.

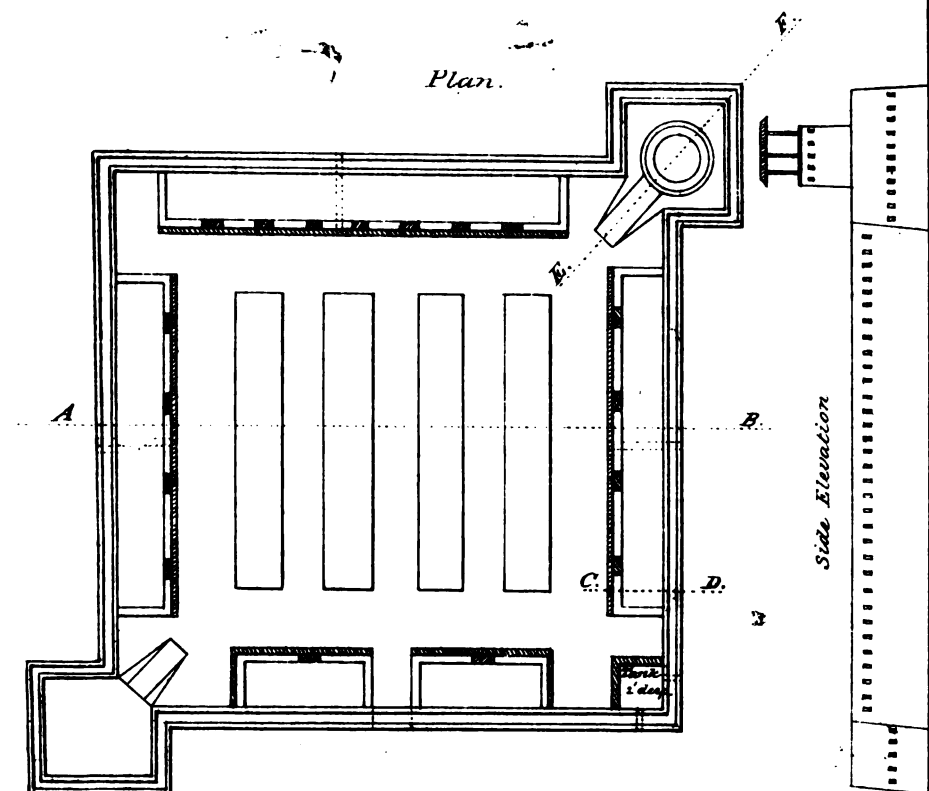
Estimate framed by LIEUT. J. BROWNE, *Exec. Engineer, Kohat Division, of the probable Expense of Building a New Outpost at Koorum, Bunnaco Frontier.*

THE proposed post is adapted for a garrison of fifteen sabres and fourteen bayonets; but could, if necessary, accommodate a larger number. It consists of a Square with Bastions at two opposite corners, the bastion facing the hills being provided with a Watch Tower 30 feet in height. The terreplein of the bastions is raised 5 feet above the general level of the ground, a step is provided along the walls so as to ease the weight of the defenders manning the loop-holes from the roofs of the barracks. The latter are 10 feet in width and 9 feet high in the clear; a small tank 10 x 10 feet and 2 feet deep, is provided in the corner to enable the garrison always to have a good store of water. The horse lines leave a clear space of 15 feet on all sides between them and the barracks. The walls are 18 feet in height, which is rendered necessary by the post being unprovided with a ditch. Drains of rubble masonry, 2 feet wide by 6 inches deep, run along the front of the barracks and converge in cross drains which carry the water out of the fort.

Specification.—The walls of the fort to be of pukka masonry with the exception of the step, 16 inches wide and 11 feet high, which runs along the inner face of the walls. The tower and walls of the barracks to be of kucha masonry. The walls, tower, &c., to be duly plastered and gobured,

KOORUM FRONTIER OUTPOST

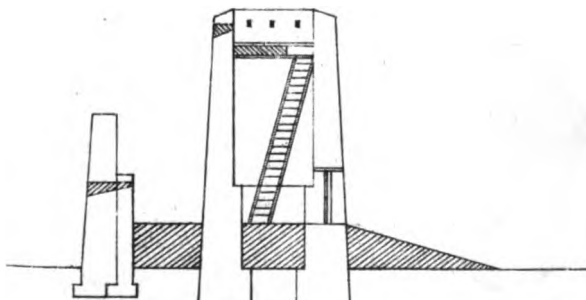
Plan.



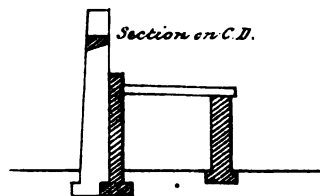
Section on A.B.



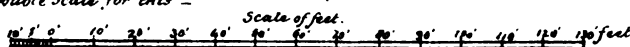
Section on E.F.



Section on C.D.



Double Scale for this -



and the barracks whitewashed. The tank and drain to be of rubble masonry well allowed to dry before being wetted. The gate to be 10 feet in width, rough hewn, and squared on the diagonal.

ABSTRACT OF EXPENSE.

c. ft.					R.	A.	P.
41,000	Pucka work, at Rs. 2 per 100,	...	...	...	820	0	0
26,774	Kucha masonry, at Rs. 3 per 100,	...	...	...	808	0	0
s. ft.							
3,068	Roofing, at Rs. 10,	...	...	...	307	0	0
32,824	Pucka plaster, at Rs. 0-8-0,	...	...	...	164	0	0
3,391	Whitewash, at Rs. 0-5-0,	...	...	...	11	0	0
c. ft.							
25,500	Earthwork, at Rs. 3 per 1000,	...	...	...	77	0	0
1,576	Rubble, at Rs. 10, per 100,	...	...	...	158	0	0
100	Gateway, at Rs. 1, per foot,	...	...	...	100	0	0
1	20-foot Ladder, at Rs. 5,	...	...	...	5	0	0
Total,					2,445	0	0
Add Contingencies, at 5 per cent.,					122	0	0
Total Rs.,					2,567	0	0

NOTE BY EDITOR.

Outposts on much the same plan as the above (except that many have one bastion only) have been built all along the Trans-Indus Frontier, close to the foot of the hills, and at distances of 10 to 15 miles apart, forming thus a chain of posts connected by a road extending from Scinde to Kohat, a distance of some 300 miles; guarding the passes into the low country and effectually checking the raids of the Hill Tribes. It is in this manner that a wild and lawless frontier has been gradually brought into subjection and quietness, which under its former native rulers, was a perpetual thorn in their side. Daily patrols are established between the posts so that early information is received of any raid in the border, and the cavalry can then sally out, leaving the infantry in charge of the post. The tower serves both as a look-out and as a citadel to the small force of infantry, which could thus defend itself and the post, in case of attack during the absence of the cavalry on service; a similar plan of defence for the N. E. Frontier might perhaps be equally successful.

No. LXXIX.

ATTOCK CHURCH—PUNJAB.

Design and Built by W. B. HARRINGTON, Esq., *Executive Engineer,*
Peshawar.

Report.—In November 1860, an estimate was called for to provide Church accommodation at Attock for the usual garrison, but capable of enlargement if required at any future day. A plan for a Church to seat 150 was accordingly submitted in July of the following year, but, until brought forward again in the Budget of 1862-63, the project remained in abeyance.

A sum of Rs. 15,000 has now been allotted to the work, with a view to erecting a building of some architectural pretension, which the fine site, enabling it to be seen from some distance on all sides, seems justly to demand.

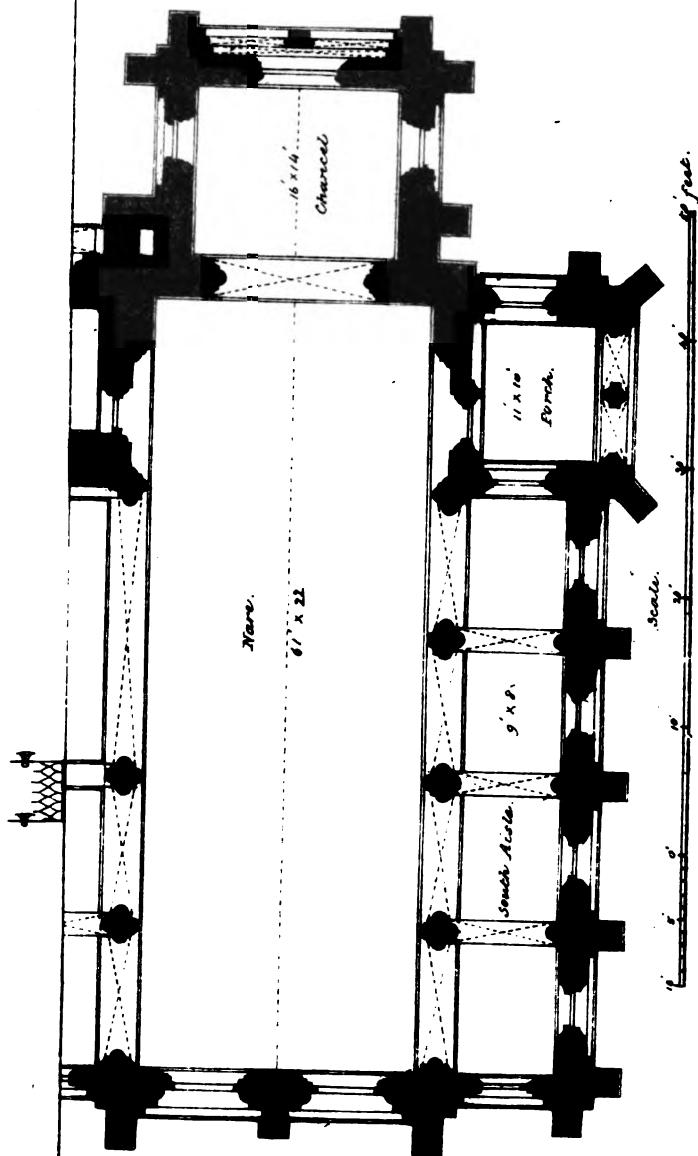
The design now submitted is for a Church calculated to seat 250 persons, being about 25 in excess of the present garrison, including the residents in the fort and "serai."

Specification.—The building to consist of a Nave (61' $\times$ 22') with north Transept (21' $\times$ 12') and side Aisles, and a Chancel (16' $\times$ 14').

A Tower (10' $\times$ 10' internally), and rising to a total height of 74 feet, is placed on the east of the transept, at the angle formed by it with the nave, and this with a porch (11' $\times$ 9') opposite to it, completes the design.

The ground-floor of the tower is appropriated to the Vestry, and the first storey can serve, if required, as an Organ loft, since it opens into the nave, and can be approached by the steps and stair-case on the north

Attock Church.



18740 T.C. MASS.



face of the tower, without going through the lower apartment. The arrangement and grouping will however be sufficiently explained by the accompanying plans.

In construction, the building throughout will be of the most solid and substantial character. The *masonry*, for the most part, to be of rough-dressed stone of the best description to be found in the neighbourhood, brick being used only in the columns of the Nave, the arch mouldings, and such other portions of the structure as may seem in process of construction advisable. All external and exposed work to be carefully finished, and plaster to be given to the interior only.

The *flooring* to be of tiles (9×9 inches) red and gray laid diagonally over brick-on-edge, the upper floors of the Tower to be $1\frac{1}{2}$ -inch planking over joists 9×6 inches.

The *roof* of the Nave, Chancel, and Transept, to consist of tiles (or shingles) over planking, over rafters and purlins resting on substantial trusses, placed $11\frac{1}{2}$ feet apart from centre to centre, corresponding to the pillars of the nave; one truss of the same pattern being given to the transept and chancel, respectively. The roof covering of the side Aisles to be similar to that of the nave, but with flying arches springing from the aisle walls in place of trusses. The pitch of the nave, transept, and chancel roof to be 51° , and of the side aisles 21° .

The Tower to be covered by a timber frame-work, sheeted with zinc, and terminating with an iron finial, with a standard at each angle; one being a lightning conductor, and having a greater elevation than the rest. The rod should pass to the ground in the angle formed by the two buttresses at the south-east corner of the tower.

The *doors* to be battened, with massive ornamental hinges, and *hung*; no chowkuts being used.

The *windows* to be glazed diagonally, and stained glass to be introduced if funds allow, giving the preference to the east and then to the west window.

Sittings (of stained deodar) to be provided for 250 persons, the benches being so arranged as to occupy the whole of the nave, the north and south aisles forming the means of ingress and exit. The remainder of the *fittings*, comprising pulpit, reading desk, and chancel rail, to be of sissoo or walnut wood.

The *punkahs* to consist of deep and full fringes, weighted with lead, and

attached to ornamental bars of sissoo, suspended from the iron ties of the roof-trusses.

The *font* to be of stone, carved at Delhi.

It is believed that in the following abstract, ample rates have been allowed to ensure work of the very best description, especially when it is considered that (as regards the masonry) no openings have been deducted. In explanation of the probable total cost, it should be noted that *at least* Rs. 1,000 will be forthcoming by private subscription, in addition to the Government grant of Rs. 15,000.

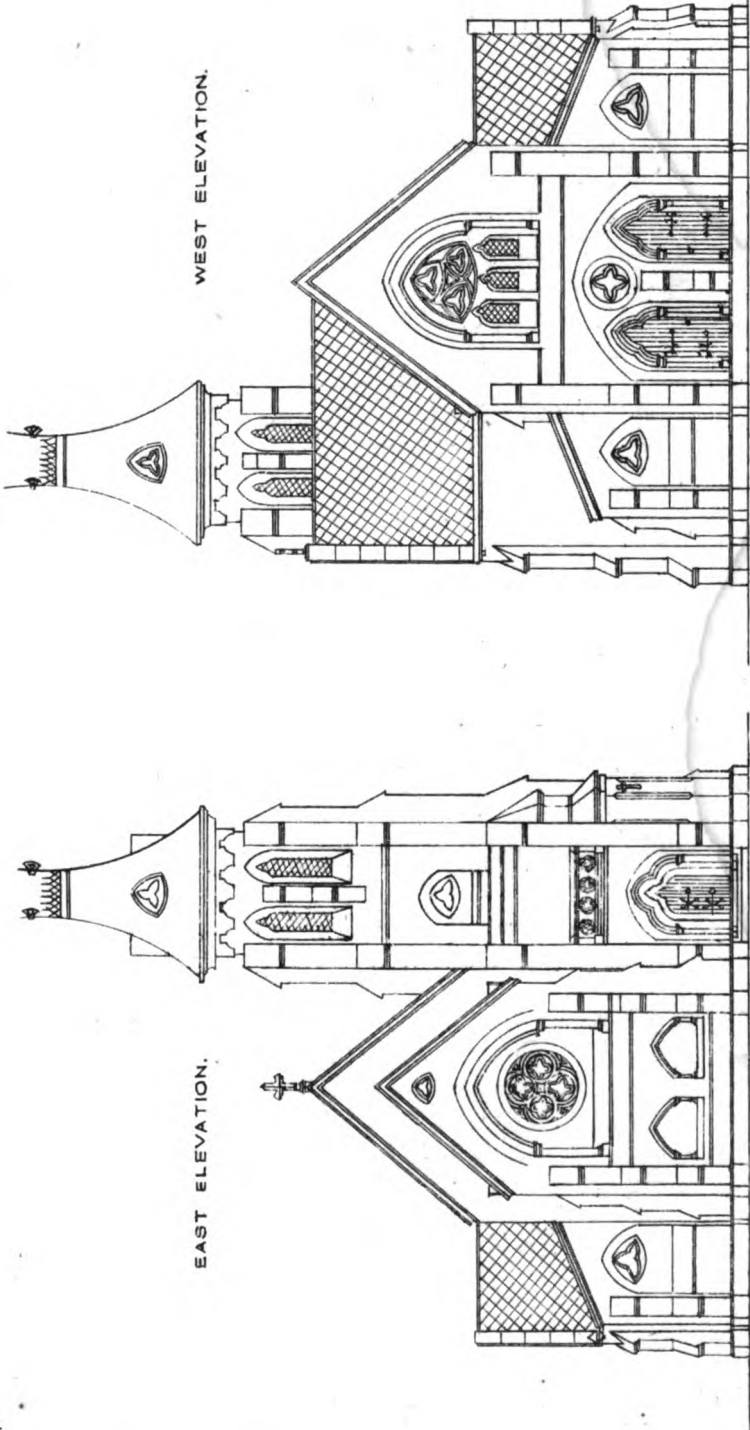
ABSTRACT OF COST.

c. ft.					R.	A.	P.
42,477.5	Masonry, at Rs. 20, per 100,	...	...	...	8,495	8	0
r. ft.							
484	Cornice, at Rs. 25, per 100,	...	...	...	121	0	0
a. ft.							
3,020	Tiled flooring, at Rs. 12, per 100, ...	...	...	...	362	6	5
400	Plank flooring, at Rs. 50, per 100, ...	...	...	...	200	0	0
3,999	Trussed roofing, at Rs. 80, per 100,	...	...	...	3,199	8	2
759	Pent roofing, at Rs. 50, per 100, ...	...	...	...	379	8	0
560	Zinc roofing, at Rs. 100, „	...	...	...	560	0	0
231	Doors, at Rs. 1-8, per foot, ...	...	...	...	346	8	0
332	Windows, at Rs. 1-4, per foot, ...	...	...	...	415	0	0
250	Sittings, at Rs. 3, each, ...	...	...	...	750	0	0
1	Pulpit, at Rs. 100, ...	...	...	...	100	0	0
1	Reading desk, at Rs. 80, ...	...	...	...	80	0	0
22	Punkahs, at Rs. 10, each, ...	...	...	...	220	0	0
1	Chancel rail, at Rs. 50, ...	...	...	...	50	0	0
1	Font, at Rs. 100, ...	...	...	...	100	0	0
Total, ...					15,829	1	7
Contingencies at 5 per cent. Rs., ...					766	7	8
Grand Total, Rs., ...					16,096	0	0

W. B. HARRINGTON,
Offg. Ex. Engineer.

PESHAWUR,
November 1862.

St. John Church.



T CIRCLE, P. W. DEPARTMENT, IN OR ABOUT THE MONTH OF MAY, 1864.

ONS.

	Goruckpoor.	Jhansi.	Mhow.	Nussacrabed.	Bareilly.	Gwalior.
Mistrie map	30 0 0	15 0 0	30 0 0	30 0 0	...	15 0 0
Skilled work	0 7 0	0 4 0	8 to 13a.	0 8 0	...	0 5 0
Ordinary do	0 6 0	0 3 0	5 to 7a.	0 5 0	...	0 3 0
Mistrie brick	15 0 0	12 0 0	30 0 0	30 0 0	10 0 0	12 0 0
Skilled work	0 6 0	0 4 0	8 to 13a.	0 7 0	0 5 0	0 5 0
Ordinary do	0 4 0	0 3 0	5 to 7a.	0 5 0	0 3 6	0 3 0
Mistrie carp	15 0 0	15 0 0	30 0 0	30 0 0	12 0 0	15 0 0
Skilled work	6a. to 1r.	0 5 0	0 8 0	0 8 0	0 5 0	0 5 0
Ordinary do	0 5 0	0 3 6	0 6 0	0 5 0	0 3 6	0 3 0
Mistrie sund	20 0 0	12 0 0	30 0 0	30 0 0	10 0 0	12 0 0
Skilled work	5a. to 1r.	0 4 0	0 8 0	0 8 0	0 4 0	0 4 0
Ordinary do	0 4 0	0 3 0	0 5 0	0 6 0	0 3 0	0 3 0
	0 0 8 0	0 4 0	0 6 0	0 4 0	0 0 6	0 6 0
	0 0 8 0	0 3 0	0 4 0	0 3 0	0 2 0	0 3 0
	0 0 2 0	0 2 6	0 4 0	0 3 0	0 2 6	0 3 0
Beldar,	0 0 2 0	0 2 6	0 4 0	0 3 6	0 2 0	0 2 6
Mate coolie	0 0 2 0	0 2 0	0 3 6	0 3 0	0 2 0	0 2 0
Coolie,	5 0 1 6	0 1 6	0 2 0	0 2 0	0 1 6	0 1 6
Boulders of	...	6 4 0	8 10 0	...	...	...
Bricks (best)	15 0 0	7 0 0	7 0 0	...	7 8 0	5 0 0
Ditto (second)	12 0 0	...	5 0 0	...	...	...
Ditto (best)	10 0 0	...	...	4 4 0	...	...
Ditto (second)	8 0 0	...	...	...	...	...
Small native	...	...	...	...	0 12 0	1 0 0
Tiles, common	5 0 0	4 0 0	2 12 0	1 8 0	1 8 0	1 4 0
" Good	30 0 0	...	...	...	11 4 0	...
Flooring tile	25 0 0	...	...	...	...	...
Lime, best	25 to 35	7 0 0	10 to 20	12 to 20	20 0 0	10 0 0

REMARKS.

there perfectly steady; while by means of the registers, he marked exactly the places of the two extremities of the chain. The chain was then taken forward, and the near end being adjusted to the scale which had before marked the fore end, a new chain's length was laid off, and so on till the base was finished. Thermometers were placed in the coffers to determine the temperature of the chain; and the rate of expansion being previously determined by experiment, the necessary corrections were made for the varying temperature of the measurement. The quantity of this correction had been found by Colonels Williams and Mudge, to be on 100 feet, $\cdot 0075$ inch for every 1° of Fahrenheit; but Captain Lambton, by some experiments performed with the chain itself, in October 1800, found $\cdot 00725$, which quantity he applied as the correction of his measurement.

Besides the original chain a second was obtained from England, exactly similar. Its length had been fixed in the temperature of 50° . This chain was preserved as the standard, and to its indications were reduced all the measurements made with the other. The length of this standard chain was afterwards corrected for a trifling discrepancy detected by Captain Kater, when comparing standards at home, previously to establishing a uniform system of weights and measures.

In May, 1804, a base of verification of 39793·7 feet was measured by Lieutenant Warren, Captain Lambton's Assistant, near Bangalore; and though the distance was 160 miles nearly, the computed and measured lengths of this base, differed only 3·7 inches, or about half an inch in a mile: a proof of the great care and accuracy with which the work had been conducted. This base was adopted for the origin of the great Indian Arc series. It is hardly necessary to say that the steel chain is now entirely superseded by Colonel Colby's apparatus of Compensation Bars.

From this base a series of triangles was carried across the peninsula to the opposite coast, and a meridional series also commenced on a meridian about 85 miles west of Madras, which was subsequently abandoned for the meridian of Dodagontah further to the west, and on which the Great Indian Arc series was gradually established from Cape Comorin up to latitude $29\frac{1}{2}^{\circ}$ N.; being the largest Arc yet measured on the earth's surface.

In his early operations Colonel Lambton was assisted by Lieutenant

Warren, of the 33rd, and Captain Kater, of the 12th, Foot. The first named officer belonged to the ancient noblesse of France, to which country he returned after the peace. His stay with Colonel Lambton was of short duration, as he was, at a very early period of the work, appointed to the charge of the Madras Observatory. Captain Kater's health having failed, obliged him to quit the department. This officer afterwards acquired an European reputation as a scientific man, having become a member of almost every academy in Europe, been employed on every business of national research, appointed a member of the Board of Longitude, and finally elected vice-president of the Royal Society. Thus it appears that, during the greater portion of his career, Colonel Lambton worked nearly single handed in the extensive and arduous operations which he carried on, amidst the formidable trials and obstacles that the baneful nature of the climate and the want of resources in the country everywhere presented.

It must also be borne in mind, that for a long period these operations were frequently interrupted by the disturbed political condition of the country, which was often the scene of warlike operations; for it was not until the Marquis of Hastings destroyed the Pindaree confederacies in 1818, that the Peninsula and Dekhan settled down into repose. The mysterious character of the instruments and operations, as well as the planting of flags and signals, have always more or less awakened the apprehensions or excited the jealousy of the native princes; it requires, therefore, no ordinary tact, firmness, and patience, on the part of the head of the department to conciliate good will.

Shortly after the commencement of his labors, Colonel Lambton was called on to demonstrate the utility of his work. It was asserted that surveys on an Astronomical basis would be equally accurate, and more economical than Geodetical operations. The futility of these views was ably exposed by the Colonel, and being supported by the Astronomer Royal of the day, (the Rev. N. Maskelyne,) all open opposition was withdrawn, and Major Rennell, who was the chief advocate of the astronomical basis, afterwards concurred in the trigonometrical system.* As this view of the subject has been confirmed by the prac-

* Colonel Lambton's operations detected an error of no less a quantity than 40 miles in the breadth of the Peninsula, as previously laid down astronomically in the way Major Rennell proposed. All the principal places on the old maps, which had been fixed astronomically, were found

tical testimony of every nation in Europe, and the importance of trigonometrical operations is now universally admitted by all practical scientific men as the only trustworthy basis for extensive national surveys, it is unnecessary to discuss the first principles any further in this place, and they are only adverted to in illustration of the formidable prejudices the trigonometrical survey in India has all along had to contend with. The Hon'ble the Court of Directors, however, when once convinced of the important practical utility of the work, have ever since continued its firm and powerful supporters, and in the words of the "Edinburgh Review," "their liberal and enlarged views cannot be too highly commended."

Colonel Lambton remained at his post till his death, which occurred on the 20th January 1823, at the age of 70, at Hingun ghât, about 50 miles from the city of Nagpore, in the Dekhan.

The professional account of Colonel Lambton's labors is given in the first five volumes of the General Report, which are deposited at the India House in manuscript. Condensed accounts of the more scientific part of his operations have been from time to time published. (*See Vols. VII., VIII., X., XII., and XIII., Asiatic Researches.*)

Colonel Lambton, between the years 1802 and 1815, covered the whole country as high as 18° latitude with a net work of triangles, whereby the Peninsula was completed from Goa on the west to Masulipatam on the east, with all the interior country from Cape Comorin to the southern boundaries of the Nizam's and Mahratta territories. Subsequent to this achievement, the great Arc triangulation was extended nearly to Takal Khera, in latitude $21^{\circ} 6'$. The greater part of the Nizam's eastern territories were triangulated by meridional series between the Kistnah and Godavery, and considerable progress was made in the longitudinal series from the Beder base towards Bombay. All these operations are described in minute detail in the volumes of the General Report, at the India House.

The area comprised by the whole of the operations prosecuted during the time Colonel Lambton was superintendent, aggregates 165,342 square miles. The expense incurred amounted to 8,35,377 Rs. Consequently, the rate at which the triangulations have been executed

considerably out of position. For example, Arcot was out 10 miles, and Hydrabad no less than 11' in latitude and 33' in longitude.

averages Rs. 5-0-10, or less than 10s. per square mile; which cannot but be considered remarkably cheap.

From the circumstance of Colonel Lambton's operations having commenced in Southern India arises the great superiority of the maps of the Madras Presidency; the atlas sheets whereof, published by order of the Hon'ble East India Company, are nearly complete. This part of India was surveyed in detail upon the basis of Colonel Lambton's operations, and on a scale of 1 mile per inch, by the officers and sub-assistants trained at the military surveying schools.

In October 1817, the Marquis of Hastings, impressed with a well-founded conviction of the important utility of the Trigonometrical Survey, resolved to transfer the control over its operations to the Supreme Government of India; and further, in consideration of Colonel Lambton's increasing age and infirmities, which were little fitted to encounter the laborious exertions, corporeal and mental, which such a task demands, selected Captain (now Colonel) Everest, as eminently fitted by mathematical attainments and practical skill to assist the superintendent, and eventually become his successor.

Captain Everest joined the Colonel as chief assistant in the latter end of 1813, and was employed, in the first instance, in the triangulation of the eastern parts of the Nizam's dominions; where in consequence of the extremely unhealthy character of the country, he twice fell a victim to jungle fever, and eventually was ordered to the Cape of Good Hope for the recovery of his health. While at the Cape, Captain Everest employed his leisure in investigating the circumstances appertaining to the Abbé de la Caillé's arc, which formed the subject of a valuable paper, published in the first volume of the Astronomical Society's Transactions.

On his return to duty Captain Everest was deputed on a longitudinal series of the great triangles emanating from the Beder Base line, and intended to connect Bombay. He was engaged on this important work at the time of Colonel Lambton's death, by which event he succeeded to the office of Superintendent, and immediately proceeded to concentrate the resources at his disposal on the extension of the Great Arc series, which after many difficulties was at length carried up to latitude 24° , where a Base line was measured at Seronj.

An account of these operations is given in detail in the fifth and

sixth volumes of the General Report, deposited at the India House. All the scientific portion relating to the fifth section of the great Indian Arc was further published by order of the Hon'ble East India Company, in the year 1830.

After the termination of the Sironj base line, Captain Everest proceeded to England for the recovery of his health; and as there was no person in India competent to succeed him, the Supreme Government resolved to retain the situation of Superintendent open until his return.

During Captain Everest's absence the establishment was usefully employed under the principal sub-assistant, Mr. Joseph Olliver, in extending a longitudinal series from the Sironj base line to connect Calcutta, for which work written instructions were given by Captain Everest. This series traverses, throughout the greater part of its extent, a wild, desolate, and unhealthy tract of hill country, which presented formidable difficulties. Notwithstanding the frequent ravages of jungle fever, which has all along been the most baneful enemy of the trigonometrical survey, as well as one of the chief retarding causes, this party, composed entirely of East Indians, successfully overcame all obstacles, and the work was eventually brought to a close in the year 1832, at the Calcutta base line, having occupied a period of six years in accomplishing a direct distance of 671 miles. The progress, therefore, was at the rate of 112 miles per annum, including branching series of secondary triangles. On account of the defective state of the instrumental equipments, the professional value of the work is only of a secondary or tertiary order. The area comprised in these operations is 33,442 square miles.

Colonel Everest returned to India in 1830, liberally provided by the munificence of the Hon'ble Court of Directors with geodetical instruments and apparatus of every description, in the construction of which the most skilful artists of the day, Messrs. Troughton and Simms, exhausted every resource of modern invention. The equipments consisted of a complete Base line apparatus, the invention of Colonel Colby, precisely similar to that employed on the Ordnance survey; a great Theodolite, 36 inches in diameter, designed by Troughton, which even at the present day is supposed to stand unrivalled by any other instrument of the kind in the whole world, and which most probably

will never be surpassed; two 18-inch Theodolites, and a variety of smaller instruments from 12 inches diameter downwards, all by the same celebrated maker. The signals, all of the most efficient kind, and recently invented, consisted of Heliotropes, reverberatory Lamps, and Drummond's Lights, of which the two former have been exclusively used; and here it may be remarked, that the substitution of luminous signals for opaque ones has contributed vastly to the improvement of the observations. These modern inventions together with the extreme precision of Troughton's graduation, as well as the high optical power employed, and the rigorous system of changing zero, introduced by Colonel Everest, has brought the terrestrial operations to a refinement of accuracy which may almost be pronounced unsurpassable.

During his absence from India, Colonel Everest had made himself acquainted with the English Ordnance Survey system, and with every modern improvement in geodetical matters that had taken place in Europe. The apparatus supplied by order of his Hon'ble masters was superior to any in the world, and London artist, Mr. Henry Barrow, was sent out to maintain the apparatus in order. Thus splendidly equipped, Colonel Everest returned to India in the prime of life, the full vigour of his faculties, and with an undaunted determination of character that never quailed before any difficulties, nor yielded to any opposition. The task before him required indeed the full display of all the vigour he possessed. In addition to the duties of Superintendent of the Trigonometrical Survey, he had now to perform those of Surveyor-general of India, to which office he had recently been appointed by the Hon'ble Court of Directors. This union of offices, though it served to facilitate arrangements, nevertheless vastly increased his labors at the outset; for the apparatus being new to India, and the establishment untrained, the whole task of teaching devolved on him unaided. In 1833, moreover, the offices of Deputy Surveyor-general at Madras and Bombay were abolished, which further increased the duties of the Surveyor-general of India, so that Colonel Everest had, in fact, to perform the work which had hitherto occupied the undivided attention of four officers. In the sequel these reductions have been found to operate conveniently enough, and so far have justified the expectations of the Hon'ble Court by whom they were

ordered, but the additional labor thrown on the Surveyor-general at the time that the Trigonometrical survey was about to recommence on a new organization, made his task a very arduous one.

He was detained by all these arrangements, by official delays, and by the measurement of the Calcutta Base line, until the end of 1832, from which time the Great Arc may be considered to have actually recommenced, after a cessation of seven years. The work was carried on unremittingly till December 1841, when the whole Indian arc, from Cape Comorin to the Himalaya mountains, forming the main axis of Indian geography, was finally completed.

These operations are fully detailed in Colonel Everest's book, published in 1847, by order of the Hon'ble East India Company. The area comprised by the Great Arc operations, principal and secondary, aggregates 56,997 square miles, including the revision of the section from Beder to Kalianpur, and the measurement of three base lines, each from $7\frac{1}{2}$ to 8 miles in length, viz., those of Beder in lat. 18° : Seronj, near Kalianpur station in lat. 24° and the Dehra base about 70 miles N. of Kaliana station in lat. $29^{\circ}30'$, where the Great Arc actually terminates, this distance being observed on account of the proximity of the Himalayas.

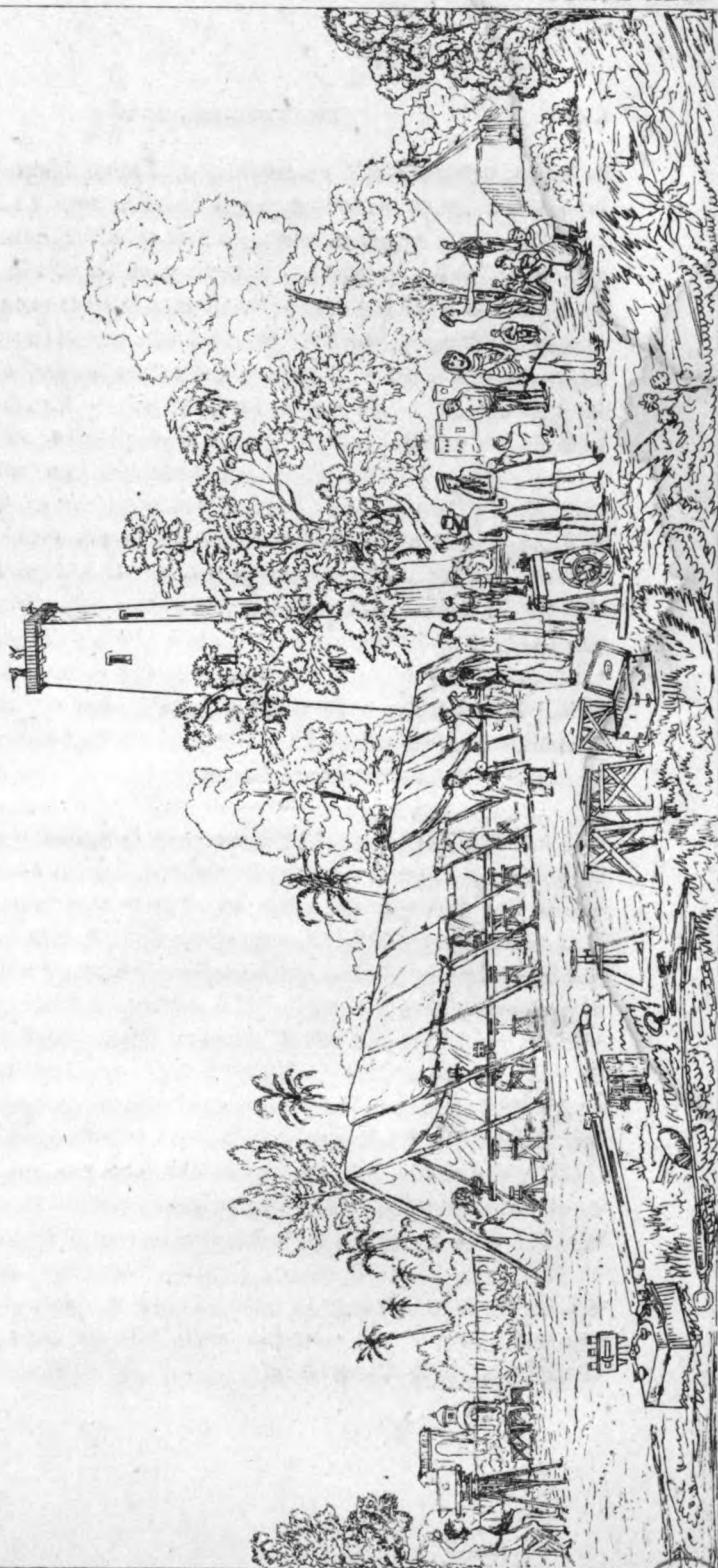
On comparing the actual measurement of the Dehra Doon base (by Colby's apparatus) with that calculated from the Seronj base measured in 1824 (by the chain), a difference of nearly $3\frac{1}{2}$ feet was found. In former times this would have been considered a very satisfactory agreement, seeing that the length of the base is $7\frac{1}{2}$ miles, and its distance from the new base upwards of 400 miles in a straight line; but Colonel Everest justly considered the difference as indicating a much larger error than ought to exist, regard being had to the precision of the new methods; and, in order to set the question at rest, he resolved to re-measure the old base with the more accurate apparatus he now had at his command. This operation was completed in January 1838, when it appeared that the length given by the chain measurement of 1824 was too short by nearly three feet, as compared with the new result.

The Plate represents the termination of the Measurement of the Calcutta Base in 1832, by Colby's apparatus. The six sets of bars are resting upon their tripods, levelled and in the act of adjustment, longi-

tudinally, by means of the directing or boning telescope, to the left hand. The boning telescope ought to have been considerably more distant from the bars, but it would then necessarily have been excluded from the drawing. A moveable covering of tent-frame work protects the bars from the influence of the morning sun; at their left extremity is seen a cast-iron tripod, firmly imbedded in the ground, bearing a brass vertical cylinder and plate, upon the surface of which is the minute dot which marks the termination of the last, and acts as the starting point of the present measurement, by the adjustment of the cross wires of the end microscope in the true vertical line bisecting the dot. These apparatus are represented on a larger scale in the foreground; as also one of the wooden boxes containing the compound bar, showing the two projecting tubes, within which lie the cross levers of the compound bars, upon which are engraved the dots, or marks to be read off by the double microscopes interposed between each box, as will be comprehended by reference to the drawing. The right extremity of the line is seen to enter the door of the tower, where it terminated in a coincidence with the original dot, engraved upon a metallic disc attached to a sunken stone pier.

The great accuracy and value of this apparatus may be judged of by the measurements of the three bases of the Great Arc. The Dehra Doon base is nearly $7\frac{1}{2}$ miles in length. The ground is undulating and by no means favorable; the line is twice intersected by the stream of the Asan; and the height above the sea level of one end of it is 186 feet greater than that of the other. The base was measured twice, first from west to east, and then in the opposite direction. After all reductions the two results were as follows:—Length in feet at the level of the sea—by the measurement, 39183·97329; by the remeasurement, 39183·77357; difference, 0·19972, corresponding to two inches and (nearly) four-tenths of an inch. Another test was applied with an equally satisfactory result. The entire line was divided into three sections, and the two end sections deduced from the middle one by triangulation. The discrepancies between the measured and computed distances were + 0·333 of an inch in the one case, and — 0·078 of an inch in the other; so that the whole base, deduced in terms of the middle section, differed from the length actually measured by scarcely more than a quarter of an inch.

TERMINATION
OF THE
MEASUREMENT OF THE BARRACKPOOR BASE.
January 1832,
(From a Sketch in the Asiatic Society's Journal.)



The other two bases, at Seronj and Beder, were measured exactly in the same manner as that in the Dehra Doon. In the case of the Beder base (nearly 8 miles) the measurement was tested by dividing the whole length into three sections, and computing the two end sections from the middle one by a triangulation. The difference was found to amount only to an inch in the one case, and about two-thirds of an inch in the other; the computed length exceeding the measured length in both cases.

The superb Theodolite above mentioned had an azimuth circle of 34 inches in diameter, and by means of five microscopic micrometers the divisions could be read to one or two-tenths of a second. It carried a telescope of 39.4 inches focal length; the attached vertical circle was 18 inches in diameter; and every contrivance had been applied to provide for accuracy and facility of adjustment, which the genius of the artist could devise.

In order to eliminate instrumental errors and obtain results of uniform precision, the angles were measured from eight different zeros on the circle, the established rule being "to observe three times at each zero with the face left and as many with the face right, then to change the zero three times by 9° each time, and at each position go through a like operation, whereby it is evident that every ninth degree will in turn fall under one or other of the microscopes."

Great importance was attached to the construction of the Stations. Throughout the Doab it was necessary to erect artificial structures of sufficient height to overtop the trees, and of sufficient solidity to afford a firm support to the theodolite. These were of a very substantial kind—square towers of solid masonry, about fifty feet in height, with walls five feet in thickness at the foundation, and two at the top. A stone slab, supported on two transverse stone beams, formed the floor on which the instrument stood: and the stage for the observers was entirely disconnected in order to avoid vibration while the observations were going on. The centre of the station was carefully defined on a plate of metal let into a stone, and sunk in the ground for further security, and the theodolite and signals were in all cases accurately adjusted over the centre. The sites of stations were also carefully selected with a view to *well-conditioned* triangles. It was a general rule, steadily adhered to, that no angle of any triangle should be less

than 80° . The sides of the triangles may be stated to be from ten to twenty-five miles. In a very few instances only are they found so much as thirty miles.

The Heliotrope was used for day observations; it affords an exquisite object for bisection, but as it must be adjusted by signals from the observer, it was only available for short distances. Reverberatory Lamps, with argand burners, and enclosed in air-tight cases, were generally used by night; and when these were found to be too feeble, recourse was had to blue lights, burned at regulated intervals. Means were provided to prevent any rays from the luminous object reaching the observer at the telescope, excepting those which passed over the centre of the station. With the heliotrope and blue lights it was found to be scarcely possible to arrange for the observation of more than one signal at the same time; and hence the usual mode of proceeding was to take the angles between a mark of reference set up at some convenient distance from the station where the instrument was placed, and the signals displayed from each of the surrounding stations successively and independently.

For computing the sides of the Triangles, the theorem of Legendre was used. Of the sufficiency of the methods, and the great precision of the whole of the geodetical operations, the most satisfactory proof is found in the agreement, almost absolute, in the lengths of the two bases at the extremities of the arc, as found by actual measurement and by computation through the series of triangles from the one near the middle. The results are as follows:—the length of the Dehra Doon base, brought out by computation from the Seronj base, was found to be 39188·278 feet, and by the actual measurement, 39188·878 feet, the difference being 0·600, or six-tenths of a foot; that is to say, a little more than seven inches, the distance between the two bases being about 430 miles. Again, the Beder base brought out by computation from the Seronj base was found to be 41578·178 feet, and the length given by the measurement was 41578·586, the difference in this case being only 0·358 parts of a foot, or a little more than four inches, the distance between the two bases being about 426 miles, and the calculation made through 85 principal triangles. The agreement is certainly remarkable.

The relative Heights of the stations were determined by means of

observations of their vertical angles, as seen from each other, made with 18-inch altitude and azimuth circles. The observations were reciprocal, that is to say an observer was placed at each of two stations whose difference of altitude was to be found, with a heliotrope or lamp by the side of his instrument, and each observed the angle between the zenith and the signal of the other at the same instant of time, according to preconcerted signals. This method is perhaps the only one which can be depended on in any country, but especially in India, where the effects of terrestrial refraction are so great and irregular.

For deducing the amplitude of the northern section (Kalianpur, (Seronj) to Kaliana) thirty-six stars were selected, half of them to the south and the other half to the north of the zeniths of both stations, but none of them having a zenith distance exceeding 5° from the nearest vertical. The observations were not, as was intended, strictly simultaneous, Captain Waugh having commenced his observations at Kalianpur a few nights before the time agreed on, and Colonel Everest and Captain Renny, who observed at Kaliana, having met with some interruption from unfavorable weather. For the southern section thirty-two stars were observed at Kalianpur and Damargida (Beder), and in this case the observations, with scarcely an exception, were literally simultaneous. Precise rules were laid down with respect to the mode of observing, reading the microscopes and levels, changing the zero points, &c.; and every necessary precaution appears to have been taken to obtain results free from instrumental errors.

Further details will be given in a subsequent paper of the methods of observing and computing employed in the Indian Trigonometrical Survey.

In the year 1829, a trigonometrical survey in the Bombay Presidency was commenced by Lieut. Shortrede, on an independent base and point of departure. These desultory principles were objected to by General Hodgson, at that time Surveyor-general of India, who recommended that the work should emanate from the Great Arc, and proceed to Bombay precisely according to Colonel Lambton's original design. This injunction, however, remained unheeded; and notwithstanding the respect due to Colonel Lambton's judgment, and General Hodgson's authority, the survey proceeded in an unsystematic manner

until it was brought under Colonel Everest's control in 1831. Finding that no use could be made of this confused net of triangulation, the Colonel directed that the longitudinal series should be taken up where he left off in 1823, at the time of Colonel Lambton's death. Lieut. Shortrode resigned in 1836, and was succeeded by Lieut. Jacob, of the Bombay Engineers, by whom the Bombay longitudinal series was brought to a conclusion in the year 1841, and the whole work now rests on his observations alone. This officer united to considerable mathematical attainments, great practical skill as an observer and mechanic; and although the instrument employed, a 15-inch theodolite, by Dollond, was small for such extended operations, no man could have turned it to better account, and the work accordingly bears a superior character for accuracy. The series extends 315 miles in length, and having occupied 12 years, progressed at an apparent rate of only 26 miles per season; but in fact the only efficient part of the work, viz., that executed by Lieut. Jacob, was performed in three seasons.

Immediately after the measurement of the Calcutta base, Colonel Everest fitted out a party under Lieutenant James Western, of the Engineers, for the purpose of carrying a triangulation along the meridian of Parianath, dependent on one of the sides of the Calcutta longitudinal series. This work commenced in February 1832, Lieutenant Western continuing in charge till September 1834, when he was relieved by Lieut. Bridgman, of the Artillery, who shortly afterwards was compelled to relinquish the duty from ill health, induced by exposure and fatigue, which obliged him to proceed to Europe on medical certificate, and soon after this promising young officer died on the voyage. No final work that could be made use of was executed up to this period, and the cost incurred, Rs. 35,224 was in fact fruitless. Lieut. (now Lieut.-Col.) A. H. E. Boileau assumed charge in 1835-36, and commenced the work *de novo*. Excepting an absence of six months on medical certificate, he continued to conduct the triangulation till December 1838, when he resigned his appointment in the Great Trigonometrical Survey for one of superior emolument and less exposure; the small portion remaining to connect the series with Lieut. Buxton's triangulation in Cuttack, was executed by Mr. Sub-assistant Kallonas. On account of defective instrumental power, this work is only of a second-rate order.

Colonel Everest at the end of 1832 fitted out another party, under Lieutenant Roderick Macdonald, of the Bengal Native Infantry, to carry on the Budhun meridional series, dependent on a side of the Calcutta longitudinal series. Lieutenant Macdonald broke ground on the 2nd February 1833, and was obliged to relinquish the work in September 1835, on account of ill health produced by exposure. Consequent on the departure of Lieutenant Macdonald, Lieutenant Ommanney, of Engineers, was placed in charge, and he remained in that post till April 1837, when he resigned his appointment, and was succeeded by Mr. Olliver. In the early part of 1838 operations were suspended on account of Mr. Olliver's services being required with Lieutenant Waugh on the Great Arc. Up to this time the progress of the Budhun series had been satisfactory as far as the hilly country extended, and ceased to be so as soon as the operations entered the flat lands in the valley of the Ganges. Until November 1839, no officer or sub-assistant of experience being available, the work remained suspended, but on the conclusion of the Amua series, the party under command of Lieutenant Renny (now Captain Renny Tailyour) was transferred to this series, and placed under Mr. Sub-assistant Murphy. After the termination of the Great Arc, on which Captain Tailyour had been employed, he proceeded to take personal charge of the Budhun series, and the work was at length brought to a successful conclusion by that able and energetic officer in one season, having occupied in all no less than eleven years from the commencement. The reasons for this slow progress may be inferred from this narrative. The area covered amounts to 12,468 square miles.

In 1832, Captains Waugh and Renny (Tailyour) joined the Survey Department, and were employed in exploring the wild and jungly country between Chunar and the sources of the Soane and Nerbudda rivers, and up to the city of Jubbulpore. This extensive survey was completed in the season 1832 and 1833, and formed the subject of a topographical and geological report, submitted in 1834. After closing the work at Jubbulpore in March 1833, they proceeded to join the approximate operations of the Great Arc series in the Gwalior country, with which they remained till August of the same year, when they were ordered to organize two parties, one for the Ranghir meridional series under Captain Waugh, the other for the Amua meridional series under

Captain Tailyour, both series being dependent on sides of the Calcutta longitudinal series. In December 1834, Captain Waugh joined the Great Arc as astronomical assistant, in which capacity he remained until he was selected to succeed Colonel Everest, on that officer's retirement from the service in December 1843.

The Ranghir series was completed in 1841, having occupied nine years. The meridional distance comprised is about 400 miles, showing an average progress of 44 miles per annum. The area covered amounts to 16,088 square miles.

The Amua series was brought to conclusion by Captain Tailyour, in June 1839. The instrument used was a good 18-inch theodolite, by Troughton and Simms, and the work possesses superior merit. The area comprised is 5,565 square miles.

Lieutenant W. Jones, of Engineers, was appointed to the trigonometrical survey in the year 1835, and remained till 1838 attached to the Great Arc. After the measurement of the base near Seronj, in which operation he took a part, Lieutenant Jones was deputed to conduct a series on the meridian of Karara, dependent on a side of the Calcutta longitudinal series. The work was commenced, but towards the close of 1838 the whole party was attacked by jungle fever, from the effects of which one sub-assistant, Mr. Scully, died, and Lieutenant Jones himself was obliged to seek for restoration to health in the hills. In consequence of this disaster, a fatal stop was put to the progress of the work. The establishment was broken up, and the work remained in abeyance till 1845, when it was completed by Mr. Armstrong, who had previously been employed in the Ranghir series. The instruments employed were of an inferior order, and this series cannot, therefore, be considered a first-class performance. It embraces an area of 5,819 square miles.

(To be continued).

BRICKWORK IN INDIA.

OVER the plains of Hindoostan and the Punjab for many years to come, must Brick be the chief material used by the Architect and Engineer for his building constructions; the cost of carriage and working, putting stone out of the question in any but very exceptional cases. The improvement of his Brick-work in material and workmanship ought therefore to be a subject worthy of his best consideration, on the part of every Engineer and Overseer in the above localities. I have already remarked in a former article (Vol. I. p. 201) on the unsatisfactory state of the building art in India, as exemplified in the tasteless plastered buildings which everywhere abound, and wish again to urge attention to this subject, because I think that with some care and skill, a great improvement in this direction may be carried out at small expense. The neglect of it has arisen a great deal from the little attention that has been bestowed on Brick Architecture in England,—where, when stone is not much used (as in London for example), stuccoed buildings everywhere abound. Old red brick houses of the age of Anne are not uncommon in country towns, and perhaps the excessive ugliness of their architecture has helped to bring the material into discredit; it is only quite recently that architects have turned their attention this way, and have showed how by care in the manufacture, and tasteful arrangement in the colors of their Bricks, it is possible to produce very pleasing architectural effects with an economical yet durable material, and which resists, far better than Stucco, the changes of a variable and trying climate.

It is rather to the Continent than to England that we must go for fine examples of chateaux and other structures in Brick which there abound, and it is from a German work * lately published and probably little known to my readers, that the annexed designs are taken. I have selected them, not because they are the best in the work, but because they are simple, and might I think be imitated by any Engineer who will take the necessary trouble.

Good clay for Brick-making is tolerably plentiful in India, and three or four varieties may be found in most districts. The bricks commonly used are well burnt, but owing to the little care bestowed on the choice or mixture of the earth, to the non-use of the pug-mill, and to carelessness in moulding, stacking, and burning, Indian bricks as a rule are badly shaped, their texture not homogeneous, and their color *dirty* and not uniform. All this it is evident may be remedied by proper care and supervision; and by reserving the inferior bricks for the unexposed parts of walls and paying a somewhat higher price for the best to use as face-bricks, a great improvement would be cheaply effected. But I am not aware that any attention has been given to the subject of *colored* bricks, to be used for cornices, pannels and mouldings, and there is a very good field here for any Engineer who will devote himself to this detail of his profession. The colors ordinarily employed in England are deep red; yellow or salmon color (such as the London malms); blue (as in the Staffordshire blues); and white (as the Suffolk whites). All these colors are produced by a careful choice or mixture† of earths and not by any expensive chemical substances mixed with the common earths. The red is due to the presence of the peroxide of iron—the blue color is produced simply by the application of greater heat to various earths which ordinarily burn red—white bricks are made from a plastic white clay—the London malms by mixing chalk and clay in a liquid state.

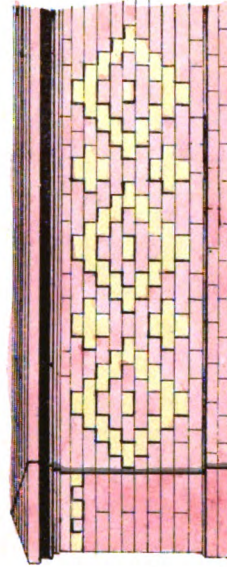
I think careful enquiry will show that one or more of these

* Vorwort, by Ludwig Degen, Ingenieur. Manchen.

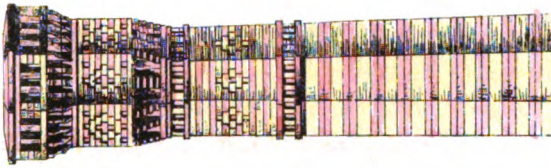
† In Staffordshire there are seven marls used, differing little in their chemical composition, and when used three sorts at least are generally mixed together (see Weale's Treatise).



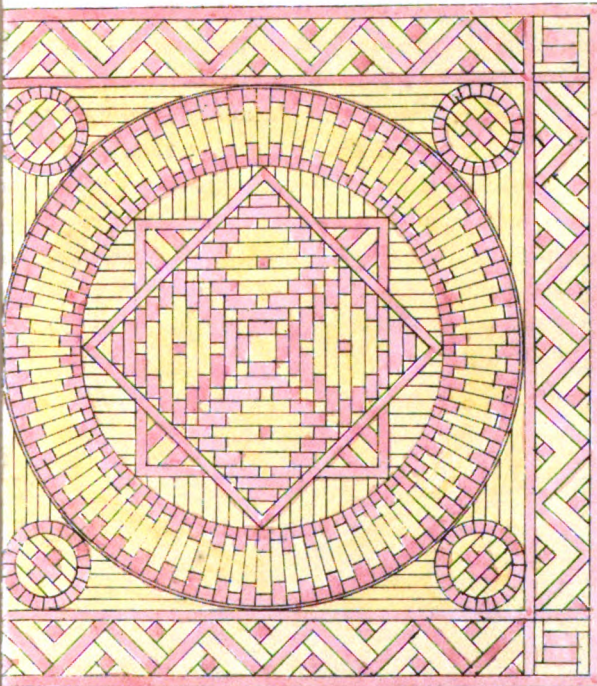
Cornice and Parapet.



Compound Wall.



Factory Chimney.



Flooring.

DESIGNED BY T. G. PRINCE



colored bricks could be produced in most districts, and, if only used in the ornamental parts of a building, it would be often worth while to import them from a considerable distance, if they were not procurable on the spot. There are surely some practical men in the profession in India who will turn their attention to so useful a subject, and give others the benefit of their experiments and experience; I shall be very happy to publish them *pro bono publico*. Any of my readers about visiting England I would strongly recommend to turn their attention to the practical solution of this question. I may add that I have sent home for specimens of colored bricks and of the raw material from which each sort is made, which will be deposited here, and may be useful as a guide in comparing Indian earths. Some experiments are also being made at Roorkee, and I have succeeded partially in making black bricks, but have not as yet been able to burn them white or yellow; should any of these trials be of sufficient interest to others they shall be duly recorded.

J. G. M.

No. LXXXII.

THE ALGUADA LIGHT-HOUSE.

Constructed by LIEUT.-COLONEL ALEX. FRASER, R.E.

At the close of the year 1853, the attention of the Marquis of Dalhousie, then Governor General of India, while on a visit to the newly acquired Province of British Burmah, was drawn to the perils of the Alguada Reef, a dangerous line of rocks to the southward of Cape Negrais, and lying on the direct course of vessels sailing from Calcutta to the Irrawaddy and to the great security that would be afforded to navigators by the construction of a Light-house there.

After some correspondence, the Court of Directors of the E. I. Company in 1856, desired that an Engineer Officer should be deputed to make the necessary surveys and submit a complete report and estimate of the proposed work; and Captain Alex. Fraser, R.E., was appointed to the duty. He was desired, after making a careful survey of the site, and taking into consideration all the circumstances that would affect the actual construction, to submit a preliminary report, and then to proceed to England for consultation with Mr. Allan Stevenson and other eminent Light House Engineers, after which his detailed designs were to be prepared. In February 1857, the first report was accordingly submitted, from which the following description of the Reef is taken.

"The Alguada Reef, consists of two totally distinct ridges of rock, running parallel to each other, separated by a channel a quarter of a mile wide, of a depth varying from 2 to 3½ fathoms, with a small detached rock in the centre appearing above the surface at low water. The rock of which the entire reef consists is sandstone. The rise and fall of spring tides I found to be 9 feet.

"After carefully examining every part of the Reef which was at all accessible, I

finally fixed upon a plateau on the eastern ridge, 600 feet distant from the S. W. extremity, as the site most suitable for the erection of the Light-house.

"The reef at this place is a firm solid mass of rock, presenting a nearly level surface of 100 feet in width, with an average height of 1·1 feet above high water spring tides."

After giving his reasons for preferring Stone to Iron as the material to be employed, Captain Fraser pointed out the island of Callagouk, distant 210 miles from the reef, as the source of supply which he would propose. Captain Fraser then proceeded to England, and in the following November submitted his detailed report and designs to the Hon'ble the Court of Directors, who expressed "their full satisfaction with the manner in which he had fulfilled the commission entrusted to him by the Government of India," and on that design the work was accordingly executed. The following is extracted from this report :—

"Of all the Light-houses that I know or have visited, the Skerryvore, designed and erected by Mr. Alan Stevenson, on the Western coast of Scotland, is in the position most analogous to that of the Alguada Reef.

"Every Engineer is, of course, desirous of submitting original designs ; but so perfect in every way does this structure appear to me to be, not only in design, but in workmanship, and not only in beauty of appearance, but in accuracy of calculation with reference to stability, that I feel quite sure I can do no wrong in taking it as my model, with, of course, certain interior alterations necessary to the different interior arrangements that will be required to suit it for the dwelling-place of people of different races, and in a different climate : and if I can, with the unskilled labor I shall be able to obtain, execute the work on the Alguada Reef in the same successful manner as that has been executed on the Skerryvore, I feel that, though I may have shown no originality of design, I shall be entitled to no small credit in the construction.

"The diameter of this Tower is 42 feet, the height of the shaft is 120 feet, and the diameter at this height is 16 feet. Above the shaft is a cylindric belt, 18 inches deep, surmounted by a cavetto 6 feet high, with a 3 feet projection. The cavetto supports an abacus 3 feet deep, the upper surface of which forms the balcony. On the abacus rests the parapet, and on it the lantern. The outer surface of the shaft is formed by the revolution of an hyperbola round its asymptote as a vertical axis—the radius at the base being 21 feet, and at the top 8 feet. The contour of the cavetto is obtained from the quadrant of ellipse revolving about the centre of the Tower with a radius of 8 feet on the level of its transverse axis.

"In adopting this curve for his Light-house, Mr. Alan Stevenson observes, in reference to the stability of buildings exposed to the force of the sea, that the sum of our knowledge appears to be contained in the following proposition :—' That, as the ultimate stability of a sea-tower, viewed as a monolithic mass, depends, *ceteris paribus*, on the lowness of its centre of gravity, the general notion of its form is that of a cone ; but that, as the forces to which its several horizontal sections are opposed decrease towards its top in a rapid ratio, the solid should be generated by

the revolution of some curved line convex to the axis of the Tower, and gradually approaching to parallelism with it.' " He then goes on to show that he tried several forms, and proves a clear superiority of the hyperbolic curve over all others, as far as the advantageous arrangement of the materials is concerned.

"I therefore think the Hon'ble Court can do no better than authorise Mr. A. Stevenson's design for the Light-house on the Skerryvore, as the model of form on which to build the one proposed for the Algnada Reef.

"The focus of the light will be 142.5 (= height of tower) + 1.1 (= height of site above spring tides) = 143.6 feet above high water spring tides, which height will permit the light to be seen, supposing the eye of the observer on the horizon, and taking into consideration the effect of atmospheric refraction at a distance of 15.85 miles. If we take the height of the observer's eye to be 20 feet above the horizon, then the light will be visible at a distance of 21.766 miles, and at 50 feet above that level, 25.204 miles."

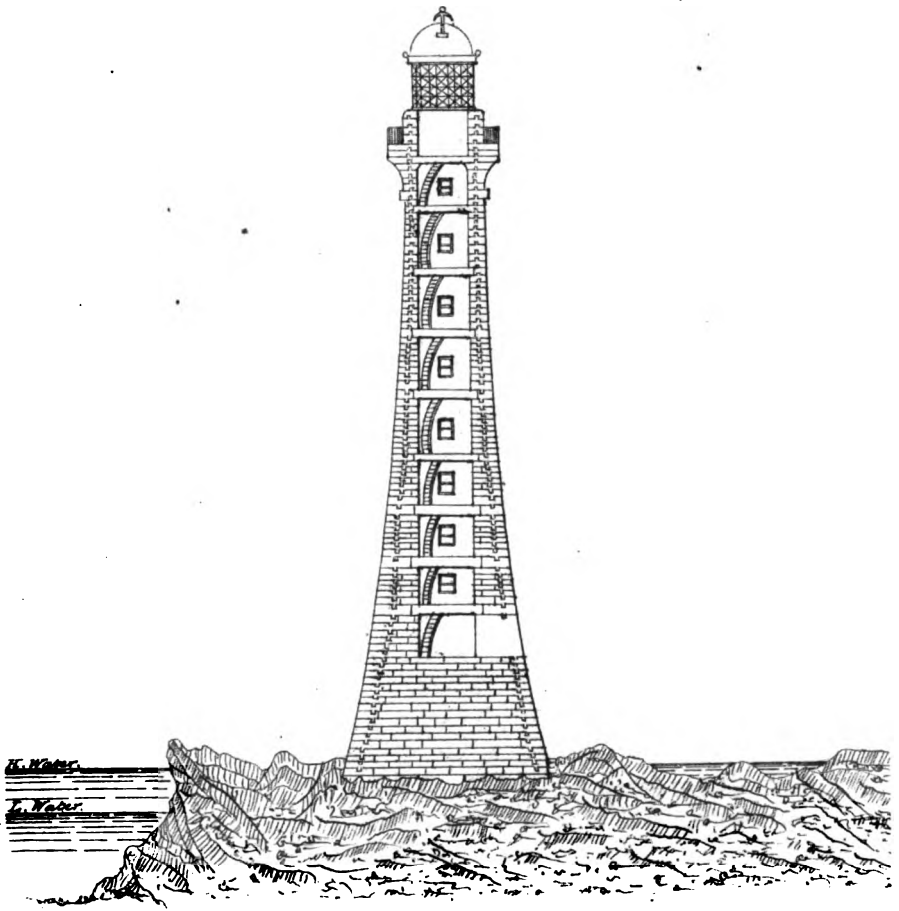
Financial difficulties, consequent on the mutiny, prevented the immediate commencement of the work, but during the N. E. monsoon of 1859-60, work was really begun, and consisted in cutting out the foundation to a depth at the lowest part of $7\frac{1}{2}$ feet below high water spring tides, about 700 tons of rock being removed. The work was done by common "classies" picked up in Calcutta, assisted by the crew of the steamer "Nemesis," and the chief trouble was to keep the water out of the foundation, which with the least sea was constantly being filled. In the mean time an establishment had been organized at the island of Callagouk, whence the granite was to be quarried and conveyed to the reef in lighters, towed by the steamer; and no little difficulty was encountered in starting such an establishment in a dense jungle on an uninhabited island. Laborers were procured from Madras and Hong Kong, and set to work under Lieut. J. McNeile, R.E., but so great were the difficulties that eventually it was found necessary to prepare part of the stone at Singapore. It was not until the 14th February 1861, that the first granite stone was actually laid, and 104 stones, weighing 74 tons, were laid before the setting in of the monsoon caused the stoppage of work for the season. The weather during this and the following season was most unfavorable and caused great delay and anxiety.

By the end of the third season, however, the seven lower courses of stones were duly laid, each stone varying in weight from half a ton to $8\frac{1}{2}$ tons. They were all lifted into position by the crane by means of *lewises* previously cut—the outside stones being laid in Portland cement, the inner in lime and soorkhee.

During the fourth season (1862-63) the work was completed up to the

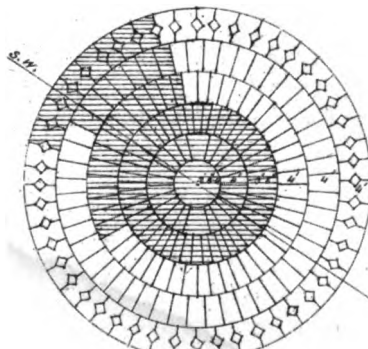
ALGUADA LIGHT-HOUSE.

Section.



Scale 4.0 feet = 1 inch.

Plan of First Course.



Scale, 2.4 feet = 1 inch.

REFERENCES.

Centre Stone,	1.
1 st Ring,	24.
2 nd " ,	48.
3 rd " ,	48.
4 th " ,	48.
5 th " ,	48.
Joggles,	48.
Total,	265.
Radius,	22.205.
Content,	3697.207.
Weight,	22945 Tons.



18th course, or above the lower room, being rather more than half the whole quantity, and by the end of the fifth season (1863-64) the whole stonework was complete with the exception of the parapet, and the four top courses of the capital, 1,600 tons of stone having been raised that year.

On 23rd April 1865, the light was for the first time shown, and the Governor General in Council offered "to Lieut.-Colonel Fraser the cordial thanks and congratulations of the Governor of India on the successful issue of his labors."

"Lieut.-Colonel Fraser," says the Government order, "applied himself to the task with a zeal and judgment which have ensured success."

"To land on the Reef is always a difficulty. For a vessel to be thrown on it at any time is almost certain destruction, and in any but the calmest weather the seas break over it. A first care, therefore, was the formation of a suitable marine establishment for the transport and landing of materials, for the safe conduct of operations, and for a secure refuge in stress of weather. Skilled workmen had to be brought from Madras, and even from Hong Kong. Materials, provisions, and water, had also to be arranged for.

"The foundation had to be cut in the solid rock to a depth of $7\frac{1}{2}$ feet below high water spring tides, with the sea breaking over and filling the pit at high water, and very little wind preventing all work.

"For the lower foundation courses, sandstone was quarried and dressed on the Reef. For the tower, granite had to be obtained from Callagouk, 200 miles, and Singapore, 1,200 miles, distant. Upwards of 4,000 tons of granite in heavy blocks, some weighing nearly four tons, requiring accurate dressing, had to be shipped and conveyed to the Reef, and there placed in position, the landing involving an almost daily contest with the elements. This was accomplished in four seasons, of which three proved very unfavorable, with the loss of no life, but only of a few boats, of one lighter with 40 tons of stone, and with injuries to only a few of the workmen.

"The forethought, resource, energy, and perseverance displayed, and the anxiety, risk, exposure, and hardships endured, entitle Lieutenant-Colonel Fraser, and all under his orders, to the highest commendation.

"It is seldom that it falls to the lot of any individual, in India especially, to carry through from beginning to end a work of such magnitude and extending over so long a period. The work itself is unique, certainly in the East, and, whether regard be had to cost, execution, or rate of progress, may challenge comparison with its somewhat smaller prototype, the Skerryvore on the coast of Scotland."

The Engraving on the Frontispiece is from a Photograph taken on the spot, and sent to the Editor by Col. Fraser. It is understood that a complete history of this important work will shortly be published by Government.

The total cost of the work was about 10 lakhs of Rupees (£100,000).

J. G. M.

No. LXXXIII.

INDUS SILT EXPERIMENTS.

(2ND ARTICLE.)

Description of the mode adopted in taking the Observations recorded below, to determine the Velocity of, and the amount of Solid Matter in, Water, at different depths in the Indus. BY COLONEL TREMENEERE, R.E., *Chief Engineer in Sind.*

As it was desirable to ascertain the amount of silt in the Indus water during the winter season when the river is low, the observations were continued at Kotree in the month of November 1864, from a boat anchored at several points in nearly a direct line between two stations on the opposite banks of the river. I hoped thus to obtain a correct section of the river with observations of the velocities, and to be able to calculate with some accuracy the total discharge. I was, however, foiled by the great depth of water, and the strength of the current in the centre of the section. On the 25th November, with a depth of 14 feet, and a surface velocity of 4·7 feet per second, I found that the wooden pole to which the instrument was fixed was unmanageable, its buoyancy rendering it almost impossible to force it to the bottom by the time it came into a vertical position, or to retain it in that position. In one portion the depth was as much as 18 feet, and I could neither observe the velocities, nor take specimens of water at so great a depth. Although the observations then taken are not so complete as I had hoped to obtain, they are still valuable.

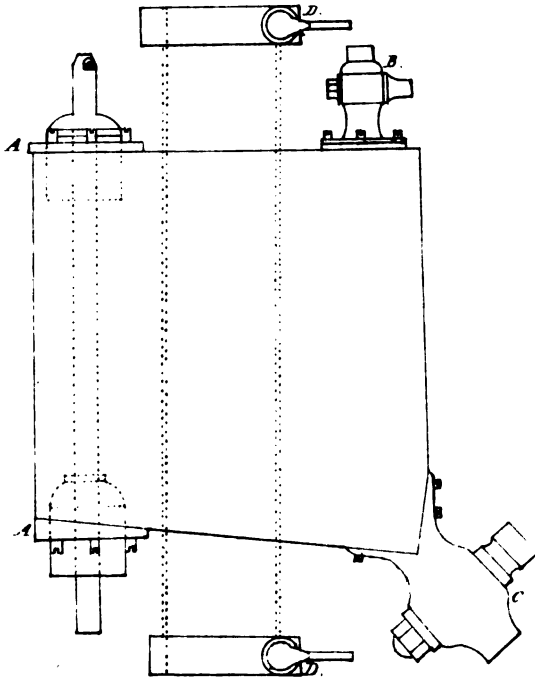
The only difference in the mode of observation from that previously described, was in the adoption of a bottle of a new pattern for taking water from the different depths.

A drawing of the apparatus is given. The cylindrical vessel slides upon

INDUS SILT EXPERIMENTS.

Bottle for taking water from below the surface, to ascertain the quantity of Silt.

Scale $\frac{1}{2}$



A A. Valves for the admission of Water

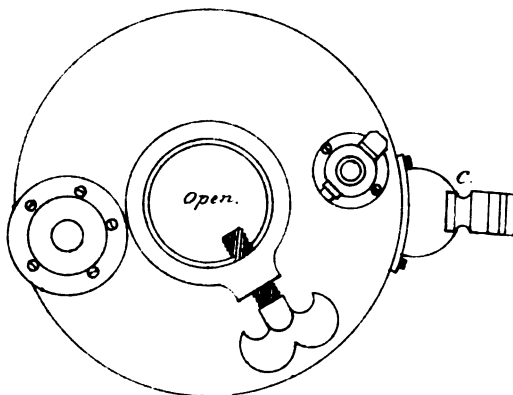
B. Air Cock opened when the vessel is to be emptied.

C. Discharge Cock.

D D. Clamping Screws.

Outer diameter of Iron Gaspipe $1\frac{1}{2}$ inches.

Weight of D. $1\frac{1}{2}$ per foot nearly.



a piece of iron gas pipe graduated to feet and inches. This arrangement is much less acted upon by the current; it is immaterial in what position it is held, and one string suffices to work the valves.

The adoption of the gas pipe for this instrument, led to its employment also for the stream measurer, instead of the wooden rod, which was found unsuitable for any considerable depths, and both instruments now work on the same rod. I was able to dispense with the groove in the rod as a guide, by having a cross head to screw on to the top of the pipe, and by taking care to arrange the axis of the stream measurer as nearly as possible in the same vertical plane as the cross head.

In all other respects the observations were taken in precisely the same manner as those previously described, and the filtering observations were conducted with the same care.

Although I failed to obtain a complete section of the river at Kotree, with corresponding observations for velocity and silt, I was more fortunate at Sukkur, where, with the same apparatus, observations were taken at eight points at intervals in a direct line across the river.

The section of the river plotted to scale is given, but as the surface level of the river varied considerably during the nine days occupied by the observations; in calculating the discharge, I have reduced the depths and mean velocities to correspond with the state of the river on the 24th December, which gives the total discharge 68,114 cubic feet per second.

The position of the section is some way above the pass of the river between Sukkur and Roree at right angles to the bank, and about 200 feet north of the building marked Karkhana on, Plate VI.

The whole of the observations are given without any attempt to reconcile apparently anomalous results. With the single exception of those taken on November 25th, the experiments were made by myself and my Assistant, Captain Cotgrave; for that day alone a clerk belonging to my office gave me his help.* For the correctness with which the filtering, drying, and weighing, have been performed, I alone am responsible. It seems unnecessary to describe these processes in detail, as they must be familiar to every one who has been instructed in chemical manipulation, and as the details are described in books on that subject.

An examination of the recorded velocities at different depths, will, I

* I take this opportunity to express my obligations to Mr. F. Jones, C.E., Acting Executive Engineer, Upper Sind, for the assistance he rendered to me throughout the observations taken in the months of July and August last.

think, show that some confidence may be felt in the correctness of observations with the instrument employed.

With respect to the variation in the proportion of silt at different depths, I would remark that the results are given precisely as they were obtained, without offering any explanation of the fact, that there was more silt in water taken on the 23rd November at 9 feet from the surface, than in water taken within a couple of minutes at the same spot, from a depth of 11 feet,—and more in water taken on the 24th November from a depth of 8 feet, than from a depth of 12 feet. The facts prove that the material in suspension is not distributed in any exact proportion to the depths and velocities. Taken as a whole, however, the results show but few of these anomalies. In the Sukkur observations, the proportion of silt increases with the depth with considerable regularity, though here also a few exceptions occur.

The mean result of the observations at Kotree in November, is that the quantity of silt amounts to the 1-672 part of the water by weight; but as no observations were taken where the river was deepest and most rapid, this fraction is too small to represent the proportion in the whole discharge of the river.

The observations taken at Sukkur give the proportion 1-516, but this again, owing to the access of flood water during the experiments, gives too large a value, and I am disposed to adopt as an approximation 1-550 or 1-600, say 16·6 parts in ten thousand as the proportion of silt by weight in the whole discharge of the river during the low season, or as nearly as possible half that contained in it during the height of the inundation, viz., 33·3 parts in ten thousand.

I have failed hitherto to find any part of the river where the banks on each side are well defined during both the high and low seasons, and where the depth in the latter period is such, that observations can be taken throughout the section. If the correct measure of the discharge at such a section during the low season could be obtained, a close approximation could be made to that of any period of the inundation, by merely taking the velocities at the surface.

The section at Sukkur herein given, being bounded on the left bank by low land which is submerged in the high season, cannot be used for the above purpose. The maximum discharge of the river at Sukkur may however be considered as 3,80,000 cubic feet per second.

RECORD OF OBSERVATIONS TO ASCERTAIN THE AMOUNT OF SILT CONTAINED IN THE WATER OF THE INDUS IN THE
MONTHS OF NOVEMBER AND DECEMBER 1864.

Date.	Site.	Gauge.	Depth of Water.	Depth from Surface.	Velocity per Second.	Quantity of Water.	Proportion of Silt to Water.	Remarks.
1864. Nov. 23,	Kotree,	3 2	13 0	ft. in.	feet.	Tbs. oz. dra. grains	1-804 1-784 1-810 1-895	
				11 0	1-68	3 1 5 27		
				9 0	2-166	3 0 4 29		
				7 0	2-37	3 0 1 26		
Nov. 24,	"	3 0 1/2	14 0	5 0	2-62	3 1 6 32	1-768=00130 1-846 1-463 1-642 1-787 1-654=00153	
				4 0	2-68	3 1 6 32		
				3 0	2-73	3 1 6 32		
				1 0		12 4 0 114		
Nov. 25,	"	3 0	14 0	12 0	1-85	3 0 3 25	1-595 1-714 1-678 1-798 1-653=00153	
				8 0	2-52	3 0 5 46		
				4 0	3-06	3 1 7 34		
				Surface	3-48	3 2 3 28		
Nov. 25,	"	3 0	14 0	12 0		12 5 2 133	1-595 1-714 1-678 1-798 1-653=00153	
				8 0		2 13 2 37		
				4 0		3 1 0 30		
				Surface	4-7	3 3 1 33 2 1 6 20		
						11 3 1 120		

Date.	Site.	Gauge.	Depth of Water.	Depth from Surface.	Velocity per Second.	Quantity of Water.	Deposit of Silt.	Proportion of Silt to Water.	Remarks.
1884. Nov. 26,	Kotree,	ft. in. 2 11	ft. in. 16 0	ft. in. 14 0 10 0 6 0 2 0 Surface	feet. 1.38 1.85 2.22 2.22 2.56	Tba. oz. dra. grains. 3 0 0 24 3 1 5 27 3 1 4 28 2 15 0 25 12 2 1 104		1.875 1.804 1.774 1.822 1.817 = .00122	
Nov. 28,	"	2 10 1/2	15 0	13 0 9 0 5 0 2 0	Variable owing to the exist- ence of a backwater.	2 15 0 45 3 0 4 40 3 1 4 44 2 15 4 24 12 0 4 158		1.457 1.530 1.492 1.866 1.550 = .00181	
Dec. 24,	Sukkur,	0 7	7 6	Total at Kotree, 5 6 3 6 1 6	1.75 1.95 2.66	59 15 2 624 2 14 3 88 2 13 1 20 2 15 0 20 8 10 5 78		1.534 1.988 1.1028 1.777 = .00129	
Dec. 26,	"	1 1	7 3	5 3 3 3 1 3 Surface	4.27 4.57 5.03 5.03	2 11 4 22 2 3 0 20 2 15 2 23 2 3 2 16 10 1 1 81		1.821 1.765 1.909 1.965 1.870 = .00115	

Dec. 27,	Sakkur,	1 8	9 8	7 8	4 86 5 5 6 26 6 47	2 2 5 2 3 2 2 6 0 2 8 0	38 36 33 35	1-398 1-428 1-503 1-487
Dec. 28,	"	2 0	9 0	7 0 5 0 3 0 1 0	5 16 5 5 6 72 6 98	8 14 7 2 5 6 2 5 6 2 6 0 2 6 0	142 90 60 45 44	1-440=00227 1-183 1-275 1-369 1-378
Dec. 29,	"	1 11	7 4	5 4 3 4 1 4 0 4	5 54 6 21 6 80 6 80	9 7 4 2 3 4 2 5 7 3 3 8	239 36 86 89	1-277=00861 1-482 1-460 1-576
Dec. 30,	"	1 7	8 5	6 5 4 5 2 5 0 5	4 07 4 74 4 87 5 12	7 12 6 2 6 0 2 6 0 2 5 6 2 8 8	111 35 83 30 21	1-492=00203 1-475 1-503 1-541 1-787
Dec. 31,	"	1 4	7 3	5 3 3 3 1 3 0 3	4 08 4 62 5 16 5 29	9 5 1 2 0 0 1 5 2 1 8 6 2 2 0	119 26 28 17 20	1-546=00185 1-587 1-382 1-637 1-748
						7 0 0	91	1-538=00186

Date.	Site.	Gauge.	Depth of Water.	Depth from Surface.	Velocity per Second.	Quantity of Water	$\frac{\text{Lbs. oz. dra. grains.}}{1000}$	Proportion of Silt to Water.	Remarks.
1865. Jan. 2,	Sukkur,	0 10	ft. in. 2 6 2 11	ft. in. 0 6 0 11 Surface	feet. 2-66 1-04 4-19	Lbs. oz. dra. grains. 2 2 6 20 3 0 0 29 2 3 5 21		1-760 1-724 1-742	
Total for Sukkur, -						7 6 3 70	1-739 = .00135		
						68 10 5 981½	1-516 = .00194		

C. W. TREMENHÈRE, COL., R.E.

No. LXXXIV.

GHAUT TRACING IN NORTH CANARA.

BY AN OFFICER OF THE MADRAS ENGINEERS.

Prior to 1862, the beautiful district of North Canara, formed an integral portion of the Presidency of Madras. Its seaboard extends from the $13^{\circ} 30'$ to the 15° parallel of latitude, and is indented with numerous river estuaries, that to the eye at least seem each of them destined by nature to be improved into splendid harbours. Towards the south, the line of Ghauts approaches within about five miles of the sea, but recedes very considerably towards the north; throwing out however long and craggy spurs, which impart a peculiar, and quite characteristic, picturesque-ness to the landscape. The Ghauts, and for the most part their spurs, are clad in the richest tropical vegetation, ever green; so that from each peak, or commanding point, there is spread out before the beholder, a prospect, perhaps not surpassed out of the Brazils.

North Canara is bounded on the east by the open champaign of Dharwar, now famous for its cotton, and by the Nuggur division of Mysore; and on the north, by the Portuguese territory of Goa, and the wild Sawunt Warree country in the collectorate of Belgaum.

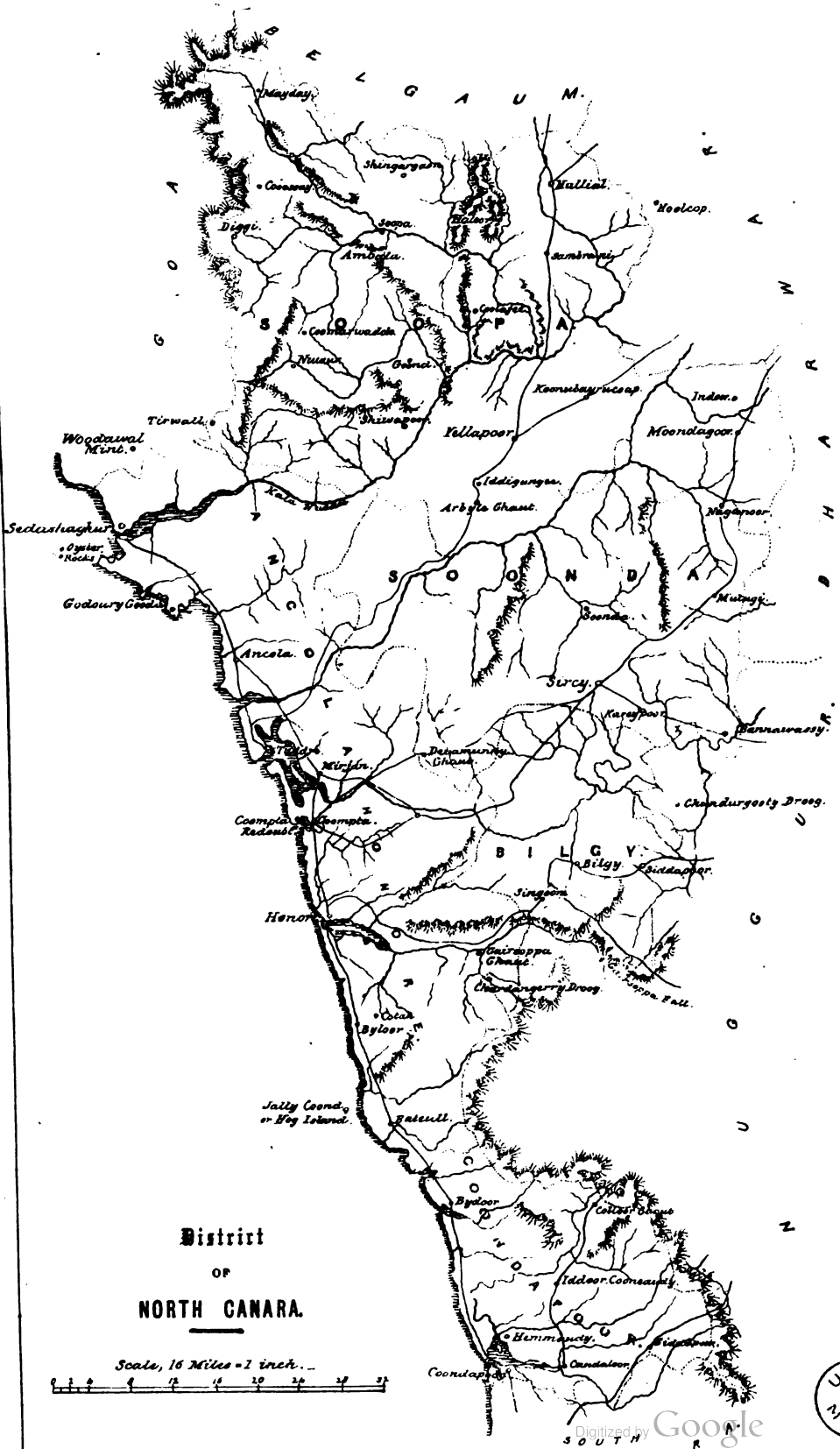
It was added to Madras in a most unimproved state, with its lines of communication undeveloped; and remained for many years uncared for in this respect. Beyond the few European officials engaged in the collection of the revenue; a small detachment of natives troops at Honore, a seaport and principal station, and an occasional visit from sportsmen; no representative of the government was personally acquainted with the

vast capabilities and interesting features of this truly romantic Indian Eden. Seaward, the chain of frowning Ghauts, having bamboo thickets at their bases; a rank undergrowth of jungle well stocked with leeches, precluding escape most of the way up; and a stretch of eighty miles of broken ground, densely wooded, to make way through on reaching the top; effectually hindered much intercourse between Dharwar and the coast.

From the east the same obstacles in inverse order, had to be encountered; while from both north and south, the sand of the sea shores is the only track by which to enter; there being to this day no made road betwixt Cannanore and Bombay. But difficulties so great, though they might deter an ordinary traveller, are made light of when they stand in the way of the requirements of trade; and at length the attention of the district officials was roused by the spectacle of droves of laden cattle passing to and fro in thick streams, and literally forcing a passage, through lonely, inhospitable forests, and along stony water channels, that take an almost headlong course down the flanks of the Ghauts. The aid of the Engineer was called in.

Before describing the different ports of North Canara, it is necessary to note that, from the beginning of June to the end of August, the monsoon rains deluge the district. On the coast some 100 inches and upwards of rain-fall are generally registered; at the crest of the Ghauts the amount is fully half as much again; gradually dwindling down, and becoming considerably less, or about 40 inches, on the Dharwar frontier, which is a hundred miles from the sea. This rainy belt is popularly known as the Mulnaad, or tract on which the south-west monsoon expends its violence, and Canara falls entirely within it. Unlike the districts north and south of it, the chief part of the North Canara Mulnaad lies above the Ghauts, or on an average at a height of 1,800 feet above the sea level; so that there is a more equable and plentiful distribution of rain over the higher ground than is found on the corresponding plateau of Mysore, which is fringed by scarps 3,000 feet high, diaphragms, that turn much of it back through the lowlands, to the ocean whence it came.

This abundance of rain gives North Canara above the Ghauts, a luxuriance of vegetation, and an impenetrability, nowhere else along the western coast to be met with on so grand a scale, or uniformly spread over so wide an area. It conspires, with the cool sea breeze, the clouds, the foliage, and the elevation, to reduce the temperature so low, that, it is



not uncommon to observe the thermometer standing at 65° at 10 A. M., while in the hottest weather it is never above 80° in the shade at mid-day. Add to these amenities, the hilly nature of the district; the torrents; the deep dells, and the tortuous ravines; the forests of lofty trees; the cascades, which thunder down from the edge of the table land to the cultivated strip below that skirts the sea; and tracing Ghauts in Canara may be fitly termed the poetry of road-making.

The chief ports are, Coompta, Tuddri, Honore, and Sedashaghur, now called Karwar in Bombay official reports. Coompta is a small town situated upon a tidal river of no great size, and was, until the transfer of the district, the place to which cotton was conveyed in large quantities to be shipped. The best "Coomptas" were as regularly quoted in the newspaper commercial lists as their rivals, fair "Dholleras," unless indeed the bales stood upon their own merits as "Dharwar saw-ginned."

It has no capabilities as a harbour, the river being narrow, and its bar shallow. The craft to convey the cotton to Bombay, where it was screwed, lay in an open roadstead, and were loaded by means of cargo boats, which could alone come along side the merchants' wharves up the river. During the continuance of the monsoon no business was transacted. Coompta doubtless gained its importance from being the nearest point on the coast to Dharwar, which could be easily reached; as it had of a certainty nothing else to commend it. Until the year 1848, the trade was conducted in the face of enormous disabilities, as there was no made road leading to Coompta, and without them the Canara district is almost impassable. Relief was afforded by the opening of the Devamunny Ghaut, and the construction of a first-class metalled road from the head of the Ghaut to the frontier, *viâ* Sircy, a lovely spot, which became the head quarter station of the district, and the basis of subsequent engineering operations. The road was prolonged westward to Coompta, the only obstruction being a wide ferry half way, which is still crossed by boats. The Ghaut is on the easy gradient of 1 in 20, and rises along the hill-side through the thickest forest, and rankest undergrowth imaginable, for nine miles without a single zig-zag. The foot of the Ghaut is fifteen miles from Coompta and 40 miles from Sircy, and the height surmounted is 1,800 feet. Any kind of wheeled carriage can traverse it with perfect ease and safety, and the line is bridged throughout.

About this time, the Indian Navy Officers were making a survey of the

Canara coast, and brought the port of Tuddri into favorable notice. It is a small bay, in the shape of a horseshoe, with the mouth pointing directly out to sea. There is deep water on the bar, and vessels are able to enter and load inside the harbour, but the monsoon squalls unfortunately strike right in, rendering it useless as a place of refuge at that season, or indeed at any time during the prevalence of a high wind. With all this, Tuddri had its share of popularity; and a Ghaut, the Arbyle Ghaut, was made for the express purpose of leading the traffic to it. The Arbyle Ghaut is situated a good way north of the Devamunny Ghaut, and is about eighty miles from Tuddri. The length of the ascent is six miles, and the gradient is a little steeper than the Devamunny, or from 1 in 18 to 1 in 16. It is also a very bold work, carried through heavy jungle, and most ingeniously led across a narrow neck connecting the main mass of hills with the spur up which the road winds, by which most unsightly zig-zags are avoided.

From Iddigungee, at the top of the Arbyle Ghaut, there is an excellent road, 25 feet wide, and bridged, to the Dharwar frontier; most of which must have been nearly as difficult to trace as the Ghaut itself, owing to the pronounced features of the ground, and its being covered with trees and shrubs. For the greater part of its length this road is formed, as are indeed most of the Canara roads, in laterite soil, which is one of the best gravels in use for surface metalling. It is not easily cut into ruts, and presents a dry hard face a quarter of an hour after the heaviest rain. In fact, so much assistance has nature lent, by clothing the surrounding country with an even coat of grass of the richest green, by grouping the trees and bushes into pleasing clumps, that a person riding along the smooth red tinted highway imagines he has entered the well kept park of a nobleman, and half expects to get a glimpse of the mansion house at every turn.

About half way between the foot of the Ghaut and the sea, the Arbyle road, as it is called, separates into two branches; one conducting to Tuddri; and the other pursuing a direct course to the trifling sea side village of Ancola whence it turns north to Sedashaghur. When the transfer to Bombay was made, the road from Ancola to Sedashaghur was under construction, but is now reported to have been completed; the distance is about 20 miles.

Tuddri soon lost the reputation it had rather hastily acquired, as the

prospect of the harbour of Sedashaghur being rendered accessible to cart traffic drew closer; and the consequences of the American Civil War still further conduced to turn all eyes to the natural advantages of the superior port. Sometime prior to the transfer, an effort was made to find a shorter route from Iddigungee to Sedashaghur, than that *vid* the Arbyle road and Ancola, and after some deliberation, a line was selected, that of course involved the construction of a new Ghaut. The work of tracing was commenced from Iddigungee, and the track lay along most rugged and peculiar features. For three or four miles the road is taken along the top of an elevated and narrow ridge, formed by the junction of deep valleys running transversely to it in opposite directions. At twenty miles from Iddigungee, the head of the Keiga Ghaut, as it is termed, is reached; the intervening country presenting magnificent views, where it is possible to see over the tangled foliage which lines the way. The trace of the new road and Ghaut to within seventeen or eighteen miles of Sedashaghur had been opened out by the close of 1861. The Keiga Ghaut is nine miles long, a good part of it is on a very gentle incline, and none of the gradients are in excess of 1 in 20, which experience has shown is the best suited to Ghaut roads on the western coast. When the bridges are built it will have no zig-zags. Thus many of them will be imposing structures, as there are rapid and formidable torrents to be crossed. Like the others, the Keiga Ghaut is richly wooded, and there is an immense amount of blasting in gneissose granite to be done in widening out the traces.

At seven miles from the foot of the Ghaut, which is situated in an almost unrelieved solitude, the road begins to run parallel with a tidal river, broad and deep, that disembogues itself at Sedashaghur. This river, or the Kalanuddy (black river), is navigable for steamers for at least nine miles inland at all times, but in the rains swells out to an impetuous and noble stream. In the dry weather, timber rafts are floated down it from the teak forest of Goond, which lies in the direction of Sawunt Warree; and the sale of the logs forms no inconsiderable part of the revenue which the district yields to Government. The harbour of Sedashaghur would take too long to describe; and it must suffice to mention that it is sheltered by a projecting head land from the gales of the monsoon, and affords a spacious anchorage for every class of vessel.

Honore is far to the south, and comparatively of no great value or

importance. On an estuary of a river bearing the same name, with a shallow and exposed bar, the traffic in spices and salt is entirely local; but even that is accommodated by a fine Ghaut, the Gairsoppa Ghaut, by which access is gained to the Gairsoppa Falls, a stupendous cataract; and to the Mysore country far beyond.

It has been necessary thus far to describe the physical aspect of North Canara, before proceeding to treat of the mode of tracing, which thick jungle and broken ground, made it desirable, and it may be said obligatory, to adopt.

Of the two, the labor of tracing a mountain road, is greater than that expended in the actual laying out of the sheer descent of the Ghaut itself, but it requires not a little scientific experience to pitch upon a general line for the latter, that will give scope for running a trace at a fixed gradient of 1 in 20, without having recourse to the clumsy expedient of zig-zags. Either a deep ravine or valley should be sought, up whose flank the road may be carried; or a long spur or series of spurs, round and about which it may wind, should be chosen: and where such a formation can be found, a combination of both features is best. Much deliberation and care has to be exercised at the outset, in judging by the eye of the practicability of the site chosen for the descent. The jungle is so close in North Canara, that a trial trace cannot well be run without great loss of time and useless expenditure of labor; all which is saved by having the ground reconnoitred by an experienced Engineer, who, with the help of the Aneroid Barometer, can pretty accurately settle the question.

The head of the Ghaut is usually a fixed point; and if it is not left open to doubt that it *must* be adopted in any case, the tracer may commence his line, working downwards, wherever his levelling staff carries him; recollecting he must ease off his slope a little when turning corners, and must cross all streams at a dead level. Once he has started, it is impossible to lay down fixed rules for his guidance, and there is frequently an ample field for the display of ingenuity and talent before he reaches the level ground beneath; in truth to pilot his instrument through the Canara forests, calls for the involuntary application of not a few principles of the inductive philosophy.

For such work, in such a country, it may be imagined the common Spirit Level is eminently unsuited. Weighty to carry, and cumbrous to set up in position, where the operator can barely find room to stand; and where

a clear prospect of even a dozen yards in front of him, is not to be obtained without felling the scrub which hinders advance and obstructs the views; its use has been wisely discarded in Malabar and Canara.

The instrument employed, is, what is known as the Gunner's Quadrant, or level for setting mortars at their proper angle, modified a little. The long bar is fitted with sights at either end, and has a universal joint screwed on at its centre.

The Quadrant* is reversed from the position it occupies in the mortar quadrant; having the arc turned inwards, and the radius outwards towards the tracer. An armature, bearing a small spirit level at its side, and a vernier to read minutes at one end, works on the Arc, which to enable the level to be used for tracing either up or down hill without reversion, has an excess arc of some 5° on the upper side of its zero point. Seeing that an angle of 3° corresponds to a slope of 1 in 20, an arc of 90° is considerably in excess of the angular accommodation necessary in tracing roads, and Messrs Elliott, Brothers, might with advantage curtail this over balancing appendage: they might also put the spirit level in permanent adjustment.

The tracing quadrant is fixed to a light stick, shod with iron, of a length sufficient to bring the pinhole of the sight within easy distance of the eye. The stick should not terminate in a point, or the levels will be vitiated. Its base ought to be about one and a half inches in diameter.

The forward staff is rather longer than the foregoing, but has a fixed vane, painted white, whose centre is exactly the same height from the ground as the pinhole of the quadrant sight. The centre is denoted by a dot in the middle of a black horizontal line.

Furnished with this simple instrumental equipment, and accompanied by an intelligent man to hold the staff, a goodly lot of pegs, and half a dozen active men with bill-hooks, the tracer begins his toils. Having set his arc, the staff holder is sent on 50 feet or so, along a path rapidly cleared by the woodsmen aforesaid, and moved by hand-waving till the cross hairs and vane spot coincide; he using one eye to catch the vane, and the other to observe the bubble simultaneously. Thus peg after peg is driven, and the trace proceeds with a rapidity proportional to the clearness of the ground, and the necessity for preliminary examination.

* I regret that the writer has not sent a drawing of the instrument above described. If he will favor me with it in time it shall be issued to Subscribers with the next Number.--[ED.]

It is a great advantage to have the pegs as close to one another as possible; for the more there are, the less risk is there of the true slope being lost when the excavation commences: a beginner is apt to put in too few rather than too many.

A party of fifty laborers follow on the heels of the tracer, to open out a bridle path a yard wide.

The pegs thus laid down are on the centre line of the future road, and when opening the guage path, the laborers are careful to stretch a strong line from peg to peg; by means of which the gradient is rigidly worked to. Before excavating; an upper row of temporary pegs, 3 feet higher up the hill side than the centre pegs, is inserted to denote the edge of the cutting in a like manner with the aid of string. If all these precautions are attended to, an even path upwards of a yard wide is speedily formed, and the slopes are preserved for ever. If nothing further is done to it, this path itself is often an immense accommodation to both men and animals; while it enables the Engineer to see his way much more clearly than if he had to grope through the jungle without so safe a guide. Any improvement in direction which suggests itself, is staked out after a thorough examination of the trace, and it is not seldom that the adoption of a deviation here and there is advisable.

A road, it has been mentioned before, through the hilly district of Canara, is more troublesome to trace than the incline of a Ghaut. This is due to the difficulty of determining by the eye alone, how particular features had best be dealt with, and it requires a great deal of care and practise to escape committing mistakes in the choice of gradients, and thereby losing both time and temper from being obliged to do work twice over. As a general rule, the saddles, over which the road must go, are first inspected; and it often happens that a small depth of cutting at the top will enable them to be crossed without exceeding the limit of 1 in 20; then the most suitable sites for bridges are roughly fixed; and after these observations are taken, the bridle path is levelled in to the best of the tracer's ability and judgment. On moderately flat ground, when it is certain all the slopes are within 1 in 20, the instrument need not be used, but the line is ranged as straight as possible, the ground to a sufficient width on either side is cleared, and the side ditches are staked out, and excavated at once, enclosing the full width of the road between them.

It has been customary in Canara to widen the 3-foot trace to a width

of 12 feet the first season, as doing so permits pack bullocks or even a single cart to pass along. The surface of the road inclines outwards slightly, to let the water run off, and no drain is allowed to be put on the inner side. There is, however, a check or intercepting channel, 18 inches broad and deep, cut some 30 feet above the road, discharging across it at convenient spots.

Experience has shown that a 12 feet road is little injured by the rains.

The objectionable expedient of giving the road surface an inward instead of an outward slope, is, by unskilled persons sometimes resorted to, a method that results in the road being soon cut up and becoming a mere water-course.

During the second season, the building of bridges and culverts used to be begun, and the road was widened to its full dimensions of 18 feet for a district, and 21 to 24 feet for a trunk road.

Everywhere, in side cutting, an inner drain was added to a road wider than 12 feet; but the transverse section of the road surface was as nearly horizontal as possible, half of the drainage falling outwards.

Before closing the article, it is only fair to state, that the Engineer must be prepared to encounter great and unlooked for difficulties, while tracing in this otherwise favored locality. From some hitherto unexplained cause, the whole of the North Canara district is eminently feverish, except at a few places on the sea coast. There is also a very sparse population, estimated at about 137 to the square mile; but as the bulk of the inhabitants congregate near the coast, there cannot be a third of that number actual denizens of the jungle. In consequence, much has to be got through with imported labor, easily scattered if fever comes among the gang.

Then, operations have to be well nigh suspended from June to September, on account of the monsoon; and during April and May, when most of the laborers seek their homes to prepare and sow their lands.

Altogether, although interruptions to progress are frequent and vexatious, and the Engineer is subject to privations and discouragement, he may reckon on being rewarded by seeing a district, between the greatest cotton field in India and the sea, and which contains such a harbour as that of Sedashaghur, rise steadily day by day into an importance, that was long ago augured for it by the few Madras officials and Engineers, who isolated in great measure from their fellows and from sympathy, were in a position to know and appreciate, the magnificence of its scenery, the value of its varied products, and the necessities of its trade.—(1865.)

No. LXXXV.

DESIGNS FOR BOMBAY POLICE COURTS.

BY CAPTAIN FULLER, R.E.

MEMORANDUM.

THE author's designs for the Fort and Mazagon* Police Courts were objected to by Government, as being too ornate for the purpose required, and because the accommodation was designed with the view to meet probable future requirements on the number of magistrates being increased, and it was decided that the buildings are to be designed to accommodate only the existing number of magistrates; and any increase in their number hereafter is to be specially provided for in other parts of the island. It is submitted that the ornateness or otherwise of a building should depend upon its locality, and not merely on the use for which it may be intended.

SPECIFICATION.

Foundations.—Basalt, rubble, and chunam.

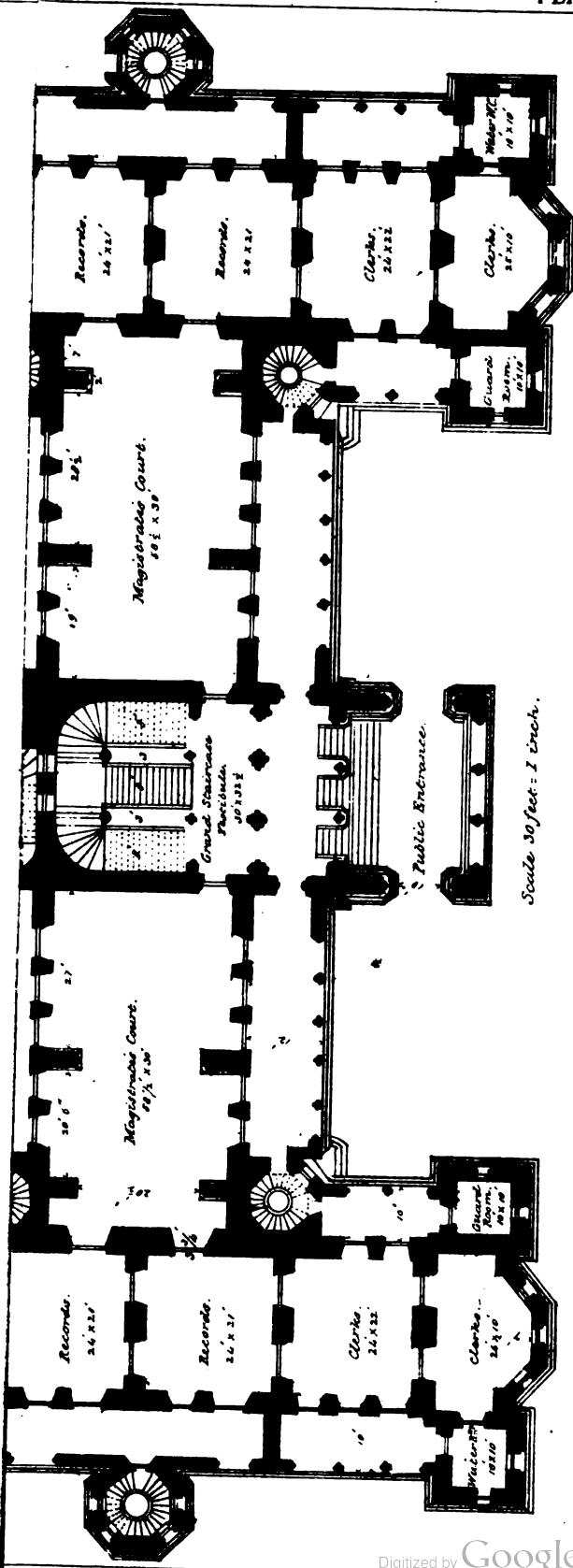
Plinth.—Basalt, rubble, and chunam, external face, with irregular breccia rubble (a light buff-colored basalt), finely pointed.

Walls.—Similar to the plinth, and faced in corridors on both sides with Breccia rubble.

Dressings, Casings, and Cornices; Columns, Bases, Capitals, Arches, Parapets, Gable, Copings, &c., of calcareous limestone, procured from Porebunder in Kattywar. The plinth coping or string, to be of cut breccia

* The design for the Mazagon Court being of a similar architectural character to that for the Fort Court, it has not been thought necessary to give both.—[ED.]

DESIGN FOR BOMBAY POLICE COURT.



Scale 30 feet = 1 inch.

instead of limestone, in open corridors, as such are subjected to great wear and tear.

Basement Floor.—Minton's floor, unglazed tiles, on (6 inches) bedding of rubble and chunam.

Upper Floors.—Minton's floor, unglazed tiles, over Fox and Barrett's iron flooring, filled with concrete and sound proof.

Ceiling.—Stuccoed with cornices under Fox and Barrett's floors.

Roof Sloping.—Galvanized corrugated iron over teak framing and tongurd, grooved and bended $\frac{3}{4}$ -inch planking. The iron to be pointed slate color, over two coats of red lead.

Roofs, Flat, over Corridors and Porches.—To be composed of 2-inch slabs of limestone over teak joists, 12 inches apart, with 2-inch concrete and polished Portland cement rendering.

Ridging.—Galvanized cast-iron with cresting in one casting, in lengths of about 3 feet, jointed, and of weight sufficient to tie on the ridges without screwing to the roof. Finials and bannerets of wrought-iron, painted maroon, and picked out with gilded points, &c.

Doors and Windows.—Teak, panelled or half panelled, and half glazed or Venetian, as required, according to the position in the building; sashes $1\frac{3}{4}$ inches thick and frames (5×4 inches). Venetian styles connected to battens by hinges to stop at a right angle.

Fanlights.—In Gothic tracery.

Ventilators.—Those in gables to be with fixed Venetians, with an half inch lead on upper and inner edge, to throw back water thus. Those in roofs to be double, with horizontal battens, as described on the exterior, and at about 9 inches, a second set of vertical (V) Venetians to be fixed; the corrugated iron extending to 6 inches behind the latter, when all rain that gets in will return by the corrugations, instead of coming into the building.



Piping.—All requisite roof pipes, water-closet pipes, and water supply pipes, to be laid on and fitted with all requisite fittings, such as hydrants, bib, and ball cocks, &c.

Plastering.—All rooms to be plastered internally, angles and borders being got up in Portland cement; no exterior walls, or those in corridors, to be plastered on any account (the latter are considered as external walls.)

GENERAL ABSTRACT.

c. ft.		RS.
1,31,768	Foundation and plinth, at annas 8·32 per foot, ...	68,519·36
4,69,805	Ground floor, at annas 7·1 per foot, ...	2,08,475·96
2,31,005	First floor of centre portion, at annas 7·1 per foot, ...	1,02,508·46
3,05,383	First floor of wings, at annas 7·27 per foot, ...	1,38,758·4
3,11,641	Second floor, centre portion, at 7·27 per foot, ...	1,41,601·88
14,49,602	Cubic feet, at annas 7·28 per foot deduced, ...	6,59,864·00

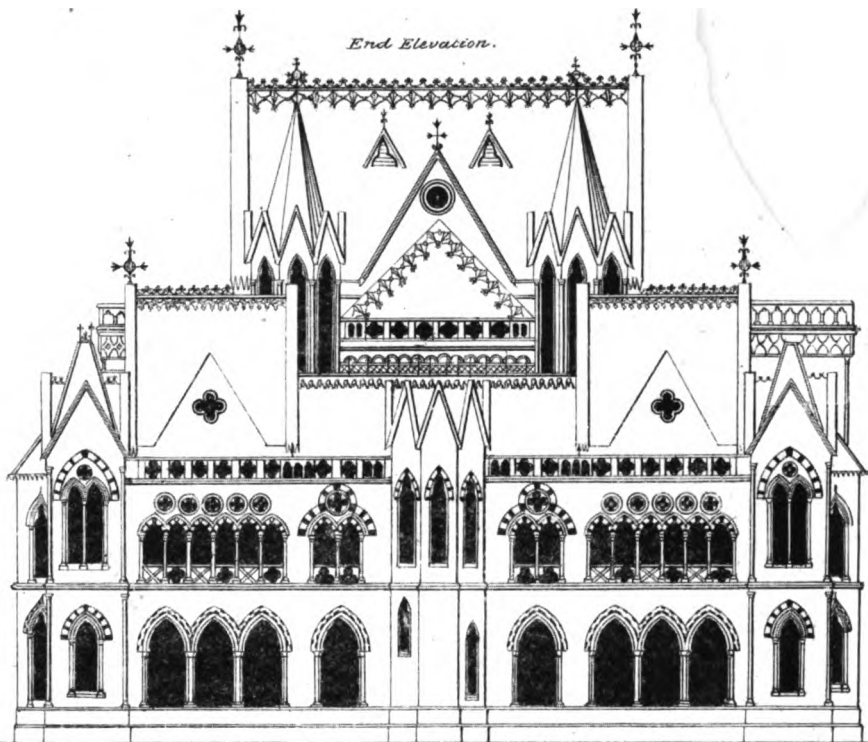
DETACHED BUILDING.

4,88,945	Cubic feet, detached building, at 6 annas per foot, ...	1,83,354·00
	Grand Total, Rupees, ...	8,43,218·00

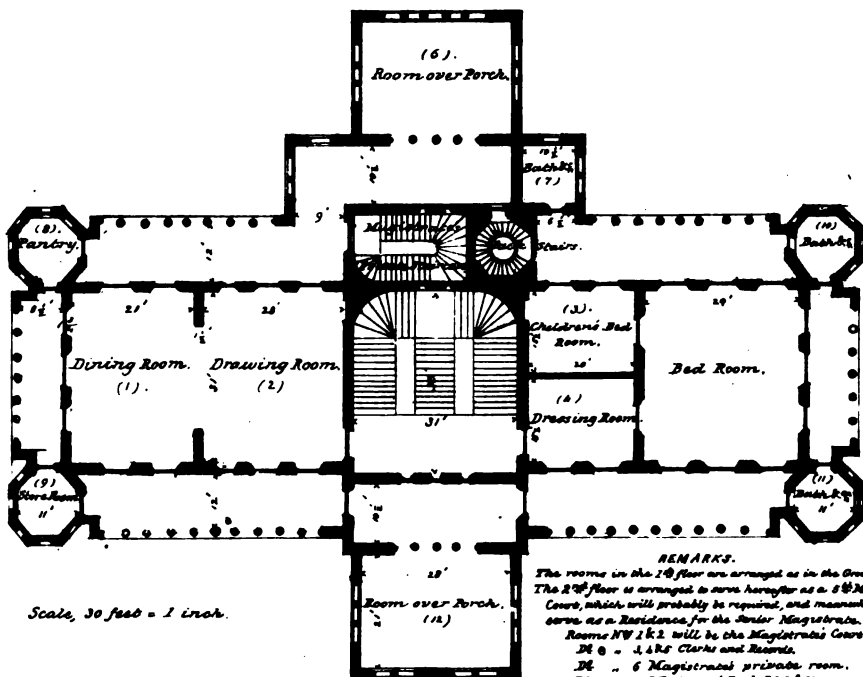
January 6th, 1865.

J. F.

DESIGN FOR BOMBAY POLICE COURT.



Plan of 2nd Floor..



No. LXXXVI.

THE SIND RAILWAY.

Description of the Line and Works of the Sind Railway. BY JOHN BRUNTON, M. Inst. C.E., F.G.S. *Abridged (by permission) from the Minutes of Proceedings of the Institution of Civil Engineers.*

So far back as the year 1842 Sir Charles Napier, the conqueror of Sind, acknowledged and publicly urged the vast importance of the valley of the Indus, as the route for military as well as for commercial communication with the Punjab and the North-West Provinces of India. He never ceased to press upon the Government the necessity of establishing new modes of conveyance, and pointed out Kurrachee, then but a small fishing town, as the port to which the traffic would infallibly tend. Acting on this conviction, and as a first step towards carrying out these enlightened views and improving the port of Kurrachee, Sir Charles Napier designed and commenced the long mole across the tidal marsh, which separates the town of Kurrachee from Keamaree. This mole still bears his name; and at the point to which it had been carried when he left Sind, and from which he embarked on that occasion, a small obelisk is erected recording these facts.

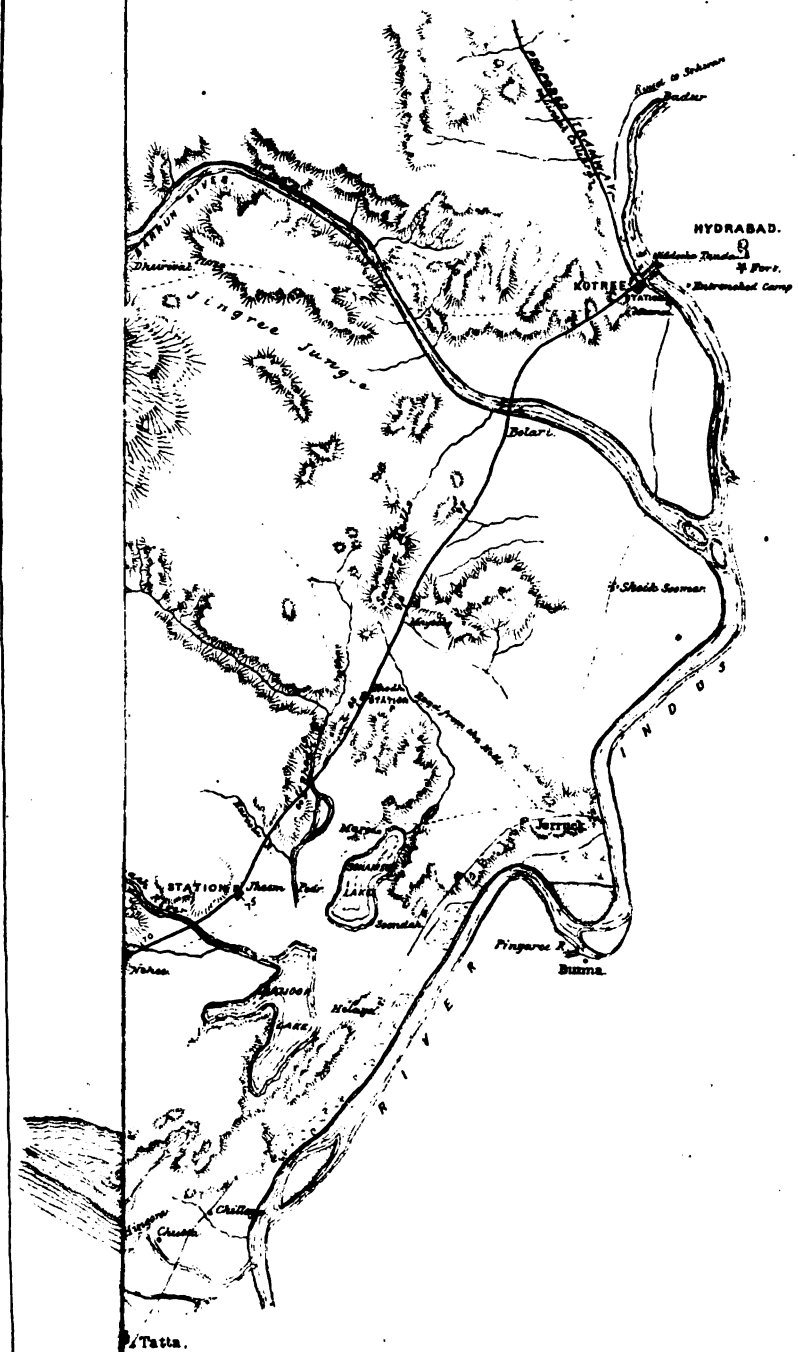
Nor has Sir Charles Napier been the only eminent man who has pointed out the natural advantages of the valley of the Indus, as the route of communication with the Punjab and the North-West Provinces of India. Amongst the many who have recorded their opinions on the subject may be mentioned Lord Dalhousie, Sir Henry Pottinger, Sir John Lawrence, Sir Justin Shiel, General Jacob, and Sir Bartle Frere.

In the year 1849 the Government recognised the necessity of introducing into India the improvements in communication which were offered by railways; and the two great lines,—the East Indian and the Great Indian Peninsula,—were inaugurated, with a view to open up the districts having the two great ports of India, Calcutta and Bombay, as the outlets for their produce. The success which attended the guarantee system, as affording facilities for raising the capital for Indian railways, was at once evident, and the importance of extending it to other districts was acknowledged.

Attention was immediately drawn to the Indus Valley route, having Kurrachee as its sea terminus; and a concession having been granted to Mr. W. P. Andrew in 1855, a company was formed, called the Sind Railway Company, but embracing under its management not only the Sind Railway proper, or the line from Kurrachee to Hyderabad upon the Indus, but the Punjab line, from Moultan to Lahore and Umritsir, and a flotilla of steam boats on the river, with a view to complete the through communication. Three distinct capitals were originally raised, under the following titles:—1, The Sind Railway; 2, The Indus Steam Flotilla; and 3, The Punjab Railway. The accounts of these sections are kept perfectly distinct, while economy and harmonious working are secured, by the concentration of the management in the hands of one board of directors. Another section of this great scheme has since been intrusted by Government to the Sind Railway Company. It is called the Delhi Railway, being an extension of the line from Umritsir to Delhi, where it will form a junction with the northern terminus of the East Indian Railway. The lengths of these sections are respectively:—Sind Railway, from Kurrachee to Kotree, on the Indus, 108 miles; Indus Steam Flotilla, Kotree to Moultan, 570;* Punjab Railway, Moultan to Lahore, 222, Lahore to Umritsir, 32 = 254; Delhi Railway, Umritsir to Delhi, 300. Total, 1,232 miles.

It is to the construction of the first section of the line, between Kurrachee and Kotree, that this paper is specially devoted. Although this section of the entire system is the shortest, it constitutes, as has been graphically observed, "the neck of the funnel." Over it must pass, not only the whole of the existing traffic, but as the other sections are com-

* This distance being measured upon the river is, on account of the windings, fully 100 miles more than the direct line by land.—J. B.



pleted, the developed commerce of this vast territory, hitherto locked up, will pour in upon it, taxing its capabilities as a means of communication, and, doubtless, realising the sanguine anticipations of its promoters.

Kurrachee, the western terminus of the railway, is situate in lat. $24^{\circ} 47' 21''$ and long. $66^{\circ} 58' 15''$, and is not only the natural port of Sind, but also of the Punjab and of Central Asia. Like many other land-locked harbours, it has the disadvantage of a bar at its mouth; but, nevertheless, the depth of water upon the bar at ordinary tides is sufficient to admit ships drawing 17 feet to 18 feet, and at spring tides, ships drawing 21 feet have passed in with safety. When once within Manora Point the depth of water is much greater. The fast-increasing traffic of the port, and the large size generally of the vessels trading there, demanded that some measures should be taken to increase the depth of the water over the bar, thus rendering the entrance to the harbour available at all seasons; and that, by the erection of wharves and other appliances suggested by modern science, greater accommodation should be afforded. With this view her Majesty's Government, in 1856, applied to the late Mr. James Walker, F.R.S. (Past-President Inst. C.E.), for a Report upon the subject; and in 1858 he submitted plans, sections, and estimates for various suggested improvements. These recommendations were accepted by the Government, and immediate steps were taken for carrying them out. There is no doubt that when the works in progress are completed, Kurrachee harbour will take a high rank as a safe and commodious port.

The population of the town of Kurrachee is about 60,000, and is rapidly increasing. The principal articles of export consist of oil seeds, and grain of all sorts, wool, cotton, hides, indigo, munjeet, drugs and dyes, raw silk, fruit, and saltpetre. The import trade comprises cotton piece goods, woollen goods, malt liquors, railway materials, metals, wines and spirits, tea, coffee, timber, pipe staves and casks, regimental necessities, spices, fruit, oilman's stores, and wearing apparel. The value of the trade for 1862-63 was estimated at £5,000,000.

Within the last few years, a large number of European and native mercantile firms have established themselves in Kurrachee, and have erected extensive warehouses, in order to meet the rapidly increasing trade of the port. Her Majesty's Government has found it necessary to erect a new and more commodious Custom-house; and the harbour improvements

now in progress, include not only the deepening of the water on the bar, but greatly extended wharf and quay accommodation. The Sind Railway will communicate directly with these wharves and landing places, and a great improvement in the system of loading and discharging cargoes has already been introduced, and is daily making rapid strides.

Hitherto all commercial communication with the upper districts has been carried on by native boats on the Indus, or by *kafilahs* of camels. No roads worthy of the name exist. Until the opening of the Sind Railway these river boats were accustomed to stop at Khettie, a river station at one of the mouths of the Indus, and there discharge their cargoes into native sea-going craft, which conveyed the greater part to the port of Bombay, only a comparatively small portion reaching Kurrachee. The import trade had to struggle with the same impediments, increased by the slow progress made in "tracking" the boats up the Indus, against an average current of 3 or $3\frac{1}{2}$ miles, per hour, and a portage at Sukkur of $1\frac{1}{2}$ mile. During the prevalence of the south-west monsoon, lasting from May to September inclusive, even this wretched and dilatory system was suspended, paralysing commerce and creating an indescribable amount of expense, inconvenience, and irregularity. The formation of the Sind Railway, and the improvement of the port of Kurrachee, have met all these obstacles, and will open up a magnificent field for commercial enterprise, introducing civilisation, with all its attendant benefits, to a district inhabited by millions of human beings hitherto shut out from its influences.

On the 29th of April, 1858, the works of the Sind Railway were commenced by Sir Bartle Frere, K.C.B., then the highly-respected Commissioner of Sind, who wheeled the first barrow-load of earth into an embankment in the neighbourhood of Kurrachee. The contract for the execution of the whole of the works was originally let to Messrs. James and Edwin Bray; but in June, 1859, the line was taken over by the Company, and the works then remaining to be completed were executed departmentally by the Engineers, Inspectors, and other officers of the Company. Without entering into a statement of the causes of Messrs. Bray's relinquishing the works, it will suffice to say, that when the Company's Engineers took possession of them, they had to encounter difficulties which were not due entirely to the peculiarities of the country. There was a great dearth of the ordinary railway plant: irregularity in the payment of the native laborers of all classes had driven many away, and

had caused an unnatural and serious rise in the rate of wages. To meet this position of affairs, and to secure the economical execution of the works, a fair tariff of wages, at a reduction of fully 25 per cent. upon those which were paid by Messrs. Bray, was published by the Company's Engineers, and daily payments were guaranteed. This had the effect of drawing a considerable number of laborers to the undertaking.

The Province of Sind contains but a sparse population, which is principally located on the low-lying alluvial land on the banks of the river, where the rich earth yields ample returns with a minimum amount of labor. The Sindee, born and bred on these plains, is naturally indolent and devoid of muscular power; at the same time he is not deficient in talent, easily acquiring a knowledge of account-keeping and writing. The natives of the neighbouring state of Cutch are a much superior race. Cutch sends carpenters, masons, smiths, and skilled handicraftsmen to the whole of the northern portion of the Bombay Presidency; and from thence came a large majority of the skilled workmen employed on the Sind Railway. From the hill tribes of Beloochistan and Afghanistan were obtained a hardy race of laborers; men of great stature and personal strength, but wholly ignorant of the use of other tools than the *phowrah*, (a large kind of hoe,) and a basket in which to carry the loosened earth. Half-wild and unaccustomed to the restraints of a more civilized state, these men required much tact, and at the same time a strong arm, to keep them in order. To secure and maintain discipline amongst such a body of men, it was found advisable to organise a regular railway police force, consisting of about 80 men. Police stations were erected at intervals along the line. To facilitate the administration of justice the Government appointed a special magistrate, whose duty it was to move up and down the line, and to hear any cases which might be brought before him. To these wise precautions may be attributed the fact, that few outrages of a serious character occurred, the majority of cases being petty thefts and attempts at imposition. This facility for obtaining justice, and the rapidity with which punishment followed crime, were highly appreciated both by the Europeans and the natives.

In districts like Sind, where the population is scanty, and it becomes necessary to depend upon distant provinces for the supply of labor, it is obviously wise policy to offer every inducement, not only to secure, but to maintain such a supply. A higher rate of wages than ordinary may, in

the first instance, draw together large bodies of men, but other arrangements are absolutely essential for establishing contentment and permanence. Hardy as these Beloochees and hill tribes were, and unaccustomed to anything approaching luxury, they appreciated highly such attentions to their feeding, shelter, and health, as policy no less than humanity suggested. When it is borne in mind, that the course of the line of railway lay at a considerable distance from existing towns, or villages, only passing through the small village of Jemedar-ke-Landi, and leaving the important towns of Tatta and Jerruck at distances of 10 miles and 17 miles respectively,—it will be seen, that a difficulty arose in obtaining food for the large masses of men congregated at the various heavy portions of the works. This was met by the Company licensing a number of *buniahs*, or native provision merchants, to establish themselves at various points along the line; their scales of charges being regulated by a *nerrick*, or list of prices, settled by the nearest *kardhar*, under the orders of the railway magistrate. To supply the workmen with wholesome water for drinking was equally imperative. When this precaution was not observed, the men were under the necessity of using such water as was most easily accessible, and as it was generally of very bad quality, the results were cholera and fever of a bad type. A regular system of water carts and bullocks was first organised, and as the railway progressed, water trains were dispatched from the Mulleer, the Indus, and the Bahrūn, to meet the daily requirements of the men. It was remarked, that a supply of wholesome water was always followed by the disappearance of the diseases above-mentioned, and more particularly of fever. To protect the men from another source of fever, mat huts were erected, which sheltered them from the heavy dews, and rendered them more comfortable and contented. To afford medical aid in cases of sickness, or of accident, permanent hospitals were erected at Kurrachee and Kotree, under the charge of the civil surgeons of these stations; and in addition, two temporary hospital buildings were erected at Joong Shaie and Doraji Gore, under the charge of a resident apothecary. These arrangements were very successful in preserving the health of the employés of the Company, both European and native, and in cases of accident, they were doubtless the means of preserving many lives.

The natives work in gangs, under a self-elected *muccadam*, or ganger, whose orders they cheerfully obey, and to whom each man pays a stipula-

ted small per-centage from each rupee earned by him. It is through the the muccadam, that all agreements are made for works, and it is he who receives the amount of the earnings for division. There exist also, in Sind and in the neighbouring States, native landholders who by inheritance, are chiefs of large districts of country, and are recognised by Government as possessing a sort of feudal right therein. They are heads of clans, and as there is no longer any necessity for summoning their vassals for defence, or for other less lawful objects, they find it their interest to use their power for the purpose of supplying laborers to any large public work, receiving a small remuneration in the shape of head money. In the year 1856, while acting as Commissioner in Sind, during the temporary absence of Sir B. Frere, General Jacob, recognising the demoralising influences which attended the system of compulsory labor, proclaimed all labor in Sind to be free. This edict is highly prized, though sometimes taken advantage of and abused, by the laboring classes.

The departmental execution of the work gave the Engineers and other officers engaged, favorable opportunities of becoming acquainted with the capabilities of the various classes of natives, as well as of ascertaining the cost of each description of work. When work of any kind was executed by day labor, it was found that its economical execution entirely depended upon the energy and honesty of the muccadam, or native overseer; but these good qualities were so rare, that it became necessary to resort to the piece-work system. It was with some difficulty that this was established as a rule; but by degrees opposition was overcome, and the earthwork, masonry, and ballasting, were let to small gangs, with considerable advantage to the Company, while the laborer himself, excited to more vigorous and diligent exertion, earned higher wages than by the day-work system.

The following are the average prices paid for earth and rockwork along the line:—

Alluvial earth excavated from side trenches and placed in embankment, the average distance of conveying it being 22 yards,	} 10 annas per 100 cubic feet, or 4·09 pence per cubic yard.
Firmly set gravel, or soft shaly material,	} 12 annas per 100 feet, or 4·9 pence per cubic yard.
Rockwork requiring bars, but no powder for blasting,	} 1s. 9d. per cubic yard.

Hard rock requiring blasting,—the powder, drills, } and other tools being found by the Company, .	2s. 0d. per cubic yard.
Ballast, consisting of small stones, or gravel, } gathered in the neighbouring jungle, selected } and placed <i>in situ</i> ,	1s. 0d. " "
Ballast of broken stone,	1s. 10d. " "

The total quantities of the different classes of work executed upon the line, and the average cost of each kind, inclusive of the cost of the provisional staff of superintendents, but exclusive of that of the permanent Engineering staff, are given in the following Table:—

Description of Work.	Quantity.	Average Cost.		
EARTHWORK.		£	s.	d.
Embankments, cubic yds.	1,881,916	0	0	11½
Cuttings (a large portion consisting of rock } of different degrees of hardness, }	482,705	0	1	6½
Diversion of roads and streams, "	212,532	0	0	8½
Ballasting, "	408,596	0	1	6
Pitching slopes, sup. " yds.	1,745	0	2	0
PERMANENT WAY.				
Leading and laying, lineal yds.	193,600	0	6	0
FENCE WALLING, "	338,700	0	3	0
MASONRY.				
Concrete, cubic yds.	10,756	0	4	6
Dry rubble, "	2,526	0	3	0
Common ditto, "	17,434	0	12	0
Coursed ditto, with rubble backing, "	352	0	15	0
Coursed ditto, "	32,550	1	0	0
Block in course, "	15,192	1	11	6
Ashlar, cubic feet.	87,806	0	1	7½

The geological character of the district traversed by the Sind Railway demands a few remarks. The aspect of the country generally is barren in the extreme, but in some places there is sufficient soil to repay cultivation. Situated in what is termed the rainless zone, the average quantity of rain is very small, not amounting to 5 inches annually. Except during the rainy season, the river beds are dry, but in them water can generally be obtained, by sinking to depths varying from 5 feet to 30 feet. All the water procured from these wells, is, however, more or less saline.

In the neighbourhood of Kurrachee, the principal features of the country are low hills, varying from 150 feet to 200 feet in height, and

consisting of a coarse-grained arenaceous rock, of a dirty yellow color, abounding with fossils. Most of these hills are capped with conglomerate, more or less disintegrated on the surface, the pebbles composing it being water-worn, and the majority derived from the nummulitic limestone of the Halla range of hills, which extend from Cape Monze, in a north-easterly direction, to the west of Mithun-Kote on the Indus. All the hills lying north of the Indus to the foot of the Halla range, of which they are spurs, exhibit the effect of considerable volcanic disturbance, and the drainage of the country passes through the fissures thus formed. One of the most remarkable of these is at Dhurwat, where, during the rains, the water of the Bahrūn occasionally rises 70 feet, rushing through the pass with overwhelming force. The Kheytriani hills are composed of pale arenaceous limestone, containing but few nummulitics. This rock is easily worked, and is an admirable building stone, hardening with exposure. It was from quarries opened in this neighbourhood, that most of the stone was obtained for the masonry of the Central district of the line. Near the Rhodh river there are many small hills, of conical shape, composed of calcined clays of various colors, and also large collections of nodular masses of flint. In the aluminous clay beds, veins of foliated gypsum abound. In the plains lying between these hills the soil is alluvial, and in many places it is covered with boulders of nummulitic limestone and conglomerate.

The distance between Kurrachee and Kotree traversed by the Sind Railway is 108 miles 10 chains. Of this distance 32 miles 50 chains are level, and the remaining 75 miles 40 chains are on inclines more or less favorable, 1 in 200 being the ruling gradient.

The total length of straight line being 74 miles 22 chains, the length of the line on curves is, therefore, 33 miles 68 chains, the sharpest curve having a radius of 43 chains for a distance of 76 chains.

Considering the nature of the country traversed by the line, these may be considered favorable features, and place it in a good position for being worked at a moderate cost.

The earthworks generally are executed to accommodate a single line of railway; but all the bridges, culverts, and stone viaducts are constructed to carry a double line. In the cases of the wrought-iron viaducts, the stone piers are adapted to support girders for a double way, while those required for a single line alone are erected. The only portion of double

line yet made, is that between the workshops at Ghizree Junction and the terminus at the Bunder Head, a distance of 3 miles 15 chains. In order to accommodate the traffic coming to Kurrachee from the districts called the Eastern Delta of the Indus, during the south-west monsoon, a short branch, $3\frac{1}{2}$ miles in length, has been constructed, leaving the main line near the workshops, and terminating in an embankment and a timber pier at Ghizree, alongside which native boats discharge their cargoes.

The Permanent Way consists of the ordinary double-headed rail, weighing 65lbs. per yard, fixed by compressed wooden keys in chairs, each weighing 22lbs. The joints are fished in the usual way, the fish plates being secured by four bolts, each 1 inch in diameter. The whole is laid on transverse wooden sleepers, at intervals of 3 feet, except at the joints, where the sleepers are only 2 feet apart. The dimensions of the sleepers are:—length, 10 feet; breadth, 10 inches; depth, 5 inches. A large proportion of the sleepers is of red and white pine creosoted, sent from England. To complete the requisite quantity, a contract was entered into with a native merchant at Lahore, for the supply of sleepers of Deodar timber, (*Cedrus deodara*), which grows upon the slopes of the Himalayas, where it attains great size. Several logs sent down to Kotree for the use of the railway measured 5 feet in diameter at the butt, and a calculation of the taper upon the log gave a result of 150 feet as the height of the tree. The trees are felled, and cross-cut into convenient lengths, for rolling to the bottom of the ravines, on the banks of which they grow. The private mark of each proprietor is cut on every log he has felled. These logs remain at the bottom of the ravines until the rains, when they are carried by the torrents into the River Indus, where they are watched for, selected according to the marks, rafted and floated to their destination. This rough treatment wastes much of the timber; many of the logs are split, and the ends of all are damaged; while the shortness of the pieces, which vary from 20 feet to 33 feet in length, diminishes their value. Owing to the deficiency of rain in the season of 1859-60, only a small quantity of this timber could be got down. The native merchant thus failed to complete his contract; and a quantity of Australian blue and white Gum, and native red Eyne sleepers was, therefore purchased. These were objectionable, on account of their great weight, and the ease with which they were split by the driving of the spikes. The respective cost of each, when delivered in Kurrachee or Kotree, was:—

	Delivered in Kurrachee. s. d.	Delivered in Kotree. s. d.
Creosoted pine,	8 11	...
Anstralian blue gum,	8 0	...
Eyne, a native timber,	7 9	...
Deodar,	...	6 0

The value of the deodar timber is becoming rapidly recognised, and means will doubtless, be adopted for supplying it in longer lengths, and in greater quantities. When first cut it possesses a very strong scent, which it retains for some years; and to this probably may be attributed its immunity from the ravages of the white ant, which does not attack it until the timber has to a great extent lost this scent. To protect the deodar sleepers from these attacks, and before the Burnettising apparatus was received from England, they were steeped in a solution of sulphate of copper. This proved to be an unfailing specific; but it possesses this serious objection, that iron nails or spikes driven into timber thus prepared are rapidly destroyed by the action of the sulphuric acid. The result of the Author's experience, with reference to the important question of sleepers, is that pine sleepers, whether red or white, imported from England and creosoted, are liable to split and twist to a great extent, probably on account of the extreme dryness of the climate. They also become very brittle, the nature of the timber being destroyed. The creosoting process only penetrates a certain distance from the surface of the sleeper; and so long as the sleeper does not split, the creosote effectually protects it from the attacks of the ant, but immediately a part of the interior becomes exposed, the ant attacks it, and soon destroys the uncreosoted core of the sleeper. Hitherto, the necessity for replacing sleepers has mainly arisen from their giving way by splitting, rather than from any damage by the attacks of the white ant, or from ordinary decay. The excellent ballast on the Sind Railway, consisting chiefly of broken stone or clean gravel, assists in preserving the sleepers from the white ant.

The cost of creosoting sleepers in India varies with the description of timber submitted to the operation. In 1854 Mr. Turnbull, Chief Engineer of the East Indian Line, gave the following summary of the details of the cost supplied in a former portion of his Report: *—sâl, $6\frac{1}{2}d.$; teak, 1s.;

* Vide "Selections from the Records of the Madras Government. Report of the Railway Department for 1854," page 238.

soondri, 1s. 5½d.; and sissoo, 2s. 1½d. per sleeper. He further states, in the same Report, that one thousand sleepers of fir wood, prepared by Sir W. Burnett's process with chloride of zinc, were landed and stacked in Calcutta, where they remained for two years. On being examined at the end of this period, they were all found to be sound, and in as perfect a condition as when they were landed. This statement led the Author to recommend the adoption of Sir W. Burnett's process, and a complete apparatus was shipped from England. The vessel was, unfortunately, lost on the passage; and considerable delay occurred in replacing the apparatus, so that the majority of the deodar sleepers were submitted to the sulphate of copper process. The cost of the Burnettising process at Kotree is 5½d. per sleeper, which contrasts favorably with the cost of creosoting.

The forests of Sind consist chiefly of Babool, a species of acacia, of which there are two kinds, red and white, so named from the respective colors of the heart-wood. The former is by far the more valuable of the two, as it is extremely hard, and resists the attacks of the white ant. This timber is used by the natives for the manufacture of carts and Persian wheels; but as it is very crooked, it is not available for railway sleepers. A few pieces of timber were carefully selected, and accurately gauged to size, with a view of testing their comparative strengths, but the experiment was not carried out. When thoroughly seasoned, the following comparative Table of the weights of each kind was obtained:—

Red eyne,	56½ lbs. per cubic foot.
Jarrah (Australian mahogany),	52½ " " "
Common jungle teak,	84½ " " "
Moulmein teak,	83½ " " "
Deodar,	81½ " " "
Yellow pine,	24½ " " "

Neither eyne nor jarrah timber will float in sea water before it is thoroughly dried. Red eyne is obtained from the forests of Guzerat, and costs in log, delivered in Kurrachee, about 1s. 6d. per cubic foot. It is not, however, very plentiful. As a pile it drives remarkably well, hardly requiring either ringing or shoeing in ordinary ground. It is reported to be impervious to the attacks of the white ant; but of this the Author has no positive proof. The Moulmein, or Rangoon teak, judging from the quality of the best the Railway Company could procure, is inferior to

the southern, or Malabar teak, which, however, is scarce and expensive. The cost of Moulmein teak in log, delivered in Kurrachee, varies from £15 to £18 per load. The jarrah is a fine Australian timber, and is obtainable in logs of large scantling and length. If not well seasoned before being submitted to the dry climate of Sind, it cracks and rends seriously, but not so if it is allowed to season for twelve months before being shipped. Its cost in Kurrachee, is about 1s. 6d. per cubic foot. The deodar timber, the qualities of which have been before adverted to, costs at Kotree in log, about 1s. 1d. per cubic foot.

The majority of the Fencing used on the Sind Railway consists of a dry rubble-stone wall, having a coping of stones on edge, set in mortar. Its height is 4 feet above the surface of the ground. Its thickness at the bottom, just above the footings, is 1 foot 10½ inches, and at the top 15 inches. Its average cost was 3s. per lineal yard. Along 15 miles of the line, between Jemedar-ke-Landi and Guggur, five-strand wire fencing was adopted, on account of the distance of suitable stone, and the necessity for its rapid completion. Its cost was 2s. 4½d. per lineal yard. The cost of maintenance of the wire-fencing is high, compared with that of the stone wall.

At Kurrachee, the locomotive erecting and repairing shops are built, at the junction of the Ghizree branch with the main line. These works consist of a sawmill, smiths', fitters', heavy and light tool shops, iron and brass foundries, with engine and carriage-erecting shops, all furnished with the requisite machinery, and with tools driven by engine power. Previous to the establishment of these works, there existed no means, nearer than Bombay, for the execution of the necessary repairs, or the construction of the numerous articles required by a railway; and even Bombay offered but few facilities, and those involving great expense. Hence the necessity for pushing forward these works, which in the formation of the line, proved to be of great assistance in the manufacture of plant, &c. The organisation of these works, with a view to their ultimate utility, and at the same time, with a due regard to economy, formed an important consideration and was surrounded with many difficulties. To man these shops entirely with European workmen would involve an enormous cost; it became necessary, therefore, to call in native assistance, as far as practicable. The Cutch carpenters and smiths, as has been before remarked, are intelligent and excellent workmen; but they were wedded to the use of their own

rude tools, in their own fashion, involving great delay in turning out work. Their usual method is to carry on all operations while seated on the ground; and, in the case of the carpenters, to make almost as much use of their toes as of their fingers. It became, therefore, the duty of the English foreman to induce them, first of all, to stand to their work, and then, to teach them the use of European tools. This has been accomplished by degrees, and the result has been most satisfactory. The carriages now framed and erected at these shops, entirely by Cutch carpenters, display workmanship which would be a credit to the best European manufactory. It is found necessary still to employ two European smiths for heavy and important work.

To keep up a supply of European foremen, fitters, engine erecters, and engine drivers, the system of taking apprentices in the workshops has been adopted. The following liberal terms were offered:—

During 4 months' preliminary trial, per mensem,				.	4	rupees or 8s.
First year from date of indentures,	"	"	"	.	30	" £3
Second,	"	"	"	.	40	" 4
Third,	"	"	"	.	50	" 5
Fourth,	"	"	"	.	60	" 6
Fifth,	"	"	"	.	80	" 8

In India there are many intelligent lads, sons of European soldiers and of men employed in various departments of the Government service as clerks, &c., who are educated in the regimental and Government schools: these lads and their parents are very glad to avail themselves of the opening thus offered for learning a trade, and obtaining substantial employment. By this arrangement a staff of men, thoroughly acclimatised, is being educated in all branches of railway mechanism, and without doubt great advantages will, in a few years, accrue therefrom.

The Electric Telegraph, with two lines of wires, is laid along the Sind Railway. The wires are carried upon posts of deodar timber, fixed in cast-iron sockets. The block system of working the trains is adopted. Needle-speaking instruments are used for conveying the information required between the several stations and passing-places. On the Continent of Europe there exists but little difficulty in obtaining suitable and intelligent clerks for working the telegraph signals; but in India the case is widely different. There, for the sake of economy, the staff of telegraph clerks is formed and recruited from the class of half-castes and more intel-

ligent natives, very often lads of fourteen or fifteen years of age. It is true they have to pass a preliminary examination as to their capabilities in writing and reading English; but the Author's experience of men who have passed this examination is, that they are often deficient in the important point of understanding the messages they transmit or receive. This becomes a more serious matter when the signaller, a native, is trusting to the verbal instructions he receives from the telegraph clerk, who, in several instances on the Sind Line, holds the combined offices of telegraph clerk and station master, a system which, for many obvious reasons, is to be deprecated. Greater security would be obtained by the separation of the train-signalling machine from the conversing telegraph, and also by the introduction of permanent train-signals, which would speak to the eye, and could not be liable to misinterpretation. Native clerks are too apt to occupy the speaking-machine, and at the same time to amuse themselves with a conversation, to the exclusion or the delay of important messages.

In India train-signalling stations on which depend the proper and safe working of the trains, are often in isolated situations, and economy only allows the maintenance at each station of one signalling-clerk; who may often be taken ill with fever, or otherwise be rendered unable to perform his duties. The reduction of the train-signalling to as simple a system as possible, and the training of all policemen and inspectors in the use of the instrument for this purpose, would be attended with much benefit.

The line of the Sind Railway, as will be seen by the map, crosses the natural drainage of a great extent of country, thus rendering necessary a large provision for waterway. The rains in Scinde are very partial, and as there are no records of rainfall which throw much light upon the subject, and no existing bridges, a careful examination of the old flood marks was the only guide as to the requirements. Fixing the spans of the bridges at the large rivers and nullahs was comparatively easy. It was in crossing wide, flat plains, such as that at Pipri, that the question was surrounded with difficulties. This plain is nearly 5 miles wide. A certain number of culverts was originally built, and in addition, large catch-water drains were cut, with a view of conducting the rain water to the Guggur river, the natural and main drain of the valley. In 1861, when the rain was very heavy for about six hours in this locality, the drains were found in-

sufficient to carry off the water in the time, and the embankment of the railway, which ponded up the water, was soon breached in many places. To remedy this, it was considered a waste of money to erect more culverts; but the plan was adopted of lowering the line to the surface, laying it, in fact in a ditch 16 feet wide and 2 feet deep, just large enough to receive the ballast, and allowing the water to flow over the line. This plan was severely tested in the unusually heavy rains of 1862, when the water passed over the rails to the depth, in some places, of 9 inches, without either damaging the line, or stopping the traffic. In districts like Sind, where the rainfall is so partial, and of such short duration, but at the same time so heavy, it is submitted that this mode of crossing a large, flat plain is the safest and most economical.*

The scarcity of pure water fit for use in the locomotive engines, except at a few points, caused considerable trouble on the first opening of the line. The watering stations are nine in number. The salts, which the water obtained at these stations held in solution, differed materially, and the consequence was, that if an engine started for Kotree, and took in water at Jheem Peer, or Joong Shaie, priming occurred to a serious extent; but this was not the case if water was taken at the Bahrūn. As the water at these stations was considered fair drinking water, and as there was nothing in the taste to induce the suspicion that they might not be used indiscriminately for locomotive purposes, it would appear desirable, that a careful analysis of the water obtainable along a line of railway in India should be made at an early stage of the operations. The Author has arranged that the waters used and obtainable upon the Sind Railway should be analysed, and when combined with a report upon the effects produced in the locomotive engine by mixing them, some useful information will be obtained for guidance in parallel cases.

The haulage of materials constitutes an important item in the cost of the construction of railway works everywhere, and especially in India. The following facts will assist in forming calculations on this head. About 5,500 tons of permanent way materials were required at Loyach, one of the stations on the line, and were conveyed by native boats from Kurrachee to Soondah, a point upon the river Indus where there was a convenient landing place. It was necessary to form a road for carts between Loyach

* The same system has, I believe, been adopted on the Umballa and Kalka road.—[ED.]

and Soondah, through the jungle, a distance of $12\frac{1}{2}$ miles, and the following were the details of the cost of the whole proceeding:—

Freight from Kurrachee to Soondah by native craft, including cost of loading and discharging cargo, 8s. 6d. per ton.
 Loading and unloading the native carts, 0s. 6d. "
 Haulage $12\frac{1}{2}$ miles, at 1s. per ton per mile, 12s. 6d. "
 The cost of forming and maintaining the road for twelve months was £323 13s. 6d., equal on the above-mentioned quantity of materials to, 1s. 2½d. "

The following is a list of the different sized culverts erected on the line, distinguishing the number of culverts, and the number of openings of each size:—

Number.	Size of Opening.	Number of Openings.
46	2 feet 6 inches,	191
2	8 "	2
2	6 "	2
113	8 feet 6 inches,	329
5	10 "	9
18	12 "	53
2	15 "	2

The line of rails was carried over the openings of 2 feet 6 inches, by placing ordinary sleepers upon stone piers, the rail itself bridging the opening. Though this appears to be an economical mode of obtaining waterway through low embankments, it was found that the vibration of the line was communicated to the piers, which, though very carefully built, thus required frequent repairs, and in some cases cramping. Whenever the height of the embankment would admit of it, and to secure the largest amount of waterway, openings of 8 feet 6 inches were extensively introduced. In such cases the ordinary permanent way was carried upon teak timber beams, 12 inches square in section, supporting a platform of planks 4 inches thick below the sleepers, to carry a thin layer of ballast, protecting the platform from fire, and forming a footway across the openings. The timber in these culverts was carefully paid over with dammer, or pitch, laid on very hot. This process protects the timber from the attacks of white ants, but it is objectionable on account of the inflammable character of the material. The other culverts in the list were built of stone, with pitched invert and aprons.

The bridges along the line are of the following number and general dimensions :—

19 bridges, containing 48 arches, each of 20 feet span.

1	"	"	8	"	"	80	"
2	"	"	10	"	"	40	"
2	"	"	4	"	"	45	"

The large stone viaduct across the Bahrun river is 1,728 feet in length. Its greatest height, measuring from the bed of the river to the rails, is 31 feet 6 inches, and its average height is 25 feet 6 inches. The superficial measurement of the bridged area is 44,064 square feet. It consists of thirty-two arches, each 45 feet span, and having a rise of 10 feet 6 inches. This was the heaviest piece of masonry upon the line, and the time required for its completion was the measure of that for the opening for public traffic. The quantities of the different classes of work in this viaduct, and the average cost of each kind are as follows :—

	Quantity.	Cost.
Excavation of foundations, .	20,518 cubic yards	s. d. 0 9½ per cubic yd.
Concrete,	6,814 "	4 0½ "
Common rubble,	4,455 "	11 9½ "
Coursed rubble,	7,233 "	20 0½ "
Block in course,	5,244 "	31 6 "
Ashlar,	29,000 cubic feet	1 8 per cubic foot.
Broken stone for backing and filling in between the spandrels, .	2,650 cubic yards.	
Ballast,	3,780 "	

The total cost of this viaduct was £27,185 12s. 10d. The cost per lineal foot of viaduct was £15 14s. 7d., and per square foot of bridged area 12s. 4d. The viaduct was commenced on the 5th of March, 1859, and a locomotive engine ran over it on the 26th of January, 1861. The work was thus completed in twenty-two months and a half.

There are six viaducts with iron girders. The girders sent out from England were on Warren's principle, of 80 feet clear span. These were erected at the following rivers :—

The Mulleer,	21 spans.
" Guggur,	8 "
" Dorbagi,	2 "
" Runnpittiani,	6 "
" Loyach,	8 "
" Rhodh,	3 "
Total,	43 "

With regard to the Mulleer Viaduct, the most extensive of this class, the Author would merely observe, that the foundations and general construction were of an interesting character, on which he abstains from enlarging as he finds that Mr. J. E. Hartley, (M. Inst. C. E.,) who was the Resident Engineer during its construction, is engaged in writing a special Paper upon it. From the experience acquired by the Author from these examples of Warren's girders, he is compelled to report unfavorably of them, when contrasted with plate girders. There is an amount of vibration, both laterally and vertically, caused by passing trains, which had the effect of breaking, or of loosening the bolts fixing the longitudinal timber stringers to the cross girders. To such an extent did this occur, that it was found necessary to appoint one, two, or three native workmen at each viaduct, according to its length, whose duty it was to inspect and repair these breakages, or loosenings, after the passage of each train. The cost of this was so serious, that it was found advisable to take up the original rails, and although it raised the line and interfered slightly with the gradients, to lay the ordinary permanent way upon transverse sleepers. This has had the effect of diminishing the evil, but not of removing it entirely. The arrangement of the timber platform over these viaducts the Author considers highly objectionable, inasmuch as while loading the bridges, it adds nothing to the lateral stiffness, nor does it distribute the load over the whole area, as might have been the case. It is submitted that two layers of planking, each $3\frac{1}{2}$ inches thick, laid diagonally, and crossed, upon which the ordinary permanent way could have been laid, would have been a better arrangement,—stiffening the bridge laterally, and distributing the load more uniformly. The sliding blocks upon which each girder is laid, for the purpose of meeting the effects of contraction and expansion caused by changes of temperature, were not found to work well. In several cases the large ashlar stones upon which the bed plates were fixed, were drawn out of their places, before the blocks would slide. It is considered that the roller system, as originally specified, would have been a better arrangement. The impossibility of getting at all the surfaces, of the ironwork, to scrape and repaint them, is likewise a serious objection; for while there is no great amount of rain annually in Sind, there are heavy dews for months together, which cause a rapid oxidisation of unprotected wrought-iron. The large viaduct across the Chinnee Creek, of ten spans, each of 100 feet, for a double line, has not yet been erected, but the

iron work is already complete, and delivered at Kurrachee. The girders are of plate iron, of elliptic form in elevation.

The majority of the works of the Sind Railway were executed departmentally, as it is termed, or by the Company's own staff, without the intervention of a large Contractor. This mode of carrying on the works was forced upon the Company by the peculiar exigencies of the case. The merits of the rival systems have frequently been the subject of discussion, but the experience of the Author leads him to the conclusion, that for the execution of large works in India, under Government guarantee, the employment of a substantial Contractor is the best mode. The departmental system allows of an amount of Government interference in every petty detail which cannot exist under the contract system. As long as the works are pushed forward in accordance with the terms of the agreement with the Company, the Contractor is untrammelled, and he can act on his own discretion in the mode of carrying on his operations, without being involved in the interminable correspondence and delays which are inevitable under the departmental system.

APPENDIX.

BAHRUN VIADUCT.

COST OF EXCAVATING FOUNDATIONS, IN LOOSE SAND, DEPTHS AVERAGING
20 FEET.

Those parts which were let by contract, cost from 12 annas to 1 rupee 4 annas per 100 cubic feet, or per cubic yard 4-36 annas. Those done by day work, (after keeping a strict account for many months,) were found to cost:—

	A.	R.	A.
One muccadum,	at 6	0	6
Nine coolies,	at 4	2	4
		<u>Rs.</u>	<u>2 10</u>

For this sum 8½ cubic yards were excavated, thus costing:

	A.	R.	A.	P.
Per cubic yard,	5	14		
About an equal number were excavated, by the two modes, therefore add as above,	4	36		
		<u>9</u>	50	
which, divided by 2, gives as the average cost per cubic yard,		0	4	9
Add for tools,		0	0	5
			<u>0</u>	<u>5 2</u>
Average cost of excavation, } or 9½d. per cubic yard, . }				

COST OF CONCRETE.

Lime, per maund of 80 lbs.,			0	3	2
Sand, per 100 cubic feet,			0	12	0
Stone per 100 cubic feet :					
Quarrying,	R.	A.	P.		
Breaking,	1	0	0		
Hauling,	2	12	0		
			<u>4</u>	<u>12</u>	<u>0</u>
Water per 100 cubic feet,			1	4	8

For 100 Cubic Feet of Concrete.

	R.	A.	P.		R.	A.	P.
Lime 17 cubic feet, at	0	3	2	per maund,	0	14	2
Stone 33 "	4	12	0	per 100 cubic feet,	1	9	4
Sand 50 "	0	12	0	" "	0	6	0
Water,					1	4	8
Mixing and depositing in place,					2	12	0
Total,					6	14	2
Or per cubic yard,					1	14	0
Add for tools,					0	2	6
Total,					2	0	6

Or 4s. 0½d. per cubic yard.

Or 4s. 0½d. per cubic yard.

COST OF ASHLAR MASONRY, PER 100 CUBIC FEET.

Quarrying,	7	4	0	
Earthwork in baring quarry,	1	0	0	
Dressing,	30	0	0	
Water for men,	0	8	0	
Mistrie,	0	8	0	
Smith-work—labor,	1	8	0	
				40 7 0
Haulage,	3	0	0	
Setting,	12	0	0	
Water for mortar,	0	12	0	
Lime,	1	0	0	
Sand,	0	4	0	
Mistrie,	0	6	0	
Tools and contingencies,	4	11	0	
				23 1 0
Total,				Ra. 62 8 0

Or 1s. 8d. per cubic foot.

BLOCK IN COURSE, (ARCHES,) PER 100 CUBIC FEET.

Quarrying,		6	4	0
Dressing,		25	0	0
Earthwork in baring quarry,		2	0	0
Water for men,		0	11	0
Smith-work—labor,		0	10	0
Mistrie,		0	10	0
Haulage,		8	0	0
Setting,		11	8	0
Water for mortar,		0	14	0
Sand,		0	8	0
Lime,		1	8	0
Mistrie,		1	0	0
Tools, coal, templates, &c.,		4	3	0
Total,				

Or £1 11s. 6d. per cubic yard.

COURSED RUBBLE, PER 100 CUBIC FEET.

	R.	A.	P.	R.	A.	P.
Quarrying,	6	0	8			
Earthwork in baring quarry,	1	0	0			
Dressing,	12	8	0			
Water for men,	0	6	0			
Mistrie,	0	8	0			
Smith-work—labor,	0	8	0			
	<hr/>			20	14	8
Haulage,	2	4	0			
Setting,	10	8	0			
Water for mortar,	0	14	0			
Lime,	1	8	0			
Sand,	0	8	0			
Mistrie,	0	4	0			
	<hr/>			15	14	0
Total,				Rs. 36	12	8

Or £1 0s. 0½d. nearly, per cubic yard.

COMMON RUBBLE, PER 100 CUBIC FEET.

Quarrying,	3	6	0			
Smith-work—labor,	0	8	0			
Water for men,	0	6	0			
	<hr/>			4	4	0
Haulage,	2	2	0			
Setting,	10	0	0			
Lime,	1	12	0			
Sand,	0	8	0			
Mistrie,	0	8	0			
Water for mortar,	0	14	0			
Tools and contingencies,	1	10	6			
	<hr/>			17	6	6
Total,				Rs. 21	10	6

Or 11s. 9½d. per cubic yard.

CENTERING.

Deodar timber in one set of centres 1,910 cubic feet.

Iron in one set of centres 36 cwt.

Timber, 1,910 cubic feet, at Rs. 1,	1,910	0	0
Iron, 36 cwt., at Rs. 12,	432	0	0
Carpenters' work,	140	0	0
Smiths' work,	120	0	0
Nails, 112 lbs., at 3 annas,	21	0	0

Total for one centre, Rs. 2,623 0 0

Cost of the 12 sets was, therefore,	31,476	0	0
Fixing and removing in 32 arches,	1,920	0	0

Total, Rs. 33,396 0 0

The timber of these centres was cut to a scantling which made it available for sleepers on the completion of the arching, and it was valued at,

18,836 0 0

Further, the centres of the Bahrun Viaduct were made use of at the Koonce and Huroola Bridges, so that the apportionment of the total cost of centering is as follows :—

	R.	A.	P.
Bahrun Viaduct, 32 arches, . . . ,	13,386	10	8
Huroola Bridge, 3 "	1,255	0	0
Koonce Bridge, 1 "	418	5	4
Total,	Ra. 15,060	0	0

TOTAL COST OF THE BAHRUN VIADUCT.

Amount paid to Messrs. Bray for work performed, up to the period of taking over the contract,	40,412	0	0
Amount subsequently paid in the departmental execution of the works, exclusive of the higher classes of superintendence,	206,944	6	4
Amounts chargeable under the head of plant, including trolleys, crabs, chains, ropes, poles, scaffolding, &c.,	24,500	0	0
Total,	Ra. 271,856	6	4
Or in English money,	£27,185	12s.	10d.

COST OF MASONRY AT KURRACHEE.

The following is a statement of the prime cost of masonry in the neighbourhood of Kurrachee, exclusive of European superintendence and working plant :—

	ASHLAR.	R.	A.	P.
Two good men will prepare 8 cubic feet per day for 20 annas $\times$ 12½, or for 100 cubic feet,		15	10	0
Two good men will set in general work 20 cubic feet per day for 20 annas, making for 100 cubic feet,		6	4	0
To labor, including coolies', nowgunnies', smiths', and mistrie's pay,		15	4	0
Cost of contractor's part,	Ra. 37	2	0	
Add for quarrying stone, exclusive of powder, &c., for 100 cubic feet,		4	0	0
Ditto for delivery of stone, if 5 miles lead and supposing each cart to contain 7 cubic feet, at 12 annas per cart load, or for 100 cubic feet,		10	11	5
Ditto for lime delivered on the works,		2	12	0
Ditto for sand, " " "		1	4	0
Ditto for water, " " "		0	12	0
Total for 100 cubic feet,	Ra. 56	9	5	

£1 10s. 6½d. per yard,
Or about 1s. 4½d. per cubic foot.

BLOCK IN COURSE.

Two good men will prepare 12 cubic feet per day, at 10 annas per day for each man, making for 100 cubic feet,	10	6	8
Two good men will set in general work 20 cubic feet per day, at 10 annas eachman per day, or for 100 cubic feet,	6	4	0
To labor, including coolies', nowgunnies', smiths', bullocks', and mistrie's pay,	10	8	0
Cost of contractor's part,	Ra. 27	2	8

	R.	A.	P.
Brought forward,	27	2	8
Add for stone in quarry, exclusive of powder, &c., per 100 cubic feet, . .	4	0	0
Ditto for delivery of stone, if 5 miles lead, and supposing each cart to contain 7 cubic feet, at 12 annas per cart load, per 100 cubic feet, . .	10	11	5
Ditto for sand, per ditto,	1	8	0
Ditto for water, per ditto,	0	14	0
Ditto for lime delivered upon the work, per ditto,	3	0	0
Total for 100 cubic feet,	<u>Rs. 47</u>	<u>4</u>	<u>1</u>

Or £1 5s. 6½d. per yard.

COURSED RUBBLE.

Two good men will prepare 20 cubic feet per day, at 10 annas per day for each man, making for 100 cubic feet,	6	4	0
Two good men will set in general work 30 cubic feet per day, at 10 annas each man per day, making for 100 cubic feet,	4	2	8
To labor, including coolies', nowgunnies', smiths', bullocks', and mistries' pay,	10	8	0
Cost of contractor's part,	<u>Rs. 20</u>	<u>14</u>	<u>8</u>
Add for stone in quarry, exclusive of powder, &c., per 100 cubic feet, . .	3	8	0
Ditto for delivery of stone, if 5 miles lead, and supposing each cart to contain 7 cubic feet, at 12 annas per cart load, per 100 cubic feet, . .	10	11	5
Ditto for sand, per ditto,	1	8	0
Ditto for water, per ditto,	0	14	0
Ditto for lime delivered upon the work, per ditto,	2	12	0
Total for 100 cubic feet,	<u>Rs. 40</u>	<u>4</u>	<u>1</u>

Or £1 1s. 8½d. per yard.

A SUPERIOR CLASS OF RUBBLE.

Two good men will prepare and set 40 cubic feet per day, at 10 annas per day for each man, making for 100 cubic feet,	3	2	0
To labor, including coolies', nowgunnies', smiths', bullocks', and mistries' pay,	8	0	0
Cost of contractor's part,	<u>Rs. 11</u>	<u>2</u>	<u>0</u>
Add for stone in quarry, exclusive of powder, &c., per 100 cubic feet, . .	3	8	0
Ditto for delivery of stone, if 5 miles lead, and supposing each cart to contain 7 cubic feet, per 100 cubic feet,	10	11	5
Ditto for sand, per ditto,	1	10	0
Ditto for water, per ditto,	1	0	0
Ditto for lime delivered upon the work, per ditto,	3	0	0
Total for 100 cubic feet,	<u>Rs. 30</u>	<u>15</u>	<u>5</u>

Or 16s. 8d. per yard.

JOHN BRUNTON.

No. LXXXVII.

CUTTACK RIVER WORKS.

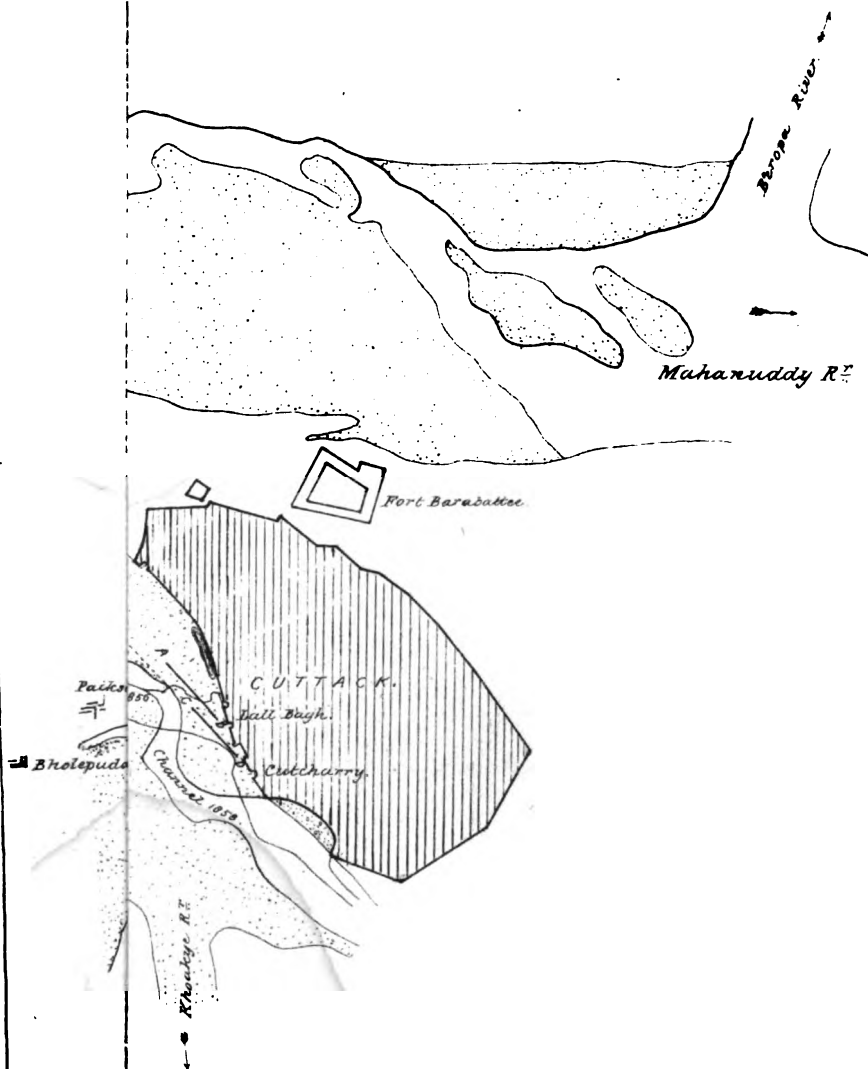
Report on the Mahanuddy and Katjooree River Floods and the works executed near Cuttack. BY CAPT. HARRIS, R.E., and MR. ARMSTRONG C.E. *Compiled from the Bengal Government Selections.* BY CAPT. F. D. BROWN, *Assist. Engineer.*

THE Mahanuddy river takes its rise near Bustar, in the province of Nagpore, and after passing the towns of Sumbhulpoor and Sonopore, and receiving near the latter mentioned place, the waters of the Tel Nuddy, enters the plains of Orissa Proper at Naraj.

For many miles above, and for nine below, the village of Tickreeporah, 83 miles above Naraj, the river's bed is rocky and irregular and channel narrow, floods rising to the extraordinary height of 60 feet above cold weather level. This channel then opens out to an average width of nearly two miles, a condition which it retains over a course of 46 miles above and 12 beyond Bydessur (28 miles above Naraj); it is then narrowed in its passage between the Rootrapoor and Domeparah hills, again expanded even to a greater extent than before; and lastly, contracted in width to less than half a mile, between the hills of Sydessur and Dawakote, whence, after a course of about 530 miles, it debouches upon the plains at Naraj, as above stated, where the Katjooree leaves the main channel, forming the head of a great delta, within which is situated the large city of Cuttack, about 50 miles distant from the sea.

Measured along the mid-channel, the distances from Naraj to the Mahanuddy and Katjooree sides of Cuttack (where the gauges, presently to be alluded to, were placed) are nine and six miles, respectively, the Mahanuddy

in the Rivers with



A.B. Position of Brushwood Spur of 1850.

C.D. d^o d^o of 1858.

E.C. Position of Brushwood Spur proposed for 1859.

Furl

LITH

falling into the sea, after a further course of 60 miles, in the vicinity of False Point Light House. Its total length therefore may be estimated at about 600 miles.

At the time of the founding of the city of Cuttack the state of this river and its branches was very different from that which now obtains.

The Mahanuddy ("maha," great; "nuddee," river) is represented to have been ever the great "par excellence;" next in succession ranked the Beropa nuddy, entitled also to the designation of a "river," and be it remarked, the only branch that was so. The Katjooree (from "khat," a log; "joor," a small nullah) is said to have been (but when, is not exactly known) an insignificant nullah, crossed by a single log of wood; and, to complete the list of the various branches of the Mahanuddy, the Khookye ("khoa," a crow; "khye," a hollow) is reported to have been a hollow in which the crows of the neighbourhood found a sufficiency of water to enable them to dip their beaks with advantage.

In February 1855, Lieutenant Short, Officiating Executive Engineer, Cuttack Circle, submitted a memorandum pointing out the yearly enlargement of the Katjooree at its head, and the proportional narrowing, by silting, of the headway of the Mahanuddy; the consequence being that, in flood, the quantity of water flowing into the Katjooree is greatly in excess of the capabilities of the channel to carry it off, thus, not only endangering the stability of the Cuttack revetment wall, on which the safety of the town depends, but also risking the great probability of the Katjooree leaving its bed and taking to the channel of the Khookye, which would inevitably flood the southern districts.

The extraordinary flood of 1855, which on the 29th July, rose to 27·35 feet above dry weather level, and by which the town of Cuttack, with its cantonment and Government offices, barely escaped entire destruction, necessitated immediate measures on the part of Government. The report of Lieutenant Harris, the Executive Engineer, immediately after this flood, thus describes Cuttack, and gives other useful data.

The Rajah Nirupa Kisseree first planted a city on the site of modern Cuttack, in A.D. 989. His reign was distinguished by the construction of a stone revetment, or embankment faced with that material. In A.D. 1174, the Rajah Aurang Bhim Deo, induced by some omen, built a magnificent palace on the site of Fort Barahittee, adjoining the town of Cuttack. The construction of the present castle of that name should,

in all probability be referred to this period, though a later date is generally assigned to it. The site of the town is low, one of the principal roads, being in parts 7 feet below the flood levels of the Mahanuddy and Katjooree, in 1855, and the town is protected from inundation by the revetment walls facing either river, connected at their ends by earthen embankments.

This revetment, constructed of large blocks of laterite and sandstone, set in mud cement, and pointed with plaster exteriorly, is raised from 17 to 36 feet above the low water line, the width at top and bottom being respectively from 3 to 4 and 5 to 8 feet. It is not known to have any foundation, other than such as it has formed for itself by settlements, either gradual, owing to the action of gravity upon the loose soil beneath it, reduced as it is, during floods to a semifluid state, or again bodily, in the form of breaches after the subsidence of the waters. It is not during the height, but after the fall of a flood, that breaches occur, owing to the difference of pressure in front and rear of the wall, caused by the fall of the flood before the backing has had time to dry.

From 12 miles below Bydessur to Naraj, the lateral limit of the Mahanuddy, though not continuously, is rigidly and clearly defined, by hills or rocks; thus the bar to any general change in the river's course between the points named is most complete.

At the head of the delta is found a sandy tract of nearly three miles in width, whence the Katjooree takes its departure. The right bank of this broad channel is comparatively low, of a light soil, offering little or no resistance to the action of the flood, whilst the left bank is generally of a higher level, or embanked, where not so, in many places; and, as in the upper portion of the river, defining permanently, by its rocky points, the limits to the lateral action of the flood. The fact should be here noticed of at least a third of a mile in breadth of the Katjooree's right bank having been carried away during the past 15 years between Naraj and Chargurreah. The soil at the latter village, for a short length and breadth, being of a very stiff clay, places a temporary restriction upon the encroachments of the river during floods.

According to the mean of a great many calculations of the discharge of the flood of the Mahanuddy made by Lieutenant Harris, it appears that on the 29th July, 1855, when the flood was at its highest, a volume of 18,00,000 cubic feet of water per second rolled into the delta, which was distributed in nearly the following proportions amongst its branches:—

Mahanuddy, 18,00,000. Velocity, 8' per sec.	Mahanuddy, 10,80,000. Velocity, 7'15 per sec.	Baropa, 1,84,000.
	Katjooree, 7,70,000. Velocity, 7'32 per sec.	Mahanuddy and Pyka, 8,96,000.
		Katjooree, 5,05,000.
		Khookye, 2,65,000.

The Mahanuddy running the more lengthened course of nine miles from Naraj to Cuttack, passed the gauge on a level of 121·13 of the division datum, its velocity and direction of current being perfectly harmless. On the other hand, the flood of the Katjooree having a course of only six miles, direct as the crow flies, from Naraj to the revetment, reached to 127·13 on the opposite or corresponding guage; i. e., 6 feet higher than the level of the Mahanuddy on the north side of the town. Its level, direction, and velocity of current, each produced a great amount of evil. tearing up the sandy bed at the toe of the revetment wall, and topping the wall itself, bursting the Kanugur bund below Cuttack, and throwing off a portion of its waters to deploy and mingle with those of the Mahanuddy in the rear attack upon the town.

State of the Embankments.—Besides the danger of the destruction of the town of Cuttack by floods, there are other evils, no less serious to the lives and property of the inhabitants of the district of Cuttack, caused by the floods, and which also have to be carefully examined before any attempt can be made towards interfering with the course of these rivers. Owing to the nature of delta rivers, the banks being on a higher level than the country beyond, when floods come down over-topping these banks, the whole district is inundated, destroying the crops, villages, and cattle of the inhabitants; the consequence is that for years the natives have been in the habit of confining the ordinary floods in their own channels by means of embankments, which, owing to their want of Engineering skill, have been very rudely laid out and constructed. Within the last 25 years, Government has taken these embankments in hand, and a report on the cause of the constantly occurring breaches was called for and submitted in August 1857, by Captain Short, Superintendent of Embankments, Lower Provinces, from which the following information is chiefly derived.

In 1804, Captain Rigny first took charge of the embankments, and repaired and strengthened them till 1845, when an order was issued prohibiting all but the repairs necessary to prevent actual breaches, while the question of abolition or retention of embankments was under discussion.

From this period to 1849, the embankments (no other orders having been issued) necessarily deteriorated and became useless. There is no doubt that, as the course of rivers changes, some embankments must become useless, whilst other new ones may be required, but this wholesale neglect of the existing bunds appears to have been deprecated by Capt. Short. Captain Beadle, Superintendent of Embankments, writes however, in June 1859, that though no doubt the bunds have deteriorated, yet with a knowledge of the fact that the great floods have an excess volume calculated at 900,000 cubic feet per second, above what the delta channels in the Pooree and Cuttack districts, embanked as they are, can contain and carry off to the sea, one can only feel it was a mercy that the embankments had not been continuously raised and strengthened up to the period of the great floods arriving. The catastrophe would only have been more disastrous, the floods would have risen higher, and the city of Cuttack must have been swept away by a flood from the Katjoree rushing into the lower level of the Mahanuddy. Practically, however, "during the last four years of great floods, a very small amount has been remitted from the revenue, and the year 1858-59 has been a year of abundant crops."

Owing to the orders of Government, prohibiting all but repairs necessary to prevent actual breaches, and of six officers having charge of the embankments during the four years from 1849-50 to 1852-53, Captain Short remarks, that they were in a state which baffles all description, the floods of 1852-53 having breached them in 1,167 localities and devastated the country; and that when he took charge of them he "found, during a careful inspection, that the head and neck of the embanking system had been destroyed, the trunk weak and insufficient, and that with corrupt and ill paid working darogahs, and with no supervising establishment, a heavy task had devolved upon him." The floods continuing each year; in 1853-54, there were 942 breaches, in 1854-55, 878 breaches. In 1855-56, the amount of Rs. 1,20,789 was expended on embankments, and accordingly in 1856-57, the number of breaches was reduced to 404. The height of the floods is increased by the direction of the wind, by spring tides, and by the Chilka or sea floods; the last rushing up the Bargovee, act as a complete barrier to the egress of even an ordinary flood, and with a flood similar to those of 1854 and 1855, the highest embankments are topped and enormous breaches occur, swamping the country.

Mr. Rayner, Officiating Executive Engineer, Pooree Embankments, in August 1857, reporting a flood on the Dyah (one of the outlets of the Katjooree), states that embankments 15 feet high were topped, and that at Neepoor, three breaches were made, one of which was 2,000 feet long. He says, "I can vouch for the very excellent manner in which this new line was completed. It was raised by layers and well consolidated throughout; it had a crest 10 feet broad with slopes 3 and 4 to 1, and was piled with strong stakes on either side; but even this was unable to withstand the combined force of a stoppage by the spring tides and a storm on the Chilka, and the effects of the floods of the Dyah and Gungird rivers.

But there are other causes at work tending to endanger the safety of such embankments wherever they exist. If the rains be not plentiful, the natives will cut through the bunds to let the water into the fields even at the risk of flooding them and ruining the country for miles around, and unless proper masonry sluices be provided, under efficient control, such a practice cannot be effectually checked. A practice is even systematised by the villagers, of inserting a hollow trunk of a tree in the embankments where they wish to obtain water, carefully concealed from the Executive Officers with earth and turfing, and the darogahs are paid to connive at the practice, while in case of discovery, some one villager, whose family is during his punishment and imprisonment supported by the rest, is voluntarily made the scape-goat. This is a common practice, and many such hidden sluices have been found by the Engineer Officer at places where it appeared to him strange that breaches were constantly occurring at the same spot. Indeed, it is not to be supposed that people so dependent upon the land for their living will stand upon any ceremony in obtaining a portion of the running stream; when the crops are being dried up for the want of water they prefer bribing the darogahs; and, rather than not get the water by cuts, they will go to jail. Unfortunately, however, for the landowners, the cut that has been opened to receive a moderate flood, is rendered an extensive breach by the sudden and unexpected increase of the volume of water, which inundates and destroys the tract of cultivation it was intended to fertilize.

It is the duration and not the height of these floods which destroys the crops. Thus of the three years, 1855-56 and 1857, though the flood of 1856 was the lowest, it was the most detrimental to the crops of the country, because of its greater duration, lasting 17 days, and thus rotting and ruining the rice plant, which is the principal crop, and quickly recovers if

only submerged for a short time. In the much higher flood of 1855, which nearly submerged the whole country, and before over-riding the embankments, caused many severe gaps in them, the revenue of Cuttack lost absolutely nothing by its occurrence, it having fallen as quickly as it rose, whereas the lengthened flood of 1856, entailed a remittance of revenue in the same district of Rs. 31,442.

Besides the great damage done by drowning the crops, large deposits of sand are left by the inundation waters, which at the high velocity in their channels is easily held in suspension, and as readily deposited as soon as the velocity is checked. Thus, near the village of Hunyank, on the left bank of the Polta, the flood of 1857 rushed through a breach 220 feet long and 20 feet deep with great velocity, and left a deposit of sand on the land which made it almost barren. There was a large tank in rear of the village, which it has entirely filled up with sand.

The height of the Cuttack floods depends much upon the state of the sea tides at the critical time, particularly in South Cuttack, where the Chilka lake, under the influence of gales from the eastward, exercises a considerable control over them. The bunds themselves contracting the waterway, tend also greatly to raise the flood level. Their duration depends more on the rain falls in the upper districts or drainage areas.

It is only within a late period that the district has been yearly devastated by inundations; it appears formerly to have been doomed rather to drought, as the following list shows, which gives the remissions of revenue made in various years:—

Year. *		Amount.
1884-85	Inundation. Revenue remitted,	1,94,363
1885-86	Not stated,	3,872
1886-87	Severe drought,	5,42,293
1887-88	Ditto,	10,184
1888-89	Not stated,	50,791
1889-90	Ditto,	7,64,222
1890-91	Want of water. Revenue remitted,	4,98,262
1891-92	Ditto,	
1892-93	Ditto,	10,858

No other Table showing the reasons for remission of revenue is given, but from a statement of remissions granted and expenditure incurred on

* The amounts remitted are taken from the Statement furnished by the Revenue Board, the cause of remittance from Report of Superintendent of Embankments, dated August, 1896.

embankments in the three districts of the Cuttack Division during the 23 years, from 1834-35 to 1856-57, the former furnished by the Board of Revenue, and the latter (only commencing in 1840) by the Embankment's Office, it appears that the

					RS.	A.	P.
Total revenue remitted was,	...	...	...	...	25,08,784	5	9½
Expended on embankments,	...	...	...	...	4,97,884	15	8½
Total loss of Government,	...	...	...	...	20,01,569	5	6½

Remedies applied.—There were thus two great questions to be determined—1, The safety of Cuttack; 2, The preservation of the delta and adjoining lands from the effects of floods.

With regard to the 2nd question, it is the opinion of most, if not all the officers who have had charge of these embankments, that (considering the natural circumstances of the district of Cuttack, the crops it chiefly produces being rice, which requires much water, but still that water should not be retained on them too long, nor rise to too great a depth), it would be advisable that the embankments should be entirely done away with rather than that ill constructed works should remain. But no further action appears to have been taken in this direction, with a view of improving the bund system or bringing it under thorough control.

With regard to the safety of the city it is evident from the above description, that the only effectual remedy for a state of things whereby the lives of 35,000 people are annually endangered, lies in effecting an alteration of the distribution of the Mahanuddy's waters in such a manner as to increase the path of current in the Katjooree between Naraj and Cuttack, diverting it the while from the revetment, and at the same time to decrease its volume. Captain Harris accordingly recommended the construction of a Masonry Weir at Naraj across the Katjooree, by which the quantity of water flowing down that river might be restricted and forced into the Mahanuddy; and a series of Brushwood Works near the city, to divert the stream from its direct course on to the revetment. By these means the Mahanuddy bed would be improved, by a gentle scour throughout the rains, and by the discharge in a single stream working during low floods, of a greater amount of silt than could be effected by the two working together; and, consequently, a diminished tendency in the bed of the main stream to rise, thus enabling it to receive during high floods

an extra volume of water. As a result of the brushwood operations, the entire silting up of the Katjooree's channel, running under the toe of the revetment wall was anticipated, and the opening of a less objectionable channel in the centre of the stream.

For these improvements an Estimate was sent in for a Weir 4,900 feet long, averaging 13 feet high, giving front and rear slopes 2 to 1 and 1 to 1, which, at Rs. 2-8-0 per 100 cubic feet, and allowing 50 per cent., for sinkage, amounted to Rs. 1,00,000. This, however, included Rs. 6,000 for brushwood operations.

Capt. Young, Chief Engineer of Bengal, proposed to throw weirs across both rivers, so as to regulate the supply passing down each and hereafter to lead off the water by irrigation channels above the weir, on the plan so successfully pursued in Madras. He then proceeds to say that, "although the object of the Madras works is irrigation, yet in the case of the Cauvery, we find there was another object intimately connected with it. On contrasting the physical conditions of the two branches (viz., the Cauvery and Coleroon) Lieut.-Col. Baird Smith writes, we find 'accordingly, on the one hand, a large volume, a more rapid slope, and a more direct channel than in the other. The natural result of such a combination, is the progressive deterioration of that branch which is less favorably circumstanced, by the formation of deposits at its head, and a consequent diversion of the great body of the main stream into the superior channel.' In that case success was obtained by building directly across the mouth of the Cauvery a similar dam to that which was originally built across the mouth of the Coleroon. These two dams then, it will be understood, were across the mouths of the two rivers which they separated from each other. I believe the results of experience in this case may be safely taken as some indication of what would be the consequence, were works such as are now projected (*i. e.*, the single weir), carried out in the Mahanuddy. The surplus water which causes so much anxiety by passing down the Katjooree would, I apprehend, after a lapse of time be found flowing down the Mahanuddy, and would cause equal anxiety and equally fatal results there; and there would be no remedy for this, until, as in the case of the Cauvery, another dam was thrown across the Madanuddy at its head, for the purpose of directly regulating its waters." He further proceeds to explain "that above the Madras anicuts is a large and quiet pool, from which the water is either drawn off for irrigation or runs to waste over the weir; whereas in the

present works (Naraj spur) owing to the main channel of the Mahanuddy being left open, there will be a scouring action along the foot of the dam. Also, the dry weather volume of the Mahanuddy being thus increased, and the left bank capable of erosion, the stream will probably enlarge its bed in that direction, and finally leave the Katjooree without any dry weather stream at all; it would either do this, or it would, by the scouring action alluded to, undermine and destroy the dam, and return to the Katjooree as before, in either case baffling the efforts to control it."

Capt. Harris' proposals were eventually sanctioned, and the result of the brushwood operations may be first detailed. These, as above stated, had for their object the protection of the Lalbagh revetment wall at Cuttack from the action of the Katjooree, which had several times breached it and had worked deep holes close to its base.

Brushwood Works.—In 1855, Capt. Harris commenced by throwing bundles of brushwood weighted with stones into the deep hollows under the Cuttack, revetment wall, "the result of which operation," he states, "was the silting up of the hollows to a large extent, and the raising of the bed of the river at sundry points. In 1856 a brushwood spur AB was constructed in the position shown in the plate, the result of which was a two-fold one. Further silting up of the hollows under the revetment wall took place, and the line of deep channel of the river was diverted from a course dead on the revetment wall to a very favorable one, parallel to it. The spur consisted of a double row of piles driven 3 feet apart from centre to centre, and a width of 3 feet between the rows. These piles averaged 15 feet long and 8 inches in diameter at the head. They were driven 7 feet into the sandy bed, and according as a length of two or three hundred feet was completed, the space between the rows was filled up for a height of 6 feet, with fascines of brushwood, firmly packed and trodden down. The top was then tightly bound down by coir ropes, crossed from pile to pile, and the whole was thus rendered very firm and secure. There was no attempt made to weigh down the fascines with stones, as it would have been too expensive, and the result proves that this was not required, for, when the water rose over the spur, none of the brushwood bundles showed any inclination to rise, float away, or resist being confined within the original space allotted to them.

The operations of 1857 were almost *nil*, on account of the absence of the Executive Engineer during the mutiny. In 1858 a second brushwood spur, CD, was constructed by Mr. Armstrong, C.E. It was 1,923 feet

long, and constructed similar to the one in 1856. This spur cost 5 annas per foot run; the one of 1856 cost 8 annas per foot; the difference is owing in part to the fact that the last built spur was erected during the dry weather, while that of 1856 was constructed in water. The great saving however was effected in the pile driving. The engine formerly used could only drive 24 piles per diem with 16 men; the light ringing engine used for the second spur required only 12 men, and drove on an average 50 piles. To assist the action of this spur, brushwood dams were run across the deep pools from a little above the cross section JJ, and from near the spur CD down to S, at various distances, from 100 to 200 feet apart, according to the depth of the water or the state of the revetment's foundation. These dams were formed of three or four fascines, in the centre were placed one or two stones, according to their size, and the fascines tied firmly round them with three coir ropes, one at each end and one in the middle; these bundles were about 5 feet long and 2 feet in diameter in the centre, and at the end 12 inches or so.

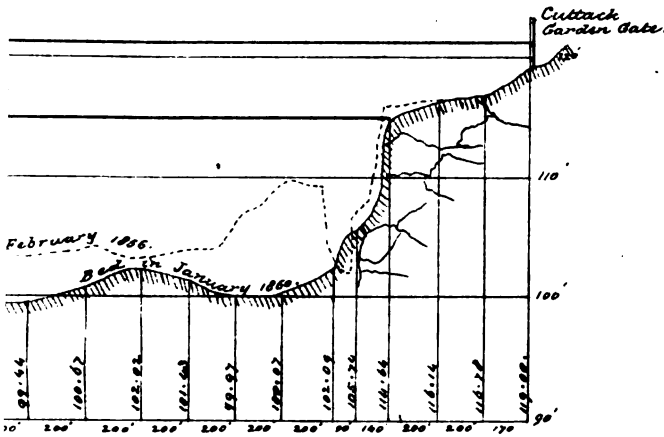
Naraj Spur.—In connection with these brushwood operations, in 1858 was commenced the rough stone Spur at Naraj, its objects, as before stated, being to lengthen the path of current of the Katjoores river between Naraj and Cuttack, to diminish the volume of flood in that river, and to improve the Mahanuddy's bed by a mild scour throughout the rainy season.

The following facts with regard to gauge measurements of rivers, first indicated to Capt. Harris the derangement of level in the two arms of the Mahanuddy.

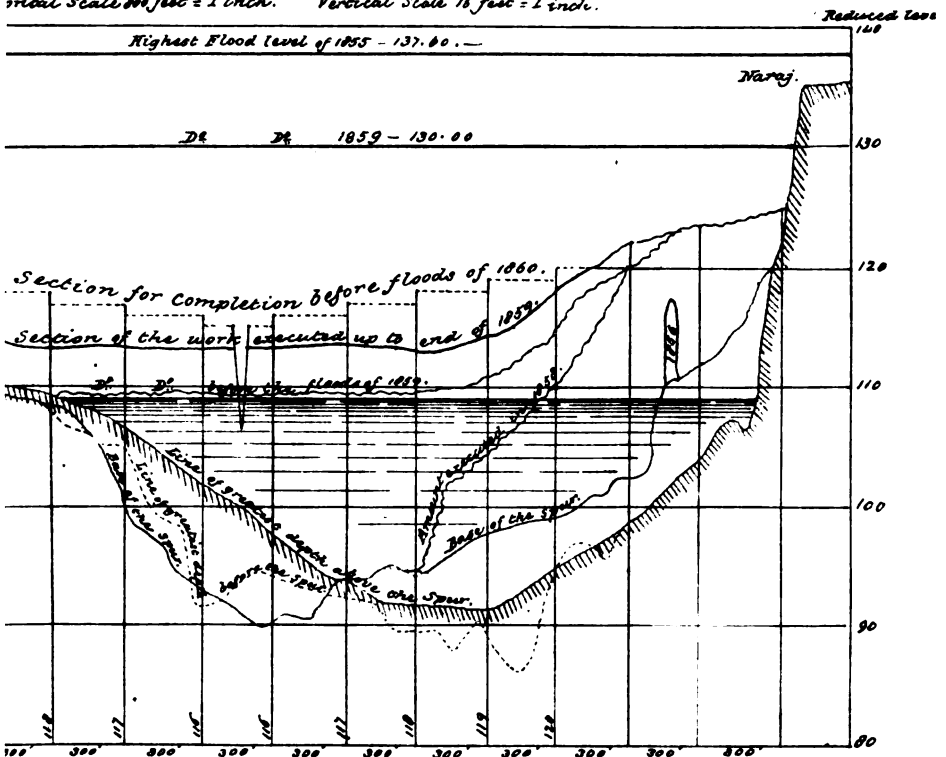
Supposing a gauge A, set up in a river, with a very regular and uniform channel, the level of low supply reading (say) 6 feet on the gauge; and again at some distance down-stream another gauge (B) set up, adjusted to the fall between A and B, so that the gauge measurements of the low supply of water should be identical; and supposing the rise and fall for low floods at these two gauges had been regular for a long time, when all at once the gauge measurements at B began to be lower than those at A; all other circumstances being the same, the conclusion necessarily would be that there was a deepening of the channel and a fall of bed between A and B. Again, supposing the gauge measurements to increase at B in excess of those at A; all other circumstances being equal, the conclusion would be that the channel between A and B was being silted up.

Now gauges having been established on this principle at the common

River's bed in Feb. 1856 & Jan. 1860.



Section of the Nanyj Spur, showing the progress made in its construction &c.
N.B. The last 600' of spur not shown. Total length = 4500'. -
Horizontal Scale 1000 feet = 1 inch. Vertical Scale 16 feet = 1 inch. Reduced.



Plan of Brushwood Spur.



head of both rivers, and at two opposite points in their respective channels, lower down (at Cuttack), a careful comparison of their readings enabled a judgment to be formed of the changes effected in the beds of the rivers by the action of their own streams, and by the operations employed to affect them.

The principles on which the Naraj spur was originally proposed to be constructed were these—1st, To place it judiciously in a position favorable to its own stability; 2nd, That the action should be such as, by annihilating the draught down the Katjooree, in the dry season, obstructing it very materially in low floods, and to a limited extent in high ones, would produce in the Mahanuddy a draught corresponding at all times to that existing in the Katjooree; an action in fact that would lead to the then actual conditions of the two arms of the parent river being completely reversed.

The Spur was originally commenced in 1856. As soon, however, as a few thousand feet of rough stone had been collected and placed in position, work was ordered to be suspended, and it was not till June 1858, that it can be said to have been practically put in hand. 750 running feet were completed before the floods of that year, and 675 more before the end of that year. Before the floods of 1859, the spur was raised to the height of the cold weather level, as far as the opposite bank of the Katjooree, a distance of 3,000 running feet; and two small pieces of rear apron, aggregating a length of 860 running feet, were also placed in position; they were run out to a distance of 100 feet from the centre line of the spur, and were made 4 feet thick. After the floods of 1859, the works previously done were strengthened, and the heightening of it proceeded so vigorously, that by the middle of November, the spur was carried right across the river, to above the water level, and a head of 2 feet of water was produced above the spur.

The revised estimate for the above work, at a cost of Rs. 50,000, was sanctioned in 1859. The general dimensions of the revised project were as follows :—Breadth of lip, 4 feet; front slope, 1 to 1; rear slope, 1 to 1; breadth of front apron equal to height of spur; breadth of rear apron equal to four times the height of spur; thickness of both aprons 4 feet; making a total of about 20,16,000 cubic feet, which, at Rs. 2-4 per 100 cubic feet, amounts to Rs. 49,680.

The amount of work done up to the end of 1859 was 15,88,936 cubic feet, at an average rate of Rs. 1-12-6 per 100 cubic feet; and Captain Harris stated that, he had every hope of being able to complete the work

to the section proposed, with the funds at his disposal, before the floods of 1860 set in. A small gap was to be left in the spur in order not to interfere unnecessarily with the traffic on the Katjooree.

The floods of 1859 rose—1st flood, 25th June, 13 inches; 2nd flood, 29th July, 14 inches; 3rd flood, 6th September, 8 inches, higher than the corresponding floods of 1855. That the third, and greatest flood of the year 1859, should only have risen 8 inches, whilst the lesser ones rose 13 and 14 inches above those of 1855, has been accounted for by finding, since the dry season has set in, that both the bed and water lines of the Mahanuddy have fallen 18 inches. That such change has been effected by the extra volume forced into the Mahanuddy there can be no doubt; and also that that extra volume was caused by the spur. It is expected that the spur moderating the velocity of the water passing down the Katjooree arm, will prevent that river deepening its bed near Cuttack and cause a silting action to set in at that place; the brushwood operations have already raised the bed 3 feet opposite the city; a very little more silting up is needed there, but at the head a more vigorous action is expected. The low floods will deposit sand between the spur and the point A (*see plate*), where a sand bank has already been thrown up, and thus add to the stability of the work. They will cut away and enlarge the head of the Mahanuddy at C, thereby relieving the pressure on the spur. And a large flood will, without doubt, add to the length of the sand bank between the points A and D, and help to close the head of the Katjooree river; it will also heap up sand at D and E.

In July 1860, Captain Harris reported that, on the 20th of that month, the head of water produced by the action of the Naraj spur was 4.76 feet. The danger to the work being proportional to the head of water caused by it, its stability was considered to have undergone a most ample test, having been acted on for 27 days by various heads from the maximum to $1\frac{1}{2}$ feet. As to its practical utility, a work which can produce such heads of water cannot fail of accomplishing its object of clearing out the Mahanuddy.

[As no further Reports have been received of dangerous inundations at Cuttack, and but a cursory notice has been taken of them in the Annual Reports, it may be presumed that the works above described have been successful in their main object—the protection of the city from floods.—(Ed.)]

No. LXXXVIII.

IRON TIE-BARS FOR ROOFS.

On the proper dimensions of Iron Tie-Bars for Circular Brick Arched Roofs.

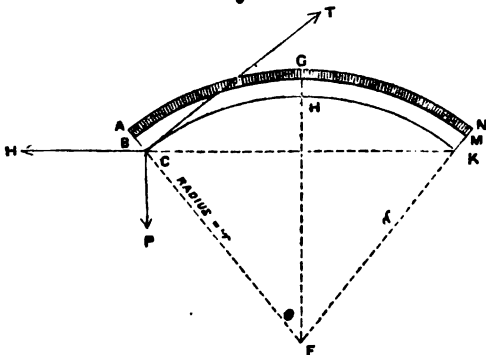
To the Editor.

DEAR SIR,—Having had occasion to estimate and design some Vaulted Roofs of late, I send the calculations on which I based my design, as they may be useful to some of your readers of the "Professional Papers."

Yours truly,
A.

Let BCKM represent a circular brick roof, ABMN the terracing laid over the roof to make it water-tight. The weight of the terracing laid

Fig. 1.



uniformly over the voussoirs will have the same effect in increasing the horizontal thrust, as would ensue if we suppose the terracing to be removed, and the specific gravity of each voussoir to be increased; so as to make the total weight of the supposed voussoirs equal to the weight of the

voussoirs and terracing as actually constructed. Let BC represent any joint of the arch, θ the angle at the centre corresponding to the half

arch. The pressure T , in the direction of the tangent at C ; P , the weight of the half arch; and H , the horizontal thrust or tension on the tie-bar; are evidently connected by the equations—

$$T = H \cdot \sec \theta = P \cdot \operatorname{cosec} \theta$$

$$\text{and } H = \text{horizontal tension} = P \cdot \cot \theta$$

Now, there must be some point at which the expression $P \cdot \cot \theta$ is a maximum, and if we make the tie-rods sufficiently strong to resist this maximum thrust, we shall be on the safe side.

To determine the value of θ for which $P \cdot \cot \theta$ is a maximum,

Let $r = CF = \text{radius of arch,}$

$z = BC = \text{thickness of arch,}$

$w = \text{weight in lbs. of one cubic foot}$

of the material of the arch, supposed increased in specific gravity to allow for the weight of the terracing. We then have—

$$P = \left(r + \frac{z}{2} \right) \theta \cdot z \cdot w \cdot \text{and}$$

$$H = P \cot \theta = \left(r + \frac{z}{2} \right) \theta \cdot z \cdot w \cdot \cot \theta.$$

which expression must be a maximum; or, since r and z are constants, $u = \theta \cdot \cot \theta = \text{a maximum.}$

Differentiating and equating to 0,

$$\frac{du}{d\theta} = \cot \theta - \frac{\theta}{\sin^2 \theta} = 0, \text{ whence } \theta = 0,$$

and the maximum horizontal thrust is at the crown of the arch.

The greatest possible thrust of the arch is therefore represented by the value of the expression $\left(r + \frac{z}{2} \right) \theta \cdot z \cdot w \cdot \cot \theta$; or which is the same thing, $\left(r + \frac{z}{2} \right) z \cdot w \cdot \frac{\theta}{\tan \theta}$; when $\theta = 0$.

Now $\frac{\theta}{\tan \theta}$, when $\theta = 0$, is a vanishing fraction, the ultimate value of which can be found by the ordinary means; or

$$\frac{\theta}{\tan \theta} = \frac{\frac{d\theta}{d\theta}}{\frac{d\theta}{d\theta}} = \frac{1}{\sec^2 \theta} = 1, \text{ when } \theta = 0.$$

Hence the greatest possible thrust on the tie-bar for 1 foot in width of the arch is

$$\left(r + \frac{z}{2} \right) z \cdot w \cdot \frac{\theta}{\tan \theta} = \frac{w}{2} (2rz + z^2); \text{ since } \frac{\theta}{\tan \theta} = 1.$$

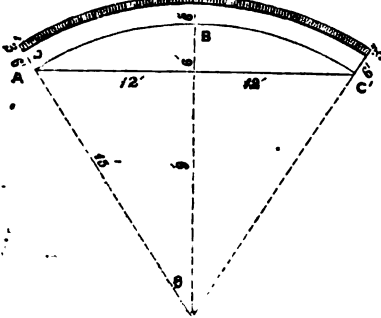
The same result may be obtained by considering that the thrust at any

point of a normally pressed ring, is represented by the product of the radius of curvature at that point, and of the intensity of the normal force per unit of length of the ring.

In this particular case, the centre line of the voussoirs may be taken as a ring, which, at the crown is acted on by a normal force whose intensity is $z \cdot w$. The thrust, therefore, at that point in the direction of the tangent, or horizontally, is $z \cdot w \cdot \left(r + \frac{z}{2}\right)$ or $\frac{w}{2} (2rz + z^2)$ the same result as before; $\left(r + \frac{z}{2}\right)$ being the radius of curvature of the middle points of the voussoirs. It has also been proved that the maximum horizontal thrust in such an arch is at the crown.

Practical Example.—Let ABC represent an arched roof, 24 feet clear

Fig. 2.



span and 6 feet rise. The arch is 6 inches thick, and the terracing above it 3 inches thick; the arching and terracing being of brick are supposed to weigh 120 lbs. to the cubic foot. If the terracing were removed the arch bricks would need to weigh $120 + 60$, or 180 lbs., so that the weight of the whole roof should remain unaltered.

We have then got in the formula—

$$z = 6 \text{ inches} = .5 \text{ feet, } r = 15 \text{ feet, } w = 180 \text{ lbs.}$$

Hence substituting, Horizontal Thrust per lineal foot

$$\begin{aligned} &= \frac{w}{2} (2rz + z^2) = \frac{180}{2} \{ 2 \times 15 \times .5 + .25 \} \\ &= 90 \times 15.25 = 1,374 \text{ lbs., or about } 1,400 \text{ lbs.} \end{aligned}$$

The Tie-bars being of 1-inch round iron capable of supporting a tension of 7,854 lbs., would therefore need to be $\frac{7,854}{1,400}$ feet, or 5.61 feet apart from centre to centre.

The Horizontal Thrust as obtained by this formula may, at first sight, seem rather small; but many roofs of 40 feet span and upwards have been

constructed with tie-rods much further apart than would have been given by this formula, and have stood well for years, although the strain on the iron is no doubt greater than what is usually considered quite safe.

The formula may also be use for determining the least safe thickness of a brick or stone circular arch of given dimensions.

Referring to the first figure and calculation

$$T = \text{pressure on the joint BC} = H \cdot \sec \theta.$$

Now, in the numerical example, the greatest possible value of H has been found to be 1,400 lbs. per running foot, and $\sec \theta = \frac{15}{9} = \frac{5}{3}$.

Hence (Fig. 2), the greatest possible pressure on the joint AD, per running foot, will be $= 1400 \cdot \frac{5}{3} = 2,333$ lbs., which may be supposed uniformly distributed over the surface of the joint 12×6 inches, or 72 square inches. The pressure on the joint will therefore be about 33 lbs. to the square inch; the safe co-efficient for brick being from 55 to 80 lbs. to the square inch.

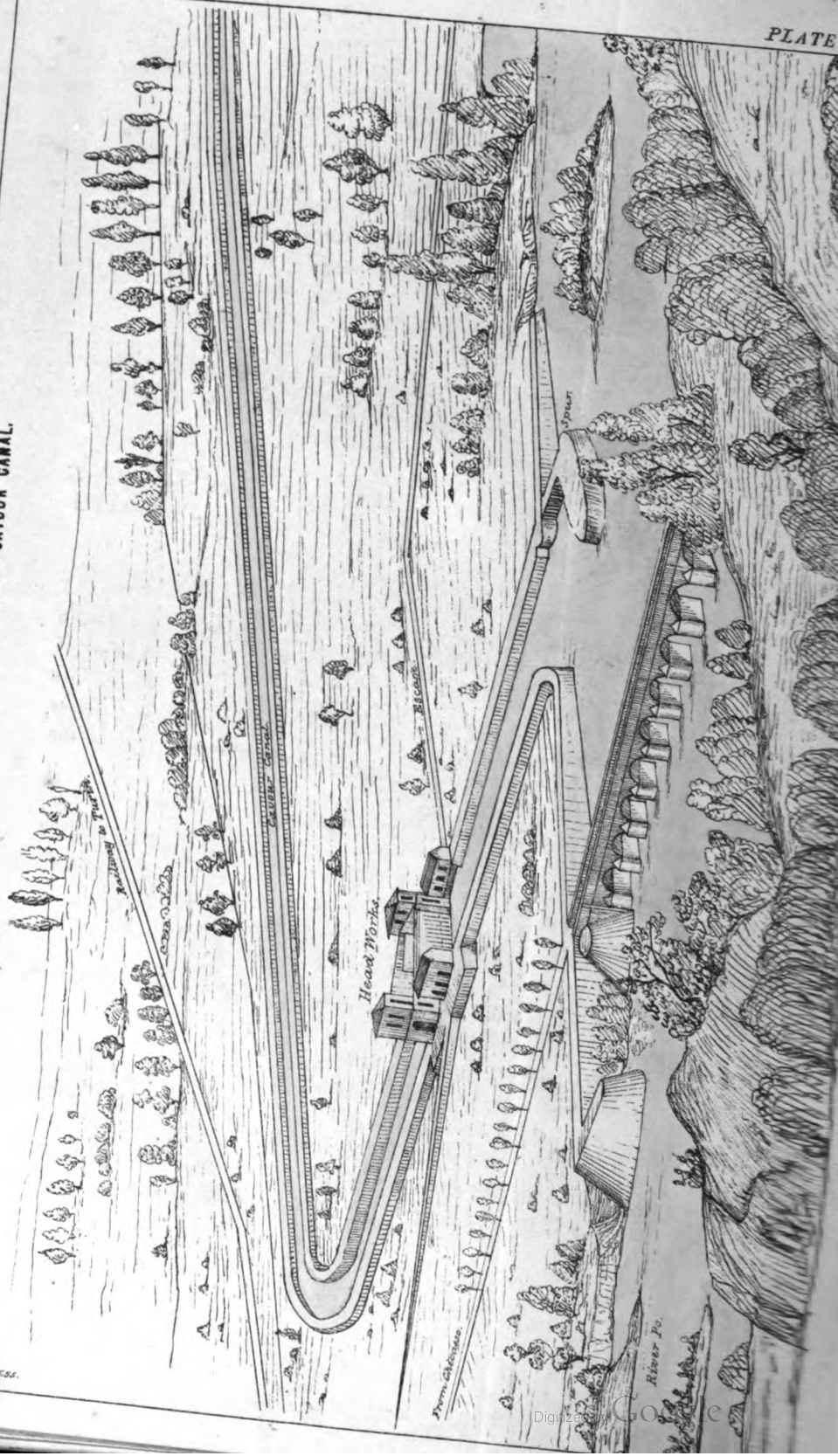
In conclusion, it may be as well to remark, that the above formulæ are strictly correct, only so long as the arch and terracing above it are of uniform thickness throughout. In practice, this is almost always the case, as far as the arch itself is concerned, but the terracing is generally curved off for the sake of appearance, and is somewhat thicker towards the abutments. In most cases, however, this extra thickness over the abutments would, by its weight and consequent friction, serve to diminish the tension on the tie-rods and not to increase it.

A.

Fig. 3.



BIRD'S-EYE VIEW OF SITE OF HEAD-WORKS—CAVOUR CANAL.



No. LXXXIX.

THE CAVOUR CANAL.

Memorandum by LIEUTENANT COLONEL J. H. DYAS, R.E., *Chief Engineer of Irrigation Works, N. W. Provinces, No. 70, dated 7th September, 1865.*

THE Chief Engineer of Irrigation Works, North Western Provinces, in November last, thinking that, with especial reference to the remodelling of the Ganges Canal, much valuable information and many useful hints might be obtained from the works of the Cavour Canal, then in progress in Piedmont, suggested that Government should procure a copy of the project, with plans, &c.

2.—The London Directors of the “Italian Irrigation Canal Company,” with prompt courtesy, forwarded several Reports, Maps, and Photographs, and wrote to Italy for drawings of the works.

3.—The following is a list of the documents received:—

- 1.—General Map of the District.
 - 2.—Bird’s-eye view of the whole line of canal.
 - 3 to 13.—Photographs of the principal works in progress, taken in November, 1864.
 - 14.—Sketch project of 1862.
 - 15.—Report of London Committee, dated 8th July, 1863.
 - 16.—Engineer’s report, and Memorandum by Colonel Collyer, dated 10th February, 1864.
 - 17.—Report of the London Committee, dated 29th June, 1864.
- 4.—The Chief Engineer, Irrigation Works, N. W. Provinces, after

extracting from the above documents the information he considered most useful, has thought it best to abstract, and throw into a connected form the notes he had made, reducing all measures, &c., to those which are in common use in Northern India, and adding such remarks as he thought might prove useful to the officers of the Irrigation Department. He now begs to submit the result to Government.

5.—It will be understood that the above documents, on which the Memorandum is founded, having been published more for the information of the shareholders and of the general public, than for the use of professional men, give occasionally but scanty direct information on points of Engineering detail, and a good deal has therefore had to be supplied by conjecture or inference. Wherever this is the case, however, it is so stated. The drawings, which have been so kindly promised by the Directors will doubtless make all clear.

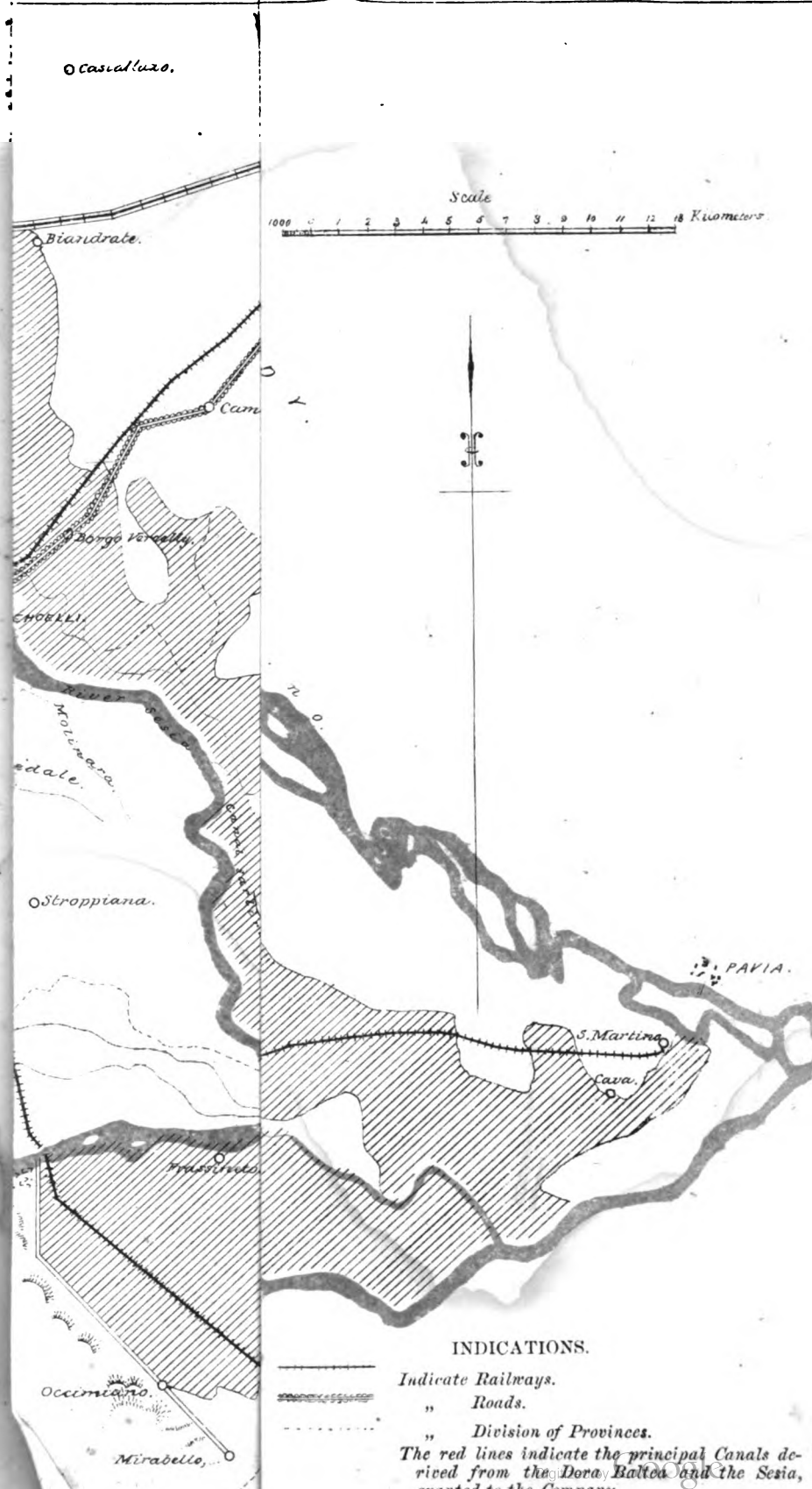
THE CAVOUR CANAL.

(*With a Map.*)

The design of utilizing the waters of the river Po in irrigation, was originated by Francesco Rossi, of the Vercellese, and was eventually brought into its present shape in 1853, under the auspices of the late Comte de Cavour, then Italian Minister of Finance.

The project which is now being carried out was drawn up by the Cavalière Carlo Noé, Inspecting Engineer of the Crown Canals. The plan was made public in 1854, and in 1862 the Italian Government resolved to grant to a Company, not only the construction of the new canal, but the cession by sale of all the existing canals possessed by the Crown in the Vercellese and in the Lomellina. The State has also guaranteed interest at 6 per cent. per annum, on the sum of £3,200,000, the total capital of the Company, for a period of 50 years, the term of the concession. Of this capital, £1,000,000 are in 50,000 shares of £20 each, and £2,200,000 in bonds bearing interest at 6 per cent. per annum.

Many of the shareholders are English; there are eight English Directors and a Chairman in London, as well as eight Directors and a President in Turin, one of the latter Directors also being English. Mr. James Abernethy, M.I.C.E., is associated with the Engineer in chief, Cavalière Noé, and three English Assistant Engineers are employed on the works. Colonel Collyer, late Royal (Madras) Engineers, is in the Direction.



INDICATIONS.

- Indicate Railways.
- " Roads.
- " Division of Provinces.
- The red lines indicate the principal Canals derived from the Dora, Bormida and the Sesia, granted to the Commanu.

The Marquis Luigi Tornielli has succeeded the late Marquis de Cavour as President of the Council of Administration.

The objects of the Company are—the construction of a trunk line of irrigation (the Cavour Canal) 58 miles long, with a capacity of discharge at the head of 3,885 cubic feet per second, to be carried across the main drainage of the Alps, from Chivasso on the left bank of the Po, ten miles east of Turin, to Galliate on the right bank of the Ticino, six miles north-east of Novara; the acquisition of the Crown Canals in the Ivrea and Vercellese provinces, for incorporation with the Cavour Canal in irrigating operations; the purchase of such private canals in the Novara province as may be necessary to give the Cavour Canal command of the whole country which lies south of Novara between the rivers Sesia and Ticino; the irrigation also of the plain between Casale and Valenza on the right bank of the Po; and the ultimate extension of the Cavour Canal into Upper Lombardy, passing it over the Ticino by an aqueduct, and at Barnate, $8\frac{1}{2}$ miles further on, tailing it into another canal (as yet only) projected by the Engineer Signor Tatti, from the Lago Maggiore, or more accurately, from the Ticino between Sesto Calende and Gola Secca. This canal was originally suggested by the Engineer and Senator Lombardini. It will have a course of $102\frac{1}{2}$ miles, running past Monza (nine miles north-north-east of Milan), and as far as Fernovo after crossing the river Adda. Signor Tatti considers it to be indispensable that the Naviglio Grande, the Martizana, and part of the Muzza Canal should also come into the system.

The first stone of the (head works of the) Cavour Canal was laid on the 1st June, 1863, by the Italian Crown Prince Humbert; and the contractors, Scanzi, Bernasconi, and Company, expected to be able to complete the whole of the works during the present year.

The average discharge of the river Po, at the site of the canal head, was ascertained by Lombardini to be 9,959 cubic feet per second for the years 1827-40, and the minimum discharge for the same period (in August 1828), 4,167 cubic feet per second.

The river Po, descending from the Monte Viso, in the Western Alps, runs through the plain of the upper Piedmont, which is formed of a deep alluvium of a most fertile character, and which is most admirably cultivated. The river irrigates the territory of Turin, where it receives the waters draining from the rich meadows that surround the town, as well as the soil

which finds its way into the under ground sewers of the city. It then pursues its course, and is swollen before reaching Chivasso by the junction of the rivers Dora Reparia, Sturia, Orco, and Malone.

The current of the Po, when full, becomes charged with an argillo-silicious mud of a most fertilizing character, of the excellence and abundance of which the most marked signs are exhibited in the course of the river. The waters of the lower Po are better than those of the Ticino and Adda, both as regards the physiological effects of the waters they contain, and the elements of fertility they bring down. The waters of the Po, tried contemporaneously at Turin and at Chivasso, with those of the Dora Baltea at Crescentino, of the Sesia at Vercelli, and of the Ticino at Bufalora, during the extreme months of winter, were found to be the highest in temperature; which property at once proves the superiority of these waters for the peculiar description of *marcite*, or water-meadows, the most perfect form of rural economy, and the ultimate resource of the Lombard agriculture in winter.

The *Doab* of the Po and the Ticino is already partially supplied with irrigation by the small Canals derived from the Dora Baltea, the Sesia, and the Ticino, all of which are ultimately tributaries of the Po. But the waters of the largest of these, the Dora Baltea, are cold from the perpetual snow of the vallies whence it rises, in Aosta, and carry down a baneful deposit of silico-magnesian sand. The mere exchange therefore, or the mixing, of the waters of the Cavour Canal with those of the existing canals will produce a considerable advantage by moderating the excessively cold and depressing nature of the waters of the Dora Baltea, as well as by securing the irrigation of the Novarese and of the Lomellina, now dependent on the Sesia which is but a precarious source of supply.

"If," observes Colonel Baird Smith, in 1851, "that noble canal (the Cavour Canal) is ever executed, as I trust it may be, not only to add new channels to those now existing, but to insure more abundant supplies to those lines which at present languish so much under the want of them: there will then be little left to desire for the action of the irrigation system of this region."*

* It is pleasant to see the terms of cordial appreciation in which Baird Smith is mentioned, and his work on "Italian Irrigation" quoted, throughout these reports.

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The channel of the Cavour Canal is revetted throughout with walls of brick-work on both sides. Its bottom width at the head is 131 feet, whence it is gradually reduced to a width of $65\frac{1}{2}$ feet at the Dora Baltea, $6\frac{1}{2}$ miles from the head. This width is maintained to the 39th mile, the crossing of the Roggia Busca, a small canal, where it is reduced to 41 feet, at which it remains constant as far as the Terdoppio, at the 48th mile; after passing which it is still further reduced to 31 feet, and this width is then maintained to the end.

The full supply depths of water in the canal are as follow:—From the head to the Elvo, 25 miles, 11.16 feet; from the Elvo to the Roggia Busca, 39 miles, 10.50 feet; and thence to the tail, 9.84 feet.

The corresponding changes of slope are not given, all that is said being that the average slope of the bed is 1.32 foot per mile, or 1 in 4,000; nor is the law of change of slope indicated, nor yet that of allotment of water.

It must be confessed that without this information it is difficult to thoroughly understand the details of the project, or even to make the dimensions given in different reports, and by different Engineers, agree in all points. However, it may be useful to draw a few inferences, even though it be necessary to correct them on receipt of fuller information.

If then we take 3,885 cubic feet per second as the discharge of the canal at its head, and 131 feet as the width of channel at the same place, we get 2.6574 feet per second as the mean velocity of the current, and 1 in 6,901 as the slope of the water's surface. In passing the Dora Baltea, the width of channel is reduced by one-half, the original depth being maintained, so that the velocity must be nearly doubled there, for it is not likely that much water is issued from the canal in the narrow strip, $6\frac{1}{2}$ miles long, between the Po and the Dora Baltea. It is probable that the width is thus reduced in order to save expense in building the massive aqueduct and embankments, &c. The soil must be good to stand so great a velocity. From the Dora Baltea to the Sesia also, no very great quantity of water can be issued, as that tract is already well irrigated by existing Canals. The Casale neighbourhood however, on the right bank of the Po has to be provided for, and the branch canal for this purpose would probably take out about half way between the Dora Baltea and the Elvo. Thus the *great* expenditure of water must take place between the Sesia and the Ticino, or from the 36th

to the 53rd miles. It is not stated how much water is reserved for the left bank of the Ticino, but, taking the width of channel at 31 feet, its depth at 9.84 feet, and the mean velocity of the current at $2\frac{1}{2}$ feet per second, we get a discharge of 763 cubic feet per second. Or, in another way, taking the discharge at the head of the canal at 3,885 cubic feet per second, and the expenditure of water between the head and the Ticino at 3,250, a balance of 635 cubic feet per second remains for irrigation on the left bank of that river. The actual quantity may lie between these two estimates.

It will be understood that in consequence of the line of canal crossing the *Doab* of the Po and the Ticino, it was possible to choose the slope most convenient for the objects in view, and to carry it out without a single fall on the trunk line. It is probable, however, that there must be a temporary fall at the tail, into the Ticino, until the completion of the works for carrying the canal across that river, unless indeed the Langosco canal is large enough to take up the tail escape water of the Cavour Canal, and high enough to do so without a fall into it being required.

Navigation does not appear to be contemplated, as, independently of the great velocity of the current, the massive granite lintels which do duty for arches (as they would have to be in Northern India) over the openings of the regulating bridge at Chivasso, are raised above the sill not much more than is sufficient to admit of the free passage of the full supply of water; there is but little head-way under the arches of road bridges, &c., and there are no tow-paths under them; and there are four siphons on the line.

Navigation is not even mentioned in the reports. The able Engineer who designed the Cavour Canal no doubt had good reasons for confining himself to irrigation. The omission of all special provision for navigation must certainly cheapen the cost of the canal as one of irrigation, and shorten the time required for its completion. The Turin and Milan Railway also runs nearly parallel with and close to the canal, which is crossed by it at the 23rd mile. Still looking to the ultimate extension of the Cavour Canal across the Ticino, and its probable future connection with the Naviglio Grande and other navigable canals, it must be regretted that the requisites for navigation could not have been combined with those for irrigation, in this work.

There are nineteen canal *Chokees* along the line, at intervals of about 3 miles each.

The head-works consist of an open weir running diagonally across the river, connected with, and in continuation of, a solid masonry spur which has been pushed out (and up-stream) from the left bank (canal side) of the river. An escape, or set of scouring sluices, is provided between the spur and the mouth of the canal; and a second escape, of 9 openings, is built close up to the regulating bridge, which is thrown back some 1,000 feet or so from the mouth of the canal and from the river's bank. Over the regulating bridge, which has 16 openings, and the escape connected with it, are built houses for the protection of the regulating gear, and of the establishment for working it. The annexed perspective view will give a general idea of the whole arrangement. All the parts of the head-works which are exposed to the action of water are built of, or faced with, large blocks of cut stone obtained from quarries opened out immediately opposite on the right bank of the Po.

In addition to the two escapes already mentioned, a third called the escape of the Poasso, with a channel 4,100 feet long, also leading into the Po, occurs at $2\frac{1}{2}$ miles from the canal head. These escapes have their channels revetted with brick-work. A fourth escape occurs at $6\frac{1}{2}$ miles, 200 feet long, into the Dora Baltea; a fifth, at the 25th mile, 4,400 feet long, into the torrent Elvo; a sixth, at the 29th mile, 200 feet long, into the torrent Cervo; a seventh, at the 36th mile, 4,400 feet long, into the river Sesia; an eighth, at $45\frac{1}{2}$ miles, 3,900 feet long, into the torrent Agogna; a ninth, at the 48th mile, 2,800 feet long, into the torrent Terdoppio; and the tenth, at the 53rd mile, is the tail escape into the river Ticino.

These escapes were originally drainage cuts, or the down-stream portions of diversion, or relieving channels, opened for the purpose of turning the stream round the works, or of getting rid of the water in the foundations while the works were in progress. They are now turned into permanent works with sluice-gates at their heads. It is probably intended to make use of some of these escape-heads as irrigation outlets, or heads of branch canals; for no mention is made in the reports of any such works, and an escape every five miles on the average would appear to be more than could be required for purposes of regulation.

It will now be seen what an expensive part of the undertaking the crossing of the whole drainage of the country must have been. But it

was in fact the only way of bringing the water to the land which it was destined to irrigate.

It will be observed also that no attempt appears to have been made to divert any of the smaller drainages into larger ones, an expedient which has been found useful in India. There were doubtless good reasons for not attempting it. There is one small torrent, the Dondoglio, near the Marchiazza, $34\frac{1}{2}$ mile, of which no mention is made in the reports; possibly it may have been diverted into the Marchiazza.

Two rivers, the Dora Baltea, deriving its supply from Mont Blanc and the great St. Bernard, and the Sesia, have been crossed, in addition to six torrents, the Elvo, the Cervo, the Roasenda, the Marchiazza, the Agogna, and the Terdoppio.

Of these, the Dora Baltea is crossed by an aqueduct 635 feet long, consisting of nine arches of $52\frac{1}{2}$ feet span each, on $9\frac{1}{2}$ feet piers, and abutments $43\frac{1}{2}$ feet each. The length of embankment formed across the valley of this river is 7,353 feet additional.

The Sesia is carried across the canal by a superpassage 820 feet wide, on five arched openings, through which, as siphons, the canal flows.

The Elvo, the Agogna, and the Terdoppio, also cross the canal by superpassages, which are siphons as regards the canal. That for the Elvo, is 656 feet wide, on five arches; those for the other two torrents are on three arches each, and have a width of 161 feet and 142 feet, respectively.

The canal is carried over the Cervo by an aqueduct 511 feet long, on five arches. The valley embankments are 2,428 feet long additional.

The Roasenda, 33rd mile, and the Marchiazza, 34th mile, flow under the canal through culverts of three vents each, the length of the former work being 178 feet, with valley embankments 2,428 feet long, and that of the latter, 102 feet, with embankments 3,260 feet long.

All these works are built in much the same style, plain and solid, of excellent brick-work, the cut-waters faced and capped with cut stone, and occasionally a string-course of the same material.

There are also numerous minor works, as road bridges, and the aqueducts, culverts, and siphons required for the passage of the waters of the several small canals whose courses have been intersected by the Cavour Canal. These were originally set down at 500 in number, but the contractors have been able, by arranging with the land-holders, to reduce the number to 326.

Of these small canals, the Ivrea, receiving 700 cubic feet per second, and measuring with its accessories, $92\frac{1}{2}$ miles in length; the Cigliano, 650 cubic feet per second, and $102\frac{1}{2}$ miles long; and the Rotto, 600 cubic feet per second, and $84\frac{1}{2}$ miles long; Crown Canals, drawn from the river Dora Baltea on its left bank, have been made over to the company; as also the Sartirana, 220 cubic feet per second, and $100\frac{1}{2}$ miles long, drawn from the left bank of the river Sesia.

The Busca, 65 cubic feet per second, $89\frac{1}{2}$ miles long, and the Rizzo-Biraga, 90 cubic feet per second, $88\frac{1}{2}$ miles long, have been purchased from the former owners, and negotiations are in train for the purchase of the Mora, 130 cubic feet per second, $32\frac{1}{2}$ miles long, and of the Langosco, from the right bank of the Ticino, 249 cubic feet per second, and 27 miles long.

The aggregate discharge of the Crown Canals made over to the Company is 2,170 cubic feet per second and their united length 380 miles. The discharge of the private canal streams is 534 cubic feet per second, and their length 188 miles. The total discharge therefore of existing canals which are, or are about to become, the property of the Company is 2,704 cubic feet per second, and the total length 568 miles.

On the Crown Canals ceded to the Company are 17 mills, yielding an annual revenue of £2,400. Collective H. P., 650.

It does not appear to be the intention of the Company to construct at their own expense the subsidiary canals from the Cavour Canal; but the Council of Administration have entered into an arrangement with first class capitalists for the establishment of an Agricultural Bank, by the aid of which the landholders may be supplied with the capital required for the construction of subsidiary water-courses, and for levelling their lands.

The total estimated cost of the Cavour Canal is £1,774,995;* in addition to which £361,005 have been appropriated to the payment of interest from the time of the first formation of the Company until the completion of the works, thus allowing £2,136,000 for the new canal; the Crown Canals have cost £812,000; and a sum of £252,000 has been set aside for the purchase of private canals, &c., making in all £3,200,000, the capital of the company.

The annual current expenditure is thus estimated—

* It is not stated whether this sum includes compensation for land occupied.

Interest, @ 6 per cent. on £2,200,000, Bonds, ...	£132,000
Expenses (establishment, maintenance, &c.,) ...	16,000

Grand Total current expenditure, ... £148,000

The returns are calculated as follows:—

Water-rate on 296,544 acres, @ about 16s. 2½d.,	
per acre,	£240,000

Water-rate on 18,534 acres (<i>marcite</i>), @ about	
6s. 5½d. per acre,	6,000

Total 315,078 acres, and water-rate, ...	£246,000
Mill-rent,	6,000

Total revenue from new canal,	£252,000
Present revenue of crown canals, ...	£32,480
Additional revenue from same by reason	
of increased supply,	4,000 86,480

Grand Total returns, ... £288,480

Thus, the net profit is estimated to be £140,480 per annum, which will give a 14 per cent. dividend on the share capital of £1,000,000.

From the foregoing, the following statistical information may be deduced.

No.	Detail.	£	s.	d.	R.	A.	P.
1	Estimated cost, of construction only, of new trunk canal, excluding cost of distributing channels, and without navigation, per mile, $\frac{1}{16}$ (£1,774,995),	33,491	8	4	(Nearly.)		
2	Estimated cost of do. do. do. per cubic foot per second of discharge, $\frac{1}{16}$ (£1,774,995),	456	17	8	3,84,914	0	0
3	Estimated cost of establishment, maintenance, and repairs, per annum, per mile of length, $\frac{1}{16}$ (£16,000),	301	17	9	3,019	0	0
4	Estimated cost of do. do. do. per cubic foot per second, $\frac{1}{16}$ (£16,000)	4	2	4	41	0	0
5	Average allotted expenditure of water, per mile of trunk canal, $\frac{1}{16}$ (8,250), ...	61.42 cubic feet per second.					
	(£246,000 : £4,000 :: 315,078 : 5,123, and 315,078 + 5,123 = 320,201 acres, the total area irrigated, including additional by Crown Canals),						
6	Estimated area irrigated by Cavour Canal, per cubic foot per second, $\frac{290,391}{3250}$...	98.52 acres.					
7	Proposed average (deduced) water-rate, per cubic foot per second, $\frac{250,000}{3,350}$...	76	18	5	769	0	0

No.	Detail.	£	s.	d.	R.	A.	P.
8	Proposed ordinary water-rates, per acre irrigated,	0	16	2	8	1	6
9	Proposed water-rate for <i>marcite</i> , per acre irrigated,	0	6	6	3	3	7
10	Actual average water-rate on Crown canals, per cubic foot per second (1,800 Fr. per module),	25	7	6	253	12	0
11	Actual lowest ordinary water-rate, per acre irrigated,	0	14	7	7	4	7
12	Actual ordinary water-rate on private canals, per acre irrigated,	1	1	0	10	8	0
13	Actual average annual rent paid on Crown canals for water-power, per H. P., <i>Rs.</i> (£2,400),	3	13	10	36	14	8
14	Paid by Company for Crown canals, per cubic foot per second <i>Rs.</i> (£812,000),	374	3	1	3,742	0	0
15	Paid by Company for Crown canals, per mile, <i>Rs.</i> (£812,000),	2,136	13	6	21,367	0	0

From which, we may say roughly, that, as compared with canals in Northern India, twice as much water must be taken into the Cavour Canal in order to enable it to irrigate during the year an equal area of land; and that the farmer will have to pay three times as much for that irrigation; or if he takes water by bulk, that he will pay half as much more, for the same quantity of water, than the Indian cultivator. That is, assuming for the Indian rates those now in use (since 1st May 1865) on the Ganges and the Eastern Jumna Canals, viz. :—

Class of Crop.	Nature of Crop.	PER ACRE IRRIGATED.		Per
		By natural flow of water (Tor.)	When raised by machinery (Dal.)	
I.	Sugar-cane, Gardens, and all lands taking a supply throughout the year,	Rs. A. P.	Rs. A. P.	Year.
II.	Rice, Tobacco, Opium, Vegetables, and Singharas,	3 0 0	2 0 0	Crop.
III.	All <i>Rubbee</i> crops, Indigo, and Cotton,	2 4 0	1 8 0	"
IV.	All <i>Kharreef</i> crops, not specified above,	1 10 0	1 0 0	"

Each cubic foot of water per second which enters those canals may be said to irrigate on the average 200 acres of land during the year. In 1860-61, this area was 296 acres for the supply of the Eastern Jumna

Canal. The Ganges Canal has not yet reached so high a standard, but its average is steadily increasing; for 1863-64 it was 110 acres, and for 1864-65, 141 acres.

The average proportion of each kind and class of irrigation in every 200 acres may be approximated to as follows:—

Class.	Area irrigated (in acres.)		
	Tor.	D&L	Total.
I.	22·96	5·04	28
II.	29·52	6·48	36
III.	78·72	17·28	96
IV.	32·80	7·20	40
Total acres, ...	164·00	36·00	200

By combining the information given in the foregoing Tables, we get the following:—

Class.	Tor or D&L.	Acres irrigated of each kind and class.	Rate per acre irrigated.	Amount of water-rate.					
				Tor.		D&L		Total.	
			R. A. P.	R.	A. P.	R.	A. P.	R.	A. P.
I.	{ Tor,... ..	22·96	5 0 0	114	12 10	...	...	131	9 8
	{ D&L,... ..	5·04	3 5 4	...	...	16	12 10		
II.	{ Tor,... ..	29·52	3 0 0	88	9 0	...	...	101	2 0
	{ D&L,... ..	6·48	2 0 0	...	...	12	9 0		
III.	{ Tor,... ..	78·72	2 4 0	177	1 11	...	...	203	0 8
	{ D&L,... ..	17·28	1 8 0	...	...	25	14 9		
IV.	{ Tor,... ..	32·80	1 10 8	54	10 8	...	...	61	13 10
	{ D&L,... ..	7·20	1 0 0	...	...	7	8 2		
Total, ...	{ Tor,... ..	164·00	2 10 5	485	2 5	...	...	497	10 2
	{ D&L,... ..	36·00	1 11 9	...	...	62	7 9		

Average rate for the 200 acres, Rs. 2-7-10 per acre. Value of 1 cubic foot of water per second for one year, about Rs. 500.

The present average (sole) rate for *Tor* irrigation in the Punjab is Rs. 2-6-8 per acre, and for *Ddl* Rs. 1-3-4.

The present rate of the Madras Irrigation Company, is Rs. 4 per acre.

The reason why in Italy, a canal must carry twice as much water as in India, in order to irrigate during the year an equal area of land, is not that the Italian farmer does not economize water as carefully as the Indian farmer, but that the sole kind of irrigation practised in Italy during the winter months is *marcite*, or water-meadow, which is of limited extent, and which, though requiring a large expenditure of water, (a thin sheet of water has to be kept constantly flowing over it,) pays but little, the rate for it on the Cavour Canal being only two-fifths of the ordinary rate. On the other hand, the area irrigated by one cubic foot of water per second in Northern India in winter (the *Rubbee* crop) is generally twice the area irrigated by the same quantity of water in summer (the *Khureef* crop.) The actual extent of *Rubbee* irrigation on the Eastern Jumna Canal amounts to 60 per cent. of the total area irrigated during the year, and on the Baree Doab Canal in the Punjab, to 56 per cent. of the same, taking in each case an average of four years.

From Italian provincial statistics it appears that the relative value, for sale or lease, of irrigated and of unirrigated land, is as 3 to 1. Mr. Abernethy adds that, "from what he has seen at the farm of the Marquis di Cavour at Leri, and in that neighbourhood, as compared with the unirrigated lands lying between Novara and the Ticino, he would be inclined to place it at a much more higher rate." Count Cavour, in 1857, stated that, "in the plains of Piedmont from Coni to the Ticino, land was letting at 32s. an acre, which is more than the average rent of land in Great Britain."

There appears then to be good ground for hope that the Cavour Canal will prove an exception to the general rule in Northern Italy, as stated by Colonel Baird Smith, that "Canals of irrigation, however they may benefit agriculture, are not generally successful as purely financial speculations."

No. XC.

NOTES ON ROAD METALLING.

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

THERE are numerous professional works on Roads and Road-making in all its branches, which have been published at various times in England, and which afford extremely valuable information to those engaged on such duties in India: some of these have been arranged and adapted to meet the requirements of this country, but the chief point on which the English and the Indian practice differs almost *in toto*, has been overlooked, and there exists at present no printed record or elementary work of reference which can serve as a guide to the scientific treatment of the heterogeneous materials that form the surface of our Indian roads, and which differ so greatly from those in use in England, as to render necessary a new system of treatment. As a consequence, there are numerous differences of opinion on the subject; one Executive Engineer reverses the system pursued by his predecessor, almost all proceed empirically without any fixed rules, and thence results a diversity of practice of which much must be wrong, and cause a considerable loss of money.

It is intended therefore in the few following remarks to attempt to reduce to rule the preparation and consolidation of the road materials generally in use, and more particularly those in Western India.

In the Bombay Presidency, the chief material used in Road-making is *Moorum*; as it is generally obtained close at hand at small cost, and affords the best sort of materials with which to commence a new road.

The rate at which moorum is procured in the province of Malwa, is on the average about Rs. 2½ per 100 cubic feet for a lead of one mile, this expense being divided among the sub-heads as follows:—

			RS.	A.	P.				RS.	A.	P.
Excavating, ...	...	...	0	12	0	Stacking,...	...	...	0	2	0
Carrying 1 mile,...	...	...	1	8	0	Spreading and consoli-	}	...	0	6	0
" 2 " ...	...	...	3	0	0	dating,...					
" 3 " ...	...	...	4	8	0	Rolling, Rs. 80 per mile.					

In using the term moorum, however, we generally include almost all descriptions of sub-soils which are suited for the surface of a road, by being at all harder than the common earth. The surface of what is usually called a moorumed road may contain in it different portions of sand, laterite, broken bricks, kunkur, yellow earth, or any hard strata, which may be met with below the surface.

The real moorum is probably rock in course of disintegration. It is met with at a depth of 2 or 3 feet in regular strata, and is nearly homogeneous in the same locality. It varies, however, in different localities at almost every mile, both with respect to its hardness and durability, as well as the size of the pieces into which it breaks. It is got with the pickaxe, and the very hardest moorum therefore that we can obtain must fall considerably short of metal. The usual form in which this material breaks is into flakes or clinkers, with sharp well defined edges; this sort is a favorable description for binding under pressure and moisture. There is another very good description of moorum which comes out in small blocks or nodules, nearly the size of a man's fist; this kind is very difficult to bind, but when once well consolidated, it makes a strong and good roadway. A third description of moorum, differing from either of the above is of a gravelly nature. It breaks up into small pieces, and forms a very smooth pleasant road in the fair season, well adapted for carrying light traffic, and does for cantonment roads. It is, however, not sufficiently strong to stand heavy traffic well, and in the rains it is not much better than an earthen road.

In some places a very inferior description of moorum, which is but little better than indurated clay, is alone procurable. It comes out in large blocks, but is so soft that it crushes under the rollers.

There is hardly any limit consequently to the size of the pieces of such moorum which may be brought on to the road.

Good moorum may generally be known at once by its gray color. It has a blueish metal-like fracture. Red moorum on the contrary is almost invariably bad.

All quarried moorum has a kind of skin or outer crust which is softer

than the interior. The binding and consolidation is somewhat assisted by this, as the pieces yield and are forced together under the rollers, but during the rains these skins becomes mud, and tend to break up the road.

In most moorum pits are found nodules or blocks of hard stone, called "tols," bedded in the strata; these make good second-class metal when broken up, but owing to the expense of so doing, it is usual to throw them into spoil banks at the pits, or use them with jungle stones to form rubble stone bottomings for the roads. By the use of these rubble stone bottoms, the surface material is separated from the sub-soil below, and we are enabled to use up all our moorum, none being pressed into the sub-soil and lost. Care, however, must be taken that the cart-wheels are never allowed to reach this bottoming, otherwise it will be broken up and forced to the surface. This is more especially necessary when the road is in a green state just after the rains; when the traffic recommences, the ruts should then be constantly raked in and generally towards the centre, to preserve the section.

From what has been above stated, we are unable to fix any limit to the size of the pieces of moorum which can be brought on the road, but must be guided by our experience at the different pits, as to the largest pieces which can be expected to bind. The softer the material is, the larger should they be as a rule, in order to give a cross section of sufficient strength to resist fracture by the cart-wheels. The same principle must be observed in forming the section of the road, the rise in the centre being greater as the material is softer.

When the moorum is procured in large pieces it will often happen that owing to a deficiency of rain or from the rolling not having been attended to, that the roadway has not bound or consolidated properly; and whenever this is the case, it should be top-dressed, with yellow earth, fine moorum, or sand, about 1 inch in thickness, and rolled; and the result will be that these portions will be well passable during the fair season. More than one inch of top-dressing would make the road heavy and muddy in wet weather, and less than this would not effect the object of binding the large moorum. Yellow earth is far preferable for this purpose to sand, as this latter hardly acts as a binder; but the former sinks down between the pieces of moorum, and consolidates them by forming into cakes in the interstices. When yellow earth cannot be procured, the next best material as a binder is fine or soft moorum. This treatment of a road surface is not to be recom-

mended as a general rule, as every heavy shower of rain disturbs the top-dressing, which may have to be renewed; but it is an expedient by means of which, a rough and inconvenient piece of road may be rendered good for the traffic during the dry season at a trifling expense.

Whenever very weak material is employed, such as sand, for the road surface, the stronger should the substratum be, as rubble stone bottoming with a layer of block moorum in large pieces. Broken brick as a material for the road should be sparingly used, being very weak, and should be brought on in a thin layer, so as to be worked up by the end of the cold weather, as it is a disagreeable material when not moist. It should be put on at the commencement of the heavy rains, and will be found when kept moist to make a somewhat tough roadway.

Such is a brief description of material with which roads are generally commenced in the Bombay Presidency. The chief fault of moorum is the facility with which it imbibes moisture. When thoroughly impregnated with it, the very best and hardest moorum will not stand traffic well, and in the rains it forms a viscous mud, and one cart at that time uses up as much material as four would in the fair season. With a few days of fine weather, the road recovers itself more rapidly than any other similar material. As a rule, therefore, in all localities where the rains are heavy, we shall have great difficulty in finding good moorum.

We are led to perceive by these facts that only the best description of moorum should be brought on in the rains, and that expense may be saved if considered advisable by using an inferior moorum for the fair weather repairs. One method of effecting this would be to screen the moorum on to the road, through a screen with meshes about $\frac{3}{4}$ -inch in size, and stack these siftings, which would still have some strength in them, for the fair season repairs.

Whenever our funds will allow, the moorum is spread in a layer of 12 inches, with a rubble stone bottoming over the sub-soil, and forms a roadway perfectly capable of accommodating the traffic for the first few years. As the traffic increases, the road crust or surface loses its spongy and porous nature and becomes more tough and consolidated with each succeeding year; but we also become aware, as our road gets into use, of a great difference in strength in the several portions of the line, owing to the varying character of the moorum. Our attention must now be turned to the elimination of all such weak and bad portions of the line. New

moorum pits must be searched for, and failing their discovery, the lead from the good pits must be extended from either side of these places, so as to shut them out, and bring the strength of the line up to nearly an uniform level throughout. We also become aware, from the complaints of the cartmen, of numerous obstacles along the line, such as muddy nullahs, &c., which stop all travelling in the rains, and cause great delay in the fair season. After our outlay on the moorumed roadway, the next most productive expenditure is to carry the roadway over these obstacles by means of drains, culverts, and bridges. In the early history of a road we must submit to the evil of having our new works at a great distance apart from each other, in order to render the outlay on new works as productive as possible, and to raise the strength of the line *pari passu* with the requirements of the traffic. If an attempt be made to concentrate the establishment and outlay on any one part of a road in the first few years, the result will be that such portion will be as much too good for the traffic as the remainder will be too bad and weak. Sound economy, therefore, dictates that the worst portions of the line should be improved one after another, in the order of the obstruction they cause.

After some years of outlay on improvement of new works, we find ourselves in possession of a road excellent in all respects for the fair weather traffic, well drained and bridged throughout (with the exception of those streams which are of some considerable magnitude), but incapable from the nature of its surface, of withstanding much traffic during the monsoon; the facilities that the road has given to transport having had its usual effect, of increasing traffic and cutting up the road surface.

To remedy the defect of the weak surface, we might proceed in the manner recommended by standard authorities on the subject, and provide a stone pavement laid by hand on the present moorum surface, with 6 inches of metal over this pavement. This process is however so expensive that no one recommends its adoption, but the expedient of metalling at this stage of our road, either with or without a rubble stone bottoming, is well worth consideration.

In the Province of Malwa, the only metal procurable is made from what is called globular trap, which has the peculiarity, that however sharp the angles of the pieces of metal may be when first broken up, they invariably disintegrate into rounded masses under friction and use, and do not

bind properly except for a limited time when first spread during the monsoon. In the hot weather, this metal becomes an unconsolidated mass of rounded stones, which cannot act as a road unless by the adoption of the very expensive methods of watering and rolling. It therefore becomes a desideratum to discover whether some more efficacious and less expensive method cannot be devised to accommodate the traffic during the wet season. In many places where the moorum spread has been of a superior quality, and the crust of the road is sufficiently strong to carry with safety a thin coating of metal, it would be advisable to substitute broken stone for moorum, in the annual repairs, as at the same expenditure, stone is more durable than moorum. A strip of metal, 12 feet broad by about 2 inches deep, laid in the centre of the roadway during the monsoon, would find a bed for itself on the moorum surface. This would give about 2 cubic feet of metal to the running foot of road, instead of $4\frac{1}{2}$ cubic feet of moorum, that would be required for repairing the roadway, 18 feet wide and 8 inches deep with this latter. But as 2 cubic feet of metal are fully equal in wear to 5 cubic feet of moorum, there is a saving in using stone, besides providing a road properly passable during the rains. The cubic foot of second-class metal would cost Rs. 6, and an outlay of Rs. 12 on metal would give results equal to Rs. 15 on moorum of the average quality.

The peculiarity of slow-moving traffic, more especially in this country in following on the same tracks, is one of which advantage might be taken to form a perfectly hard roadway for the wheels of the carts in the manner detailed below, which would be available throughout the year, equally in the rains as in the fair season. By laying down stone tracks at a distance apart from centre to centre equal to the average gauge of the carts using the road, we should obtain a nearly perfect roadway at about one half the expense of metalling. This system has been tried in many places in England, and has been invariably very successful wherever the heavy nature of the traffic demands its adoption.

The following comparative statement shows the expense of these stone tracks and that of metalling, the rates being those prevailing in the province of Malwa :—

						RS.
Original cost per mile,	{ Metalling,	..	..	..	..	10,989
	{ Stone tracks,	..	..	..	..	4,905
Saving by stone tracks, per mile, Rs. ..						<u>6,084</u>

Annual maintenance per mile,	{	Metalling, 1½ inches, rolling, and watering ..	2,935
		Stone tracks, 8 inches, moorum, ..	970
Annual saving by stone tracks per mile, Rs.			1,965

It is a fact well ascertained in practice, and supported by the experience of the best authorities, that the draught upon well laid stone tramways is less than one-quarter of what it is on a gravel road, and the proportion is probably still less with reference to a moorumed road. This would make the productive draught upon these tracks but little less than on an iron tramway, if we take into consideration the greater dead weight of the rolling stock in use on that description of road, and the difficulty of providing full loads for each van. The lowest estimate that has ever been made for a single line of iron tramway, is Rs. 20,000 per mile, and however great the facilities that would be given by the system to transports, they must be attended with a double break of bulk and consequent delay, &c., of goods. This, it is evident must deter a large amount of long distance goods, and nearly all the short distance traffic, from coming into the tramway at all.

Stone tracks might be advantageously laid along-side the present lines of road and act as feeders to the railway, at a fraction of the cost of the proposed light railway or iron tramway, and without their risk and trouble. They can be used for all descriptions of traffic for all distances without charge; there is no break of bulk, and they would develop the productive power of districts by freeing labor and keeping down the price of carriage, in a manner similar to that effected by railways.

On most lines of road, steep places, called ghauts, are met with, and as these have generally been constructed many years ago, it will be found that they are too steep in many parts for cart traffic. They have been laid out and drained at considerable expense, and could not now be altered, except at a very heavy outlay. We are enabled, however, to attain the same result, by providing stone tracks for the ascending traffic, at about a tithe of the outlay, as if the ghaut had been entirely reconstructed at a proper slope, as the draught on an ascent of 1 in 18 with these, is as light as 1 in 30 on an ordinary road. Stone tracks on even the steepest of these ghauts would facilitate the traffic as much as if the ghaut had been re-made at an incline of 1 in 30.

One mile of these tracks has been sanctioned as an experiment on the Bombay and Agra road, by the Supreme Government of India, in this

year's budget. About half a mile will be laid in the plains, and an equal length on a ghaut incline, and the result is to be reported on after a twelve months' trial. The following is the specification to which they are to be constructed.

"The tracks will be excavated in black soil, and the stones used in their construction to be invariably of the best quality, fine and close grained. The size of the track stones to be 18 inches broad by 9 inches in depth, and not less than 1 foot in length each; to be bedded in well rammed moorum and stone chips, so as to prevent the stones from sinking. The foundation will be 1 foot deep and 6 inches on sides. The tracks will be flush with the general level of the road; their junction will be supported by a boulder or large stone, in length not less than that of the joint itself, and containing about $\frac{1}{2}$ cubic foot each. The top or exposed faces of the stones to be scored across with a pick to give a hold to the animals' feet. Each stone to be closely jointed to the next, by chisel dressing the end face. Amount of estimate, Rs. 4,905 for one mile."

It would be an additional precaution if the ends of the track stones were joggled together and laid in lime mortar, and it may perhaps be found necessary to do so. A plan and section of these tracks is given. They will be used by the traffic in both directions in a similar manner to the plank roads in Canada. The moorumed surface of the roadway would only be used as a "turn-out," as it is called when two carts meet. The rule of the road is very simple, and can be easily complied with by the cartmen. All non laden carts would "turn-out" for those laden; and when two carts meet, whether both were laden or were unladen, the traffic passing north would "turn-out" for that moving south, as the latter has usually the heavier loads. The traffic on the Bombay and Agra road consists for the most part of strings of carts, laden with cotton, opium, piece goods, Europe stores, &c., varying in number from 10 to 30, so that in a day's march the "turn-out" would probably only be used two or three times by any particular cart, and then only for a couple of hundred yards each time. One line of tracks would therefore accommodate any conceivable amount of traffic.

But, whatever may be the material used for the surface of the roadway, whether metal or moorum, it is necessary to bring it into a state properly passable for wheeled vehicles. This is effected by means of Rollers, by which the road surface is compressed, when saturated with moisture, into a smooth and compact stratum or pavement, by which the draught is greatly

assisted, and the material is worn more equably and lasts much longer than if used in an unconsolidated state. Rolling operations, as usually conducted, are expensive and troublesome, and in most cases are not so efficacious as they should be. They ought to be so conducted that when the road is once consolidated, it should remain so throughout the year, and the constant top-dressing, watering, and rolling, which goes on in the fair season under the present system, would be avoided. With the globular trap more especially, its nature is such that the only chance of forming a proper road surface with it, is to crush it down into a pavement, and thereby prevent the pieces from separating and working up to the surface; a very few rollings with rollers of the proper weight would be of more effect than any number with light rollers, and a great saving would be effected in labor, bullock power, and expense, by the adoption of rollers of great weight.

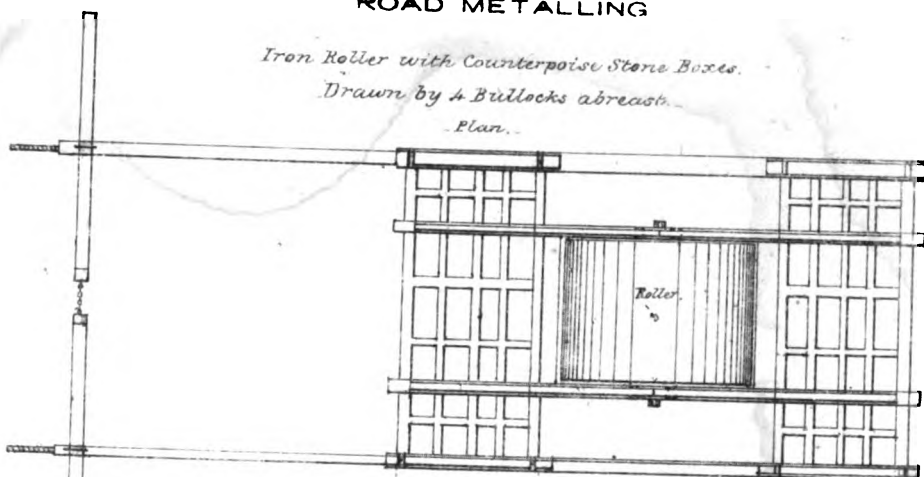
X. | The rollers usually employed on moorum roads are made of stone, such as hard trap; they are in length about 4 feet, and 2 feet diameter, weighing say 1 ton each, or 47 lbs. to the inch of bearing surface. To ascertain whether the effect of these rollers is sufficient to give us a surface hard enough to carry the traffic without injury, we must compare the compression exercised by them with that of the wheels of a laden cart, which carry in all probability the greatest weight per inch of bearing surface of any traffic using a road. Our rolling operations will evidently be of little efficacy unless they provide a stratum sufficiently tough to resist the action of the cart-wheels, or in other words, the weight of the rollers should be, inch for inch of bearing surface, at least equal to that on the cart-wheels. We may assume that each laden cart has a total weight of at least half a ton, including the cart itself; this gives 5 cwts. on each wheel, and taking the tire at 2 inches broad, a pressure is produced of 280 lbs. per bearing inch. This is six times the pressure of our stone rollers, and leads to the belief that there is little efficacy in rolling with such light weights. It is evident that if it be possible to procure rollers with a bearing weight of 280 lbs. per inch or upwards, our labors would be much lightened. These views are confirmed by experience, as we find that with light stone rollers, the upper crust or surface is only made smooth, and below this is material in an unconsolidated state; the roadway being consequently soon cut through and broken up by the traffic. With metal, these rollers are entirely useless; wherever they are now in use, they should be got rid of as soon as possible and others substituted,

ROAD METALLING

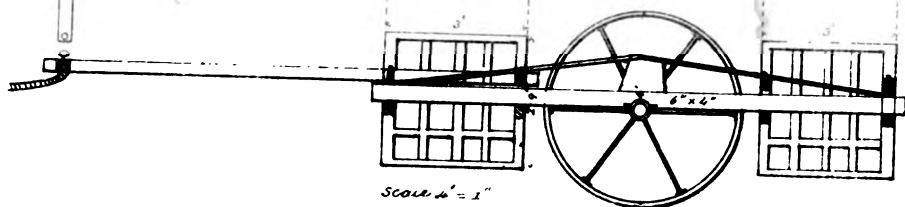
Iron Roller with Counterpoise Stone Boxes.

Drawn by 4 Bullocks abreast.

Plan.



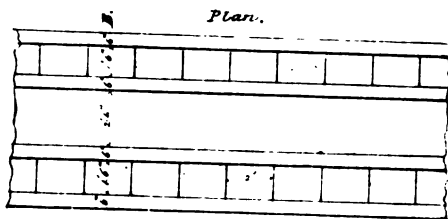
Elevation.



Scale 1/4" = 1'

Stone Track.

Plan.



Scale 1/8" = 1'

Section on A. B.

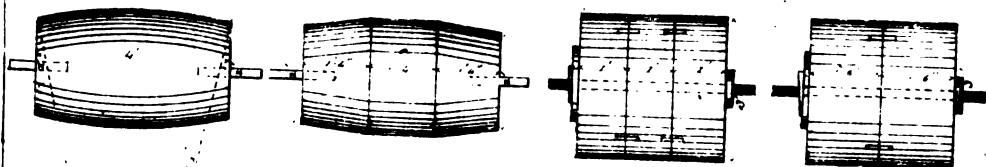


Stone Rollers.

Burrel Shaped

Revdant.

Formed of 2 or 3 Stone Wheels.



Scale 1/2" = 1'

which permit of being weighted up with stone boxes and in other ways.

Before however proceeding to describe the superior kinds of rollers, it will be as well to show what can be done with the present stone rollers, so as to make them in some degree efficacious, at least for the consolidation of moorum and similar materials, it being always borne in mind that as near an approach as possible should be made with these machines to the weight on a cart-wheel. Instead of being made cylindrical, they should be either barrel-shaped or bevelled. The effect of this shape is that the bearing surface is reduced to about one-third of its former extent and the weight per inch is trebled, being now 141 lbs., or half that on a cart-wheel. These rollers can be made at the same price as the usual cylindrical ones, and are easier to turn and lighter in draught than these latter. They should more especially be made of the hardest stone procurable. There is one point about the barrel-shaped roller which appears to give it an advantage over all other shapes. It is evident that with each successive rolling as the road becomes harder, the bearing surface of the roller decreases and the compressive effect is increased at the time it is most wanted. Iron rollers should be cast in this form as being probably a more scientific shape than any other. Any slight invert or cusps caused by this roller would disappear under repeated rollings, and by the wear of the traffic.

We now come to the consideration of those Rollers which permit of being weighted up, and for this purpose a stout iron axle running through the body of the roller is necessary. We are limited, consequently, by this consideration to the common English iron roller, and a country roller made up piece-meal with stone wheels similar to those used in grinding chunam. Drawings of these two are given, and a frame work with counterpoise stone boxes shown with the iron roller; the same frame-work does for the stone roller and is not therefore shown with it. These stone wheel rollers cost about Rs. 60 per cent. more than those cylindrically shaped, say Rs. 40 and 25, respectively. Their weight is 3,780 lbs. or 105 lbs. to the inch bearing. One ton can be added to this by means of the framework and stone boxes, which gives 167 lbs. per inch bearing. We are still however far off the weight necessary for rolling metal, for which the iron rollers are most effective. The compressive effect of these stone wheel rollers might be greatly increased by making them barrel-shaped or bevelled, but their construction would not permit of this.

The width of the English rollers is 3 feet, and diameter 4 feet, and the weight about 2 tons. The stone boxes and framework would give another ton; and if the interior be boxed up and filled with scrap-iron, such as unserviceable pickaxe heads, &c., of which every Executive Engineer must possess a quantity, we should have a total weight of say 5 tons, or 311 lbs. per inch bearing. These rollers may therefore be depended on for consolidating both moorum and metal. They might be made much heavier by filling the interior with lead, but it seems doubtful whether any corresponding advantage would be gained to counterbalance the increased difficulty of draught.

The stone boxes are useful as counterpoises, which is effected by removing a few stones from one box to the other; as for instance, on an ascent a certain weight removed from the rear to the front box would much facilitate the draught of the bullocks, according to a well known law.

In all the foregoing calculations, it has been assumed that all the rollers insist or stand on an area proportional to their length only; this is not strictly true, and is only the case where the surface of the roadway is perfectly hard and in practice the area is proportional to the diameter of the roller. This is an important fact, as thereby the effect of the larger rollers is considerably reduced. To recapitulate then, and to exhibit the effective power of each kind of roller after taking all the above into consideration, we have the following results:—

No.	Item.	Weight per inch.	Proportion.
1	Cartwheel, say 4 feet diameter on the average,	280	1.000
2	Iron rollers, weighted up, 4 feet diameter, ..	311	1.117
3	Stone wheel rollers, weighted up, 3 feet diamr.,	223	0.796
4	Bevilled or barrel-shaped rollers, 2 feet diamr.,	282	1.007
5	Cylindrical stone rollers, 2 feet diameter, ..	94	0.336

There are many officers in the Indian Engineers, in the three Presidencies, who have had a great experience in Road-making, and if they could be induced to come forward and favor us with the results of their knowledge in the treatment of metal of all sorts,—kunkur, laterite, and other materials which are used for roads,—they would expedite the public service by opening up an entirely new subject, and enabling the operations to be conducted in a scientific manner.

MHOW, 1st October, 1865.

A. C.

	Details.	Quantity.	Peeshawur.
	RATES OF MATERIALS, (Continued).		
	Tiles, common, native, at kiln,	per 1000.	5 0
	" Goodwyn's, large, ditto,	"	15 0
	8 tiles ditto,	"	..
	Flooring tiles, 12" square 1½" thick, ditto,	per 100.	16 0
	Ditto hexagonal or diamond shaped, at kiln,	"	..
	Ditto glazed and colored, white, blue or black, at kiln,	"	..
Mis	Lime, best Kunkur, at kiln,	per 100 mds.	.. 0
Skil	Lime, Stone, at kiln,	"	22 30
Ord	Chunam, for polished surface, at kiln,	per md.	.. 0
	Soorkhee, pounded, at kiln,	per 100 mds.	5-8 to 0
	Sand, clean sharp river, on work, carried—miles,	"	..
	Bujree, carried—miles,	"	..
Mis	Kunkur, for metalling, at quarry,	"	.. 0
Skil	Broken stone, for metalling on work, carried—miles,	per 100 c. ft.	6 00
Ord	Kunkur, block for building, at quarry,	"	.. 0
	Brick, broken, carried 8 miles,	"	..
	Timber.		
Mis	Saul, rough in the log, on work, carried—miles,	per cub. ft.	..
Skil	Deodar, do., do.,	"	1 8
Ord	Sissoo, do., do.,	"	1 8
	Toon, do., do.,	"	..
	Cartage.		
	2-bullock cart, to carry 12 maunds,	per day.	0 14
	3 " " 18 "	"	.. 0
	4 " " 25 "	"	.. 0
	RATES OF WORK.		
	Roads.		
	Maintenance of pukka road, including mending of holes and repairs to earthen slopes,	per mile, per annum.	..
Be	Collection and stacking of metal, including cost and cartage for—miles.—		
Mi	a. Kunkur,	per 100 c. ft.	..
Co	b. Stone (broken to size,)	"	6c 00
	c. Broken brick,	per 100 c. ft.	..
A/	Consolidation of metal, at per 100 cubic feet of consolidated work. a. Kunkur,	"	.. 0
Se	b. Broken stone (macadamizing),	"	1 00
Be	c. Broken brick,	"	..
Ri			
Be			
Di			
Di			
Sm			
	Earthwork.		
	Earthwork, excavated in light clay or sandy soil, carried if necessary up to 75 feet and deposited in bank,	per 1,000 c. ft.	4 00
	Ditto, hard clay or with shale, friable stone or boulders, requiring the pick occasionally (deposited in bank,)	"	6 0

* At road

No. XCII.

THE GREAT TRIGONOMETRICAL SURVEY OF INDIA. (2ND ARTICLE.)

Compiled from a Return to an order of the House of Commons. By
LIEUT.-COLONEL A. S. WAUGH, R.E., *Surveyor General* (1850).

BREVET Captain Du Vernet, of the Madras Army, who had previously been employed on the Hyderabad Topographical Survey, was appointed to the Trigonometrical Survey in the year 1840, and in the year 1841 proceeded to prosecute the triangulation of the Himalaya Longitudinal Series, extending from the Great Arc along the southern face of the sub-Himalayan range, so as to connect the northern limits of all the meridional series. This work, together with the Pilibit series, conducted by Captain Waugh, forms a portion only of the "North Longitudinal Series," under which head it will be discussed.

Previous to Colonel Everest's departure, Captain Du Vernet was ordered to continue the North Longitudinal Series, between the meridians of Amua and Karara, which he successfully accomplished in one season. During the year 1844-45 he was employed in prosecuting the triangulation from the north along the meridian of Karara, to form a junction with Captain Shortrede, who was working from the south, as already explained.

On the termination of this duty, Captain Du Vernet was directed to take up the Gurwani Meridional Series, depending on a side of the Calcutta longitudinal series. This work commenced in 1845-46, and was accomplished in two years. The area embraced is 6,298 square miles. In this series was employed for the first time a 24-inch Theodolite, made up by the Surveyor General from various materials belong-

ing to Government, and lying useless in store, the fundamental part being a 24-inch circle hand, divided by Mr. Simms, formerly appertaining to the astronomical circles. It was fitted up with five micrometers, and the results showed that it was capable, in good hands of measuring angles to half a second of the truth.

On the completion of the Gurwani meridional series, Captain Du Vernet with his establishment was transferred to the North-West Himalaya series, proceeding from the Great Arc to Peshawur. This work was intended to form the foundation of the triangulation of the newly conquered Province of the Punjab, and its progress will be detailed further on.

On the termination of the Great Arc, the two parties which had been engaged on that work were reduced, and placed respectively under the charge of Mr. George Logan, a Surveyor of experience and ability, and of Mr. James, principal Sub-assistant. These parties were deputed by Colonel Everest before his departure, to take up the Chendwar meridional series, and the Gora meridional series, dependent on sides of the Longitudinal series, both of which were completed by 1846.

On the conclusion of the Budhon series, Captain Renny Tailyour was ordered to take up the Maluncha meridional series, dependent on a side of the longitudinal series, which was completed by Lieut. Reginald Walker of Engineers in 1846.

The Calcutta Meridional series was commenced at the base line in 1844, by Mr. Sub-assistant Lane, in 1848. The series in its whole extent traverses the alluvial plains of the Ganges, in which great difficulties had to be surmounted. The instrument employed was an 18-inch theodolite, by Troughton and Simms. On closing at Sonakoda base the linear error amounted to 0.64 feet in seven miles, from which is inferred an average error of 0.09 foot per mile; which considering the size of this engine-divided instrument, and the extent of triangulation, 260 miles, entirely in a flat marshy country, may be considered creditable. The area comprised amounts to 4,136 square miles.

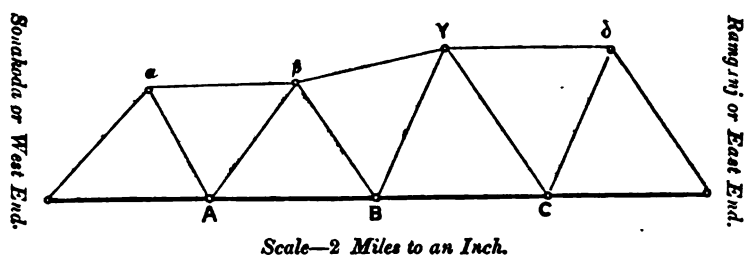
In the year 1845, Captain Thorold Hill, of the Madras army, who had formerly been employed in the Madras Topographical Survey, was nominated by Government to succeed Captain Shortrede. He was

deputed to the charge of the Coast series, intended to extend from the the Calcutta base line to the Madras Observatory, according to Colonel Lambton's original design. For this work Capt. Hill was supplied with a new 24-inch theodolite, of which four had lately been made by Mr. Simms for the Indian Survey, and graduated by his new self-acting apparatus. Colonel Lambton, in his project for this series, contemplated that great difficulty would be experienced in carrying it over the flat lands between Balasore and Calcutta, and the obstacles proved as great as that officer anticipated. The low lands are covered with water, and very unhealthy till December. During the cold season fogs are prevalent, and at the vernal equinox, as well as during the hot season, tornados, or circular hurricanes, are of frequent occurrence, producing the most devastating effects. During one season the whole tent equipage of the party was utterly destroyed. The country is not only flat and covered with groves, but intersected with creeks and marshes, which renders triangulation both slow and expensive. On the other hand, the unhealthiness of the climate was such that every season the party was driven away by sickness, and Capt. Hill's health suffered so much that he was compelled to proceed to sea for two years. From all these causes combined, progress was very slow.

The North Longitudinal Series extends from the Debra Doon base to the Sonakoda base, a distance of 690 miles along the frontier. This work has been executed by various parties at different times. The first part from the Great Arc series to the Ranghir series, was executed by Captain Du Vernet, as already stated. The next portion, between the Ranghir and Amua series, was completed by Capt. Waugh, prior to his succeeding to Colonel Everest. The part between Amua and Karara was executed by Captain Du Vernet, but on account of some defect in the instrument was not considered satisfactory, and was revised by Mr. Logan, who completed the whole extent as far as the Chendwar series, under great difficulties as regards climate and forest, from which his party suffered greatly. The whole of this portion is excellent, having been executed with Barrow's great Theodolite, by Mr. Logan himself. From Chendwar to Muluncha series the work rests on Messrs. Peyton's and Nicolson's observations, with a 24-inch Theodolite by Barrow. The remaining portion from Maluncha series to Sonakoda

base depends on Lieutenant Walker and Mr. Lane's observations, with Troughton's great Theodolite.

In the year 1847-48 the Sonakoda Base line, was measured for the verification of the North Longitudinal and the Calcutta Meridional series, as well as to furnish a new basis for the extension of operations into Assam, and up to the extreme frontier of British India on the east. This base line was very satisfactorily measured with Colby's compensation apparatus, and being proved by minor triangulations, in four sections, exhibited the following results.



Each Section of the Base compared with the whole Base.

	West end to A.	A to B.	B to C.	C to east end.
Measured length, inches, ...	109625.15	110881.17	116428.94	108794.45
Computed from the whole base, do,	109625.00	110881.17	116428.03	108794.51
Error, inches, ...	+ 0.15	0.00	- 0.09	- 0.06

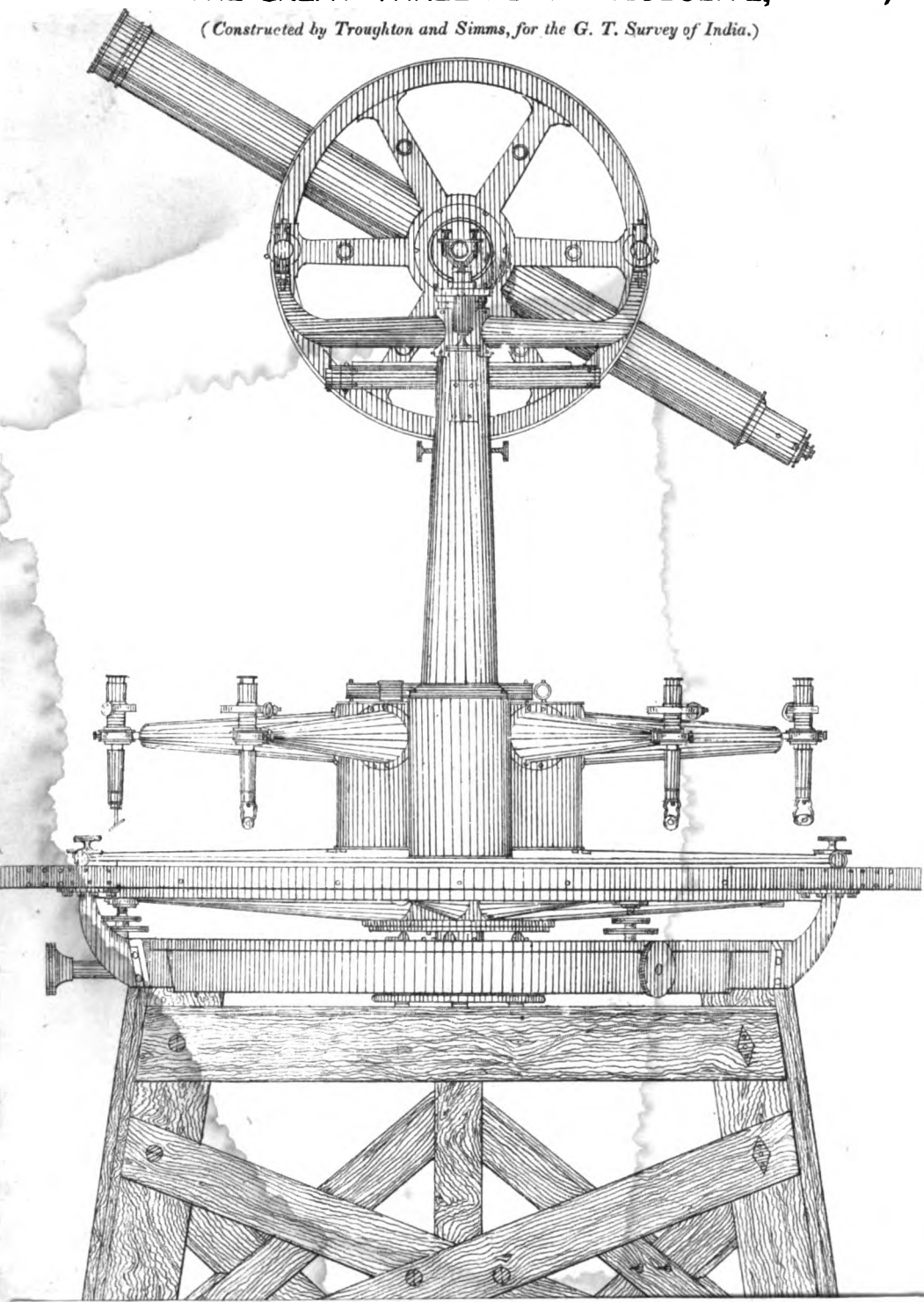
Each Section compared with the other Sections.

Measured length, inches, ...	109625.15	110881.17	116428.94	108794.45
Computed from 1st section, "	...	110881.32	116429.20	108794.65
" 2nd " "	"	...	116429.66	108794.51
" 3rd " "	...	...	...	108794.43

The area comprehended by the North Longitudinal Series amounts to

THE GREAT THREE-FEET THEODOLITE,

(Constructed by Troughton and Simms, for the G. T. Survey of India.)



15,826 square miles, exclusive of the mountain operations in Sikim and along the frontier, which cover a further area of 73,920 square miles, giving a total of 89,746 square miles.

Captain Renny Tailyour, while in England, made himself acquainted with the progress of the Ordnance survey, and returning to India in 1847, gave his assistance at the Base line, after which he was deputed to proceed to Sironj with Troughton's great theodolite, for the purpose of extending the great Longitudinal series from the Sironj Base to Karachi in Sind. Some account of this important series will be given below.

After the conclusion of the Bombay Longitudinal series, Captain Jacob proceeded to England on sick certificate, and was succeeded by Lieut. Harry Rivers, of the Bombay Engineers, by whom the Trigonometrical operations in that presidency were conducted for some time. These consisted of the South Konkan series, dependent on a side of the Bombay longitudinal series. This work was completed between the years 1842 and 1844. After its conclusion Lieut. Rivers took up the North Konkan series, in the prosecution of which the health of his party suffered so much that it became necessary to withdraw from it when it had attained the parallel of $21^{\circ} 54'$. He next took up the Khanpisura series on the meridian of 75° , which he continued up to Ajmere. The area comprised in these several operations conducted by Lieutenant Rivers, amounted to 45,854 square miles.

[The following observations by Colonel Waugh, on the general state of the work up to 1850, have been abridged from his report for that year, and will be found interesting to read before proceeding with the subsequent history of the Survey].

The accuracy attained by the modern operations may be thus briefly stated. In the large triangulation, where of course the greatest refinement and most scrupulous care is observed, an error of one inch per mile, or $\frac{1}{55456}$ part, amounts to 500 inches or 42 feet, or nearly half a second in arc of latitude or longitude in 500 miles, which distance is even exceeded between some of the bases. The work is reckoned liable to half this error when executed with the great Theodolite on the principle of double series; the results attained by the new 24-inch theodolites are but little inferior to this degree of accu-

rary. When the series are single, the liability to error is reckoned to approach nearer to one inch per mile; when performed with good 18-inch theodolites, the error will exceed one inch per mile, according to the character of the graduation. With inferior instruments, or a less careful system, the accumulation of error would approach a foot per mile, which is equal to a ratio of $\frac{1}{5180}$ in linear dimension, or $\frac{1}{10360}$ in area, or $\frac{1}{10}$ per cent., or six seconds of arc in the above distance.

In reviewing the whole progress of the Trigonometrical Survey of India from its commencement by Colonel Lambton to the year 1848, it appears that the grand total of area triangulated amounted to 477,044 square miles, and the grand total of cost to Rs. 34,12,787, or say £312,389, showing an average cost of Rs. 7-2-5 per square mile, or about 13s. 1d., which cannot be but considered remarkably moderate, especially when the nature of the country and climate, as well as the absence of all the usual resources to be found in Europe, are taken into account. The hardships and exposure of surveyors working in the field for the greater part of the year, in such a climate as India, are either little known or little appreciated. They have on several occasions kept the field throughout the year. The duties of the trigonometrical survey likewise are often unremitting day and night, because the best observations are obtained during the nocturnal hours, when the dust raised by hot winds subsides, and the atmosphere becomes clear and calm.

The total area of British India as it stood in 1850, including Sind, Punjab, the and Tenasserim, was carefully estimated at 800,758 square miles,* and the native states at 508,442 square miles, making a grand total of 1,309,200 square miles as the area of survey. A complete delineation of this vast superficial extent, amounting to 1½ million of square miles, confined within an external boundary of 11,260 miles in length, including every variety of configuration and climate, is an undertaking of unprecedented magnitude, demanding considerable time to accomplish with any pretensions to mathematical accuracy. The exertions hitherto made have been unremitting, and it is but justice to say that the progress has been, generally speaking, as honorable to the officers employed as the results have been useful to the country.

* Since then, the great Provinces of Oudh, Pegu, and Nagpore, have been added.—[ED.]

The programme of future operations, as laid down by Col. Waugh in 1850, was as follows:—According to Colonel Everest's design, an ellipsoidal space is included between the great arc on the west, the Calcutta meridional series on the east, the great longitudinal series on the south, and the north longitudinal series along the frontier; which are verified by four base lines at their origin and termination; all measured with Colby's apparatus. This immense ellipsoidal area is filled up by subordinate meridional series nearly one degree of longitude apart, which series depend on the Great Longitudinal series for origin, and on the North Longitudinal for verification. This has been denominated the gridiron system, and obviously possesses superior facilities for rapidity and accuracy. This design of Colonel Everest's has been completed and the country to the west of the Great Arc is intended to be triangulated on precisely the same principles—1st, The North-West Himalaya series will extend from the Dehra Doon base line to Peshawur, where it will be verified by a measured base; 2ndly, the Great Longitudinal series will be extended from the Sironj base to Karachi, where a base will be also measured;* 3rdly, between the Attock and Karachi bases extends a great meridional series,† between which and those before described is included an immense ellipsoidal area, averaging 9° of latitude by 10° of longitude. As all the bounding series will be executed with superior instruments and duly verified by base lines, whereby limits are placed to the intrusion of error, those series will be fit to verify the subordinate meridional series by means of which the intermediate space is intended to be rapidly filled up at every degree of longitude apart, according to Colonel Everest's system.

To the east of the Calcutta meridian it is proposed to extend the North Longitudinal series, from Sonakoda base into Assam. From this series will depend other meridional triangulations at one degree apart, upon which the accurate geographical delineation of eastern Bengal will be based.

The Bombay party will complete the remaining triangulation of that presidency in a few years. There only remains, therefore, to be considered the vacant space to the south of the Calcutta longitudinal

* Since completed.—[ED.] † The Indus series, since completed.—[ED.]

series, in which is embraced the hill country of Gondwana and tributary mahals, between the sources of the Son and Narbada, the Godavari river, and the sea. This region, inhabited by aboriginal tribes, is unhealthy in the extreme, and of no value; but from its rugged configuration, any survey not based on triangulation would accumulate vast errors. It is proposed to triangulate this region by meridional series at every two degrees apart, filling up the interstices with secondary triangulation. In this way that space can be most rapidly surveyed.

The instrumental equipments are admirably adapted for the work in hand, and in 1850, consisted of the following apparatus :—

- 1 Colby's compensation apparatus for measuring base lines.
- 2 Great theodolites, 36 inches diameter, by Troughton and Simms, and Barrow, respectively.
- 4 24-inch theodolites, by Simms and Barrow.
- 2 18-inch theodolites, by Troughton and Simms.
- 6 14-inch Vernier theodolites, by Simms.
- 6 12-inch theodolites, by Troughton and Simms.
- 20 7-inch theodolites, by Troughton and Simms.
- 2 Astronomical circles of 3-feet diameter, by Troughton and Simms.
- 5 Astronomical clocks.
- 14 Chronometers.

The signals consist of Argand lamps and Heliotropes.

With regard to the rate of progress, much depends on the efficiency of the officers, and on the accidents of climate to which the parties are so much exposed. In a hilly country, the average advance made per season by each party is about 120 miles in length by 30 in breadth, or say 3,600 square miles. In a flat country the average is 80 miles in length by 12 in breadth, or about 1,000 square miles. The average for both kinds of ground may be taken at the mean, or 2,300 square miles.

As to the land surveys by which the interior is filled up. The greater part of the Madras peninsula has been taken up on the basis of the great triangulation, by means of minor triangles and military plane table surveys, executed on a scale of one inch per mile. This style of work is remarkably cheap, the cost per square mile not exceeding Rs. 6, or less than 12s.; and in favorable localities, free from jungle fever, which is the dire enemy of all survey operations in India, the expense

becomes much lower. This kind of survey being based on triangulation cannot accumulate error, and gives an admirable representation of the land, but it requires good draughtsmen, who are difficult to be obtained in India. The system is peculiarly adapted to mountainous countries, where the value of the land being small, an expensive system is inapplicable. It has already been extensively carried out in the native states, and it is proposed to extend the same principles to the remainder.*

The Revenue Survey of Bengal commenced in the year 1822, and consists of the measurement of the boundaries of estates, which are executed by theodolite and chain, upon the traverse system. Up to the year 1880, the rate of progress at which the operations proceeded was extremely limited, only 8,020 square miles or little more than half a square degree had then been performed in seven years, with ten officers employed in the department, the annual rate of progress of each surveyor ranging from 50 square miles to 388 as a maximum. The officers employed in those days, however, had little or no assistance, and the duties performed then by the revenue surveyor himself, are now entrusted to competent Assistants and Sub-assistants, with large native establishments under them, whilst the Surveyor acts as a superintendent over the whole; the result of which has been, that since 1830, the whole of the North Western Province districts, all Behar and Orissa, and a considerable portion of Bengal proper, have been completed.*

As respects the accuracy attainable by the measurement of the Revenue Survey, it may be stated generally that the maximum error allowed in linear dimension, according to the test it is submitted to by traverse proof, is 10 links in 100 chains, equal to 5.28 feet per mile; but in the actual prosecution of the extensive surveys of the season 1847-48, covering an area of about 16,000 square miles, the average ratio of correction employed for the closing of the traverses is found to be only two feet per mile, or rather more than one-third of the allowed correction: $\frac{1}{10}$ per cent., therefore, for the pergunnah or main circuit measurement is fully within practicability; $\frac{1}{10}$ per cent. also may be allowed for the area of the district; $\frac{1}{3}$ per cent. for the village survey area, and 1 per cent. for the interior detail measurement of cultivation and waste. But the most severe test to which a Revenue

* Col. Waugh's Report of 1850.

survey can be subjected is, the comparison of its results with those of the Trigonometrical survey; and that this comparison may be performed as readily as possible, a due and proper connexion between the two surveys is essential, and is now scrupulously maintained.

The azimuth of any side of the large triangles likewise proves a check on the deduced azimuth of the revenue survey, as conveyed from one main circuit to another, and this comparison is carefully carried out when opportunity is afforded for so doing.*

It will be apparent, from the foregoing statements, that the Revenue surveys supply the interior filling up of the triangles in the British revenue districts, which are chiefly flat lands, to which that system is most applicable. In native states and wild hilly countries, the Topographical surveys before described are admirably adapted to the object in view, which is a complete and inexpensive first survey of all India. Considered, in this point of view, the work may challenge comparison with any in the world. The Triangulation supplies a permanent and accurate basis for the present, as well as for future internal surveys; for it must be borne in mind that, as the resources of this country become developed under the fostering protection of British rule, the topographical aspect of many districts must, in a moderate number of years, be completely changed. Tracts now covered with jungle will be reclaimed, canals will be dug, marshes drained, and roads established. New towns and villages will arise, fresh groves be planted, and rivers will change their course. That these views are not chimerical may be attested by experience, for places where the tiger, the bear, and the boar, were formerly hunted are now covered with fields, yielding a plentiful harvest to the cultivator. The greatest difference is also perceptible in the extension of towns and villages, showing the increase of productive wealth which is taking place on all sides. These alterations cannot but produce, in the course of time, considerable changes in the topographical features of the country, for which reason revised surveys will be required, and these, like the present ones, will be based on the operations of the Great Trigonometrical Survey of India, which are intended to form a lasting monument for future generations, and an imperishable record of the landmarks of the present time.*

(To be continued.)

* Col. Waugh's Report of 1850.

Correspondence.

THE Editor acknowledges, with thanks, the receipt of the following Papers:—Loondehara Tunnel—Kurrunnassa Bridge—Levelling Operations of the G. T. Survey—Machinery for Punkahs—Nagpore Church—Rawul Pindee and Murree Road—Progress of the G. T. Survey from 1800-1850.

To the Editor.

Poona, November 20th, 1851.

DEAR SIR,—Sir William Mansfield's attention having been attracted by the para and note in your article on the Finance of Engineering, relating to the employment of Soldiers, the Regimental Workshops, &c., His Excellency thinks it may be agreeable to you, with regard to following out the subject hereafter, to learn what has been done in the Army of the Bombay Presidency.

I have therefore received his directions to enclose certain printed papers showing the economical effect of such labor in the Bombay Army, by applying the principle of free labor. The two illustrations of Mhow and Asseerghur are highly satisfactory. It is pleasing to know that through adherence to the principles of voluntary labor and free competition, the institution of Regimental Workshops seems to be really taking root with great advantage to the individual soldier, and in a manner not contemplated by the originators of the system, but affording the further result of checking estimates and tenders from the bazars in a manner which had not been anticipated by the originators of the institution.

Barrack furniture, repairs of barracks, &c., are now being completed in many stations of this Army by the European soldiery, according to freetenders, which are accepted by the Departmental Officers if they be advantageous. No favor or affection is shown, and all parties seem to be satisfied.

With His Excellency's sanction this principle is now being applied to the Native Regiments, experimentally; but Sir William Mansfield is sanguine of being able to organise a labor movement throughout the Native Army which will occupy the time of the men, and add considerably to their emoluments.

The experiment has been commenced at Poona; many hundreds of the Sepoys having been employed on the Government Works, voluntarily on their part, the men

so employed received the wages of the market. They are not permitted of course to evade either duty or drill; but by the employment of their leisure hours at such task work as they can obtain from the Executive Engineer, they have been able to earn several rupees per month per man to their own great satisfaction. The Executive Engineer has been highly satisfied with their work, which is much more rapid than that of ordinary laborers, in consequence of their habits of discipline, and of its being therefore easier to obtain larger joint results from them as a body working together than is generally observed amongst native workmen.

Believe me, &c.,

R. PHAYRE, LIEUT.-COL.,
Qr.-Master Genl. of the Army.

(Enclosures in the above letter.)

MEMORANDUM REGARDING THE EMPLOYMENT OF THE EUROPEAN TROOPS
 UPON PUBLIC WORKS AT ASSEERGHUR.

1. When sanction was received, in September last, to proceed with the Iron Shelves in the Asseerghur Barrack, the Native Blacksmiths proved unequal to the task, and competent European Smiths were found in the Detachment of Her Majesty's 83rd Regiment at that Station. The Native Carpenters (those employed upon Contract Work excepted) were also unequal to the work of making the Arm-racks, and European Carpenters were found for that purpose. Again, in the removal of the slab stone eaves from the roof of the old Musjid, the Native laborers could not do it, and Europeans were employed.

2. During the month of October, fever in the Pettah caused serious reductions in the muster of all classes of Native labor, and the Railway Agents about the same time made their appearance with large sums of money, and enticed away some of our unskilled labor at high rates of pay,—in fact as high as seven (7) annas per day for a biggarie. To sit down and see the works come to a stand-still was out of the question; equally imprudent would it have been to compete with the Railway for labor. Lieutenant Mant, while here, increased the biggarie's pay from 3 to 3½ annas per day, and as subsequent increase to 4 annas failed in inducing some of the work-people to remain, our only recourse became the employment of the Soldiers. It was found that the Detachment could furnish as follows:—

2 Carpenters—2 Blacksmiths, 1st Class—2 Blacksmiths, 2nd Class—4 Stone Masons—2 Sawyers—1 Glasier—and from 50 to 60 Laborers out of a total strength of about (90) ninety. The Sergeants do not work, as none of them are Mechanics, and it would not be prudent for them to work as laborers. A Non-Commissioned Officer is however employed as Time-keeper with the laborers. The following rates of pay were adopted from the first, viz:—

	R.	A.	P.
1st Class Blacksmith, per day	1	4	0
2nd " " 12 annas per day,	1	0	0
Carpenters, per day,	1	4	0
Laborers, working from 8 A. M. to 5 P. M.,	0	12	0
" " 8 to 10-30 A. M. and from 2-30 to 5 P. M.,	0	8	0

Those men only who could work under cover have been allowed to work all day. The work performed by the men of the Detachment consists of—

1. Plaster to half the Left-half Barrack 8,500 superficial feet.
2. Completing paved floor of " 1,500 "
3. Whitewashing Left-half Barrack.
4. Paving water-room to Left-half Barrack.
5. White-washing "
6. Iron-shelves to two half Barracks.
7. Arms-racks to "
8. Arms-racks to the old Musjid (temporary Barrack).
9. Petty repairs.
10. Removing slab-stone eaves of the old Musjid.
11. Excavating moorum floor of Right-half Barrack.
12. Making footpaths in European Lines.
13. Collecting tiles from sites of old Pendalls and placing them on the roof of the Left-half Barrack.
14. Levelling sites around the new Barracks.
15. Demolishing old Native Infantry Pendalla.
16. Demolishing other old Buildings.
17. Glaziers' work to the new Barracks.
18. Repairs to Barrack Furniture.
19. Iron doors to Solitary Cells.
20. Iron windows to Quarter Guard.
21. Carrying dressed stone from Quarry to Barracks.
22. Drawing Carts laden with stone " "
23. Repairs to the Road inside the Fort Gate.

3. The men have worked well, and conducted themselves admirably, always sober on the works without exception, and strictly obedient in the performance of whatever work may be pointed out to them; without the aid of the Troops it is almost impossible to say when the Barrack would be completed.

4. It deserves particular mention that the Europeans will work as laborers to Native Masons in carrying stone, bricks, mortar, &c., &c., and that no complaints have been made by the Native women, who were rather shy at first of working near the Soldiers.

5. Captain Trent's presence amongst his men, every day, while employed upon the Public Works has materially added to the success of their employment.

6. Of the value of the European labor, employed at Asseerghur, as compared with that of Natives, it may be remarked that the works, numbered 1 to 5, 9, 11, and 13 to 23 inclusive, have been carried out within the estimated rates, and, in some instances, cheaper than they could have been by Native labor, notwithstanding that Tools had to be made, or provided especially for the Europeans, and that the cost has been included in the accounts of their works.

(Signed) W. F. KNIGHT,

Supervisor, Public Works Department.

Asseerghur, 18th December, 1863.

REPORT BY ORDER OF HIS EXCELLENCY THE COMMANDER-IN-CHIEF.

Head Quarters, Bombay, 22nd February, 1864.

This Memorandum, forwarded by the Officer in supervision of Public Works at Asseerghur, under date the 18th December, 1863, with regard to works performed by Soldiers of Her Majesty's 33rd Foot at that Station, is considered a most satisfactory illustration of the development of the Workshop system, which has been yearly gaining strength in the Artillery and the several corps of Her Majesty's Forces serving in India, and goes to show that wherever European troops are stationed, the very best description of skilled, as well as ordinary labor is available; in this instance at a cheaper rate than the Native labor could be obtained—one consideration only being essentially necessary, viz., that the men should not be exposed during the day. Although in some cases shops have not thriven so well as in others, it is known that opportunity is alone wanted to develop them. In every Battery and Regiment the organization is complete, and application has only to be made to Commanding Officers to receive prompt attention, they being quite alive to the good results which follow the employment of their men, and consequent relief to the men from the monotony and tedium of an unemployed life.

The system of Workshops is founded on the principle of voluntary labor, the same being afforded for what it is actually worth. It is strenuously ordered and enforced that no favor is to be given to the Soldiers, and that they must depend entirely on underselling the Native artisan,—this being shown both in price and the quality of the work, and the amount done.

The Public Works, Commissariat or Barrack Departments, can take the tenders of the Workshops or not as they please, according to such a principle. It is, therefore, absolutely necessary, in the Commander-in-chief's opinion, that the principle should be preserved intact, and that the soldier should obtain all he can thus earn without regard to a working pay system, which was designed to meet the necessities of an opposite principle. That principle rests on the fact that under certain circumstances of service, the Soldier can be ordered under the Articles of war to perform particular kind of skilled work. The order having been obeyed, he receives a moderate remuneration for the time thus spent, the work which he has performed being, in point of fact, an extra Military duty. This is a very different thing from the development of voluntary labor. There can be no doubt that to recur to it would at once shut up every Workshop in Her Majesty's Regiments, and so defeat one of the most useful reforms which was ever introduced.

The distinction between an Infantry Regiment, which is recruited merely for Military duty, and of enlisted Sappers and Miners, who receive higher rates of pay and according to particular rate of scales, puts skilled labor at the disposal of the State, is, His Excellency thinks, too obvious to require further disquisition on his part.

By order of His Excellency the Commander-in-Chief,

T. STOCK, LIEUT.-COLONEL,

Adjutant General of the Army.

*Public Works, Execution of, by Contract by Troops.**Bombay Castle, 13th April, 1864.*

RESOLUTIONS.

1. Government have had lately under consideration a case where very valuable assistance was afforded by the detachment of Her Majesty's 83rd Regiment, in the execution of Public Works at Asseerghur.

2. Government consider that the arrangement, which in this case has proved so very successful, might with great advantage both to the State and to the soldiers, be adopted elsewhere in expansion of the workshop system, which has already been established.

3. Government are therefore pleased to direct that at all stations where there are European Troops, the Executive Engineer, on receiving sanction for a work that might with advantage be executed by such agency, shall communicate with the Commanding Officer, and shall indicate the nature of the work to be executed, its probable cost, and the period within which it should be completed, and at the same time invite a tender for its execution by contract by the Troops.

4. If the tender by the Troops is too high, or higher than any which may have been received for the same work from any other person, it may be rejected; but if it is favorable in all respects it should be accepted. It being clearly understood on both sides, that in any arrangement of this nature, the ordinary rules of trade must be attended to; that the workshops must compete in the open market, and depend for their success on underselling the native tradesmen, and manufacturers; and on such terms make what profit they can.

5. Much of the success of the plan will depend on the manner in which negotiations are conducted between Commanding Officers and Executive Engineers. A hearty co-operation is both necessary and desirable, if the wishes of Government are to be fully carried out; and while enjoining this spirit in treating this question on the part of the Officers of the Public Works Department, Government desire to move His Excellency the Commander-in-Chief to issue such directions as he may deem best, to ensure a like feeling on the part of Commanding Officers.

6. A quarterly report should be made to Government of all works performed by European soldiers, which should be in the form of a concise narrative of the progress of the works to which it relates, accompanied by a tabulated form showing the quantity of each particular item of work performed, its cost, and a brief specification of its nature. This return should also show the average strength of soldier-artisans, and laborers daily, employed on the works.

7. Government consider Mr. Supervisor Knight deserves great credit for his arrangement in regard to the work performed at Asseerghur by the soldiers of Her Majesty's 83rd Regiment.

(Signed) M. K. KENNEDY, LIEUT.-COL., R.E.,
Secretary to Government.

The other case referred to in the above letter is too long to print, but is as satisfactory an example of the economy and utility of Regimental

Workshops, as the first case is of the advantage of employing soldiers upon Public Works.

In the article referred to by Col. Phayre, I expressed an opinion adverse to amateur, i. e., voluntary, work of this kind, which I am very glad to have corrected on such good authority.

It is a minor question, whether the profits of such work should be enjoyed by the soldier alone, or whether they should be shared by the State. The main point to be insisted on I take to be, that soldiers can be occupied either on Public Works or in Regimental Workshops to the mutual advantage of themselves and the State, and without any diminution of their efficiency as soldiers. If this can be done by voluntary means, as in the two cases above quoted, no doubt it is best—if not, I believe it should be insisted upon as part of the duty of a soldier just as much as his parade duties or rifle drill.

But when Commanding Officers so seldom recognize the importance of their men being adepts in such strictly military work as the use of entrenching tools and the construction of field works,* and, indeed, as a rule greatly dislike their men being employed in any such work, how can it be hoped that they will cheerfully encourage their working as laborers on roads, as masons on buildings, or even as carpenters in their own workshops?

It all depends on the Officers—let the feeling be once established that *all* kinds of work useful to the efficiency of an army are as honorable as actual fighting and as much part of a soldier's duty, and there will be little difficulty in the matter; and it is most encouraging to see that the attempt is being seriously made in at least one of our armies. I believe that such employment is a corollary to the Regimental schools. It is of no use educating men unless you give them vent for their awakened energies, or at least for their physical powers. You simply make them dissatisfied with their position. The large number of time expired men who are now taking their discharge, seems to show this.—[Ed.]

* There are few Engineer Officers who have had to superintend line working parties at a siege who do not know this, and yet who would not also bear witness that the smartest Regiments in the battle field also furnish the best working parties. Why should not every Regiment be employed during part of the cold weather in field works?

Correspondence.

THE Editor acknowledges, with thanks, the receipt of the following papers:—Public Works Progress Report for 1863-64—Report on the Gogra—Brick-making in the Tropics—Design for a Canal Fall—Railway Institute, Lahore.—Laying out Curves—The Yangul Bridge.

NOTICE TO CONTRIBUTORS.—Any Contributor who may desire to have a few extra copies of his own paper, can be supplied *gratis* on application to the Editor in time.

To the Editor.

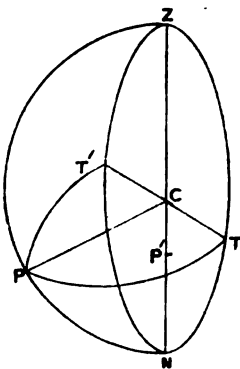
SIR,—Will you be good enough to explain how I am to construct a perpendicular Sun Dial, such as are erected on the south face of some village churches at home—say for N. Lat. $31^{\circ} 30'$? It is an easy matter to make the calculations for the ordinary horizontal dial, but I can find no book that gives instructions in respect to the other.

Banks of the Ravee, }
February 15th, 1865. }

Your obedient Servant,
PUNJABEE.

To construct a prime vertical Dial.

Let TNZ be the plane of the Dial produced to cut the celestial sphere,



P the pole of an opposite name for the latitude, PZN the plane of the meridian, and CPT the plane of an hour circle, and CP the direction of the style. Then PN is the co-latitude, and TCT' the hour line corresponding to that meridian, which gives the hours of the same name at T and T' in the forenoon and afternoon. Let l = the latitude, h = the hour angle in degrees, c = the co-latitude PN. Then we have in the spherical triangle PNT.

$\text{Cot } h : \text{rad} :: \cos l : \tan t$, where t is

the angular distance of the hour lines in succession from the hour line of noon, or

$$\log. \tan t = \log. \cos l + \log \tan h - 10.$$

Example.—To construct a vertical Dial for a place in latitude $31^{\circ} 30'$.

Angular distances of the hour lines from noon will be—

For 1 P.M. or 11 A.M.	$\tan t = \cos 31^{\circ} 30' + \tan 15^{\circ}$
12° 52'	= $\tan 12^{\circ} 52'$, nearly.
For 2 P.M. or 10 A.M.	$\tan t = \cos 31^{\circ} 30' + \tan 30^{\circ}$
26° 12'	= $\tan 26^{\circ} 12'$
For 3 P.M. or 9 A.M.	$\tan t = \cos 31^{\circ} 30' + \tan 45^{\circ}$
40° 27'	= $\tan 40^{\circ} 27'$

and so on.

The angle formed by the gnomon with the vertical face of the dial will of course be $58^{\circ} 30'$ (= co-latitude.)

A correspondent from the Central Provinces, writes:—

“With reference to a paragraph in a paper by you in No. V., I take this opportunity of telling you that we have recently built a large covered saw pit (for 10 pairs) for the shops of this subdivision, and the men have taken to it well. The top sawyers stand up to their work like Englishmen and men, instead of sitting down as they all do hereabouts.”

Correspondence.

THE Editor acknowledges, with thanks, the receipt of the following papers :—Indus Silt Experiments (2nd Paper)—Reports on Indian Railway Gauge—G. T. Survey Report for 1863-64—New Police Courts, Bombay—Ghaut Tracing in N. Canara.

NOTICE TO CONTRIBUTORS.—Any Contributor who may desire to have a few extra copies of his own paper, can be supplied *gratis* on application to the Editor in time.

To the Editor.

SIR,—I have just seen No. VII of your "Papers," containing an elevation of a Clock Tower for Umritsur. It is not mentioned in the letterpress, whether this Tower has yet to be built, or whether the work is in progress, or has been completed. If the Clock has not yet been set up, I would offer for the consideration of those concerned this opinion, that if the intention of placing in this Tower the dials described in the Report be carried out, disappointment will be the result, for 5 feet dials are not at all adapted for such a situation.

The Tower is described as being 133 feet in height ; and, accordingly, the drawing gives the height of the clock dial as about 76 feet from a platform, which is itself raised 10 feet above the ground level.

For such an elevation as this, the clock dials should not be less than 8 or 8½ feet in diameter, in order to be clearly visible from ordinary distances. Consequently, the proposed 5 feet dials, would only offer to view an area of 19½ square feet, instead of a proper area of 50 square feet !

It is mentioned in this report, that the Tower was originally projected of a height of 100 feet, and proportionately the dial in this design would have been about 57 feet above ground. A dial from this height, not counting the platform, would be 5½ feet in diameter, and probably the dials mentioned in the estimate were intended for this height, whereas they are totally unfit for their new position.

Your obedient Servant,

POONAH.

May 24th, 1865.

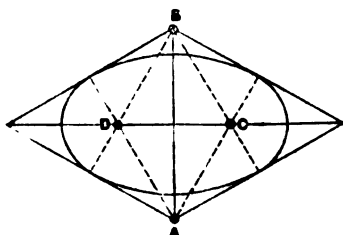
The Clock Tower is still under construction, and "Poonah's" remarks will no doubt be duly considered by the Architect.—[Ed.]

A correspondent sends the following :—

No doubt, most people have found in Isometrical Projection, that, however simple the method may be when dealing only with straight lines, there is a considerable amount of time and patience required in delineating curves; especially, in the projection of machinery, where each cog-wheel entails so many constructive lines, that this alone would prevent the method coming into very general use.

The following method of projecting a circle may not be generally known, and though not quite correct, will be found sufficiently so in practice. It consists in

laying down a three-centered curve, which will co-incide as nearly as possible with the true ellipse.



Let AB be the isometrical rhombus of the square circumscribing the circle; from each of the obtuse angles A and B let fall perpendiculars upon each of the opposite sides; these perpendiculars will bisect the sides, and intersecting in C and D, will give the centres of the two small arcs—A

and B will be the centres of the larger ones.

Correspondence.

THE Editor acknowledges with thanks, the receipt of the following Papers:—Lengths of Elliptic Arches—On Vaulted Roofs—Le Comptage Ambulant—Memo. on the Cavour Canal—Notes on Road Materials in India—Measurement of Irrigated Lands—Strains on Lattice Girders—Jamboosur and Broach Railway—Notes on Levelling.

To the Editor.

Dalhousie, 10th Oct., 1865.

SIR,—IN No. VIII. of the Professional Papers on Indian Engineering, of August last, in your article on the Ganges Canal Controversy, you say, "it began to be removed not very long ago, that many of the important masonry works of the Canal, were in a dangerous state. In 1862 it was entirely closed for six months, to effect repairs; and though this was a solitary instance, it was known that the cost of ordinary annual repairs was very heavy, while it was reported that the quantity of water carried by the Canal was considerably under what had been originally intended."

As I was in Executive charge at that time, I think it is my duty to correct this mistake. The solitary instance referred to, was the dangerous state of the Mahmood-poor Falls, which are 15 miles below Roorkee. The state of these works was reported by me early in August 1862, and by orders of the late Superintendent General of Irrigation, the supply was then reduced.

From this time, till the 15th October, 1862, the Canal was running with a small supply, and on this date the Canal was closed for the annual repairs; after completing the repairs, as directed by the late Superintendent General, water was re-admitted into the Canal on the 25th November, 1862, but after it had been kept open for nearly two weeks, it was found that these Falls were again breaking up; consequently, the Canal was again closed on the 8th December, 1862, and a second set of repairs were completed, as directed by the late Superintendent General.

On the 22nd of the same month, water was again re-admitted, but the following morning it was found that the work had again failed, which necessitated the closing of the Canal a second time.

The third and last set of repairs, carried out on a different plan, were completed on the 10th January, 1863, when the Canal was again opened; and I am happy to observe, by Major Crofton's report, published in 1865, that they still stand.

You will observe, therefore, that there were three distinct sets of repairs; the first, occupying one month and ten days; the second, two weeks; and the last, eighteen days; and taking them all together, the whole period the Canal was closed on this occasion only occupied about ten weeks, instead of six months.

The probable cause of this mistake, was that the *supply* was reduced for upwards of six months on this occasion, but as it is liable to cause the public to consider the Canal to be in a much worse state than it is, I beg you will kindly insert this letter in the next number of the Professional Papers.

I have, &c.,

T. LOGIN,

Late Supdt., Northern Division, Ganges Canal

The Editor's attention was drawn to the mistake, above-mentioned, when some 50 copies of No. VIII. had been sent out. In all the other copies, the word *six* in the last line of page 203, was corrected with the pen to *three*. In explanation of the failure of the repairs above alluded to, it may be stated that the whole difficulty consisted in the water having to be turned on before the green masonry had had time to dry. A cement that can be laid in water, and which will harden under water, within 48 hours, is, so far as Editor knows, still uninvented, and its utility in the repair of Canal works could scarcely be over-rated.—[Ed.]

MY DEAR SIR,—You must of course be aware of the difficulty of getting good drinking water in many of our Himalayan Hill Stations; and how this difficulty has decided at once against the adoption of many sites in other respects admirably adapted for Sanitaria. Not only is water not easily obtained, but what is obtained is often very bad; and it is as well not to question the *dhceestie* too closely, as to where it comes from.

Now the annual rain-fall in most of these Stations, is somewhere over 80 inches at least; and it seems to me to reflect little credit on our Indian Engineering, if we cannot manage to catch some of this tremendous fall, before it finds its way into the rivers below. Why should not large Tanks be built in suitable hollows as reservoirs of rain water? Cities at home are supplied in that way, and with the most satisfactory results. The size and form of such tanks would be a matter of simple calculation. Their construction in the hills where all building materials are at hand would be easy and inexpensive. To keep them pure they might be vaulted over, and the water filtered through gravel beds.

Can you, or any of your readers tell me if Tanks have ever had a fair trial, and if so how have they answered? I do not mean by *tanks*, the weedy ponds with masonry sides, which the Hindoo so admires, but properly constructed water reservoirs. For it seems to me, that by this simple expedient, we render ourselves independent of natural springs, in the choice of new hill Stations.

Perhaps some of our Bombay brethren could favor us with a history or description of the celebrated Aden tanks, which form the sole water supply of the garrison, and which I believe are only filled by the rain falling, not more than once every two or three years.

Believe me, &c.,

C. C. S. M.

UNIVERSITY OF MICHIGAN



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