

of which they dread. One company of Kalihants (Mysore Labor Corps) which was sent for work on the Angoombee road soon deserted in a body, and on presenting themselves at Bangalore scarcely a man was able to stand from the effects of fever. The only place from which labor could be drawn to any extent was Canara, but now since the large works at Sheda-segur, &c., have been started, this source has completely failed; not a man is to be procured.

One most fruitful source of difficulty with reference to labor, is the competition arising from the extension of coffee plantations. It frequently occurs that no sooner has one of our subordinates by great labor collected a sufficient body of coolies, than a planter's agent steps in and carries off the whole under heavy advances. So common is this occurrence that it is believed to be systematic. An advance in ready money has thus been made to a single influential cooly of 60 rupees the rest of the gang getting smaller sums. While, however, it may be satisfactory to know that some of the planters have politely acknowledged the services the subordinates thus render, the difficulties with which our department are left to struggle are most disheartening.

In justice to the planters it must be admitted that they are at times put to grievous stress for want of labor, and when this occurs at a critical time for the crop they have no choice but to get labor at any price. In Munzerabad only a very few years ago, coolies could be got for Rs. 2-8. They are now 5 and 6 rupees, and ere long will probably be 7 rupees per mensem. In Nuggur the rate has not gone as yet much higher than 4 rupees, but it is rapidly rising.

In the concluding portion of Lieutenant-Colonel Kennedy's Report on the works in north Canara, he draws attention to the grave difficulties attending the supply of labor in that part of the country; when, therefore, I mention that to north Canara, Captain Palmer had till lately to look for much of his labor for the works in the Mulnaad, and that even that source is now cut off, the importance of the question as concerns this department will be sufficiently apparent. Spite of every effort works only creep into existence in Nuggur. No contractors can be obtained. Every subordinate either loses his health there and has to be sent away, or, still worse, deserts his post. This is but plain matter of fact, which I think it right to state in justice to the Executive Engineer.

Yet it is absolutely necessary that the valuable coffee land at the back

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of the Bababoodens and about Coppa, Kig, Namur, &c., should be opened up, and a line of communication established between the Boond ghaut and the country lying north, much of which has probably never been visited by any European; means must therefore be found for grappling with this labor difficulty.

As in some measure likely to effect this object, I would venture to propose that the great bulk of the Kalihaut Corps, now about 852 strong, be sent to the Boond ghaut and Nuggur; that an apothecary with all requisite medicines be attached to each company, and that every man be given good warm clothing; further, that the pay while so engaged be raised to 6 rupees per mensem. In addition to this I would raise more companies in Nuggur itself, and enlist men if possible down the coast. I do not say that this will succeed; much, however, I think can be done by selecting in the first place really able-bodied men, taking care of them and giving high pay.

The Commissioner has lately seen fit to recommend the advisability of making the Executive ranges conterminous with the new civil districts, and there can be no doubt that if this be acceded to, great relief will be given to the Executive Engineer of Nuggur, who is no less overburdened by the difficulties connected with his subordinates, and the supply of labor, than he is by the undue extent of his range. I now beg to pass on to my tour undertaken during the last week of April, the extent of which is given above, and having already made this report too long, I shall endeavor to be as brief as possible.

One main object of this tour was the inspection of the Railway feeders to the east of Bangalore, which have been under execution during the past year. I found them extremely well laid out, and all, with the exception of the line between Colar and the Marmootal (near Coppum) station, nearly completed. Even on this line rapid progress was being made. There being in no case large streams to cross, the masonry works have been extremely light; still I think the rapid and efficient manner in which they have been executed, shews the great advantage of a proper system of contract by which they have all been carried out. The whole of these roads should be complete by the end of next month, or several months before it is probable the railway will be open to the public.

Proceeding round by Tulgarah and Thadgole, I inspected the fourteen terminal miles of the new Cuddapah road, the frontier being about two

and a half miles beyond Ralpand. Much of the end portion of this road lies through a hilly country covered with scrub jungle, and though there is no bridge here above thirty feet span, a good deal of minor lateral drainage had to be provided for. The work has been performed very creditably, and, with the exception of one or two breaks at nullahs in the Madras territory, the line is complete from Bangalore to Cuddapah; and notwithstanding that perhaps no very great amount of through traffic can be expected, it will be a most useful line. New bungalows at Tulgarah and Ralpand had been opened for the use of travellers shortly before my visit.

Returning along the same road I was enabled to examine the trace of the proposed line, thirty-two miles in length, leading from Chintomonipett to Bangapilly *via* Sandly, and which it is very desirable should be opened soon, both in the interest of the Railway Company and that of the country generally. I was enabled to suggest several improvements in the trace, which, with other matters, have been dwelt upon in my detailed report. Here it will suffice to say that throughout the line both the soil and gradients are favourable, and setting aside the provision for minor drainage, only three bridges will be required, one over the Pennakerray (three arches of twenty-five feet each), another over the Coosbavutty (one arch of twenty-five or thirty feet), and the third across the Chittravutty river, near Bagapilly, at the junction of the new road with the existing main road from Bangalore to Ghooty. This last river will need seven or eight arches of twenty-five feet.

Some wild rocky country is passed through on this road, and a little blasting will be required. The survey and estimate originally prepared under orders of the Executive Engineer, Mr. Dobbs, will require but little alteration, and will ere long be forwarded to Government for entry in the next budget.

An alternative site had been proposed for crossing the Chittravutty river, but I was led to recommend the one above alluded to as possessing the advantage of placing the Cusbah town of Bagapilly in immediate communication with the main road, and of enabling a plough tax road to be pushed forward, when funds may admit, to the important town of Goom-naickenpollium, which, buried in the rocky mountains to the east, has at present no proper communication with any of the main lines of the country.

On referring to the Trigonometrical Survey it will be observed that the Cusbah town of Goreebednore (about twenty-five miles north-west of

Nundeeroog) is situated in a valley bounded by a range of hills on the east, stretching northwards from Nundeeroog, on the west by the range containing Daveroy and Mudgherrydroogs, and on the south by Munclyproog, and is thus cut off from communication with other parts of Mysore. There exists, it is true, a track through the mountains on the east by which pack cattle and even half laden carts can proceed to Goodybundah and thence to the Bangalore Ghooty road, and again on the south there is a steep ghaut on the south-east of Manelydroog, which gives an exit to some of the produce southwards; but for all the practical purposes of trade the valley is at present excluded from the system of roads in Mysore. The natives consider it as belonging to the country below the ghauts.

For many reasons it is most desirable to alter this state of matters. Not alone is the valley rich and productive, but the Madras (Bellary) authorities are most anxious to have Goreebednore placed in immediate communication with the town of Hindoopoor to the north, to which place they have carried a line in continuation of that leading through Handy-anantipoor and Pennacondah.

An inspection of the Map will shew that if we carry a road from Doda-battapoor through Goreebednore to Hindoopoor, we shall not only open up this hitherto closed valley, but lay the basis for establishing a more direct route than now exists from Bangalore to Ghooty and thence to Hyderabad. I inspected the greater portion of this line with Mr. Dobbs, and as a trace will be made before long followed by a detailed estimate, the subject will probably be definitely brought before Government in connection with the next budget.

Another obvious line of road is that which would connect Mudgherry with Goreebednore, and thence through Wottabahosshully and Goodybundah to the main Bangalore Ghooty road. We have now a line almost finished between Seerah and Mudgherry to the westward, and this proposed road would simply form its continuation, piercing the Goreebednore valley from east to west, which is very much needed. The whole of this line, with the exception of the ghaut leading down from Goodybundah to Wottadahosshully, might be constructed from the plough tax fund, the ghaut which will require careful tracing and working out being left to this department for execution.

I may mention that in addition to these lines a plough tax road is projected from Goreebednore to Mauchanhully to the south-east and thence

to Chickballapore. The only difficulty in this communication will be a small ghaut leading through the hills between the two latter places. My examination of this ghaut led me to conclude that it must also be carried out by our department, and that before commencing, the line must be accurately surveyed and traced, the ground being extremely difficult and encumbered from end to end by piles of rock.

Before leaving this interesting valley I must make a brief allusion to the Wottadahosshully tank, which is, without exception, the finest work of the kind I have seen in the country. It is situated at the end of the valley which has its head near Goodybundah, and receives the whole of its drainage, converting the country below, opening to the westward into a wide irrigated plain. The approach to the head of this beautiful sheet of water is by the pass in the mountains leading down from Goodybundah; its length, when this tank is full, is perhaps two and a half miles by over half a mile in width. Though thus much smaller than many of the tanks in Mysore, it is remarkable for the great height, (sixty feet) of the bund, which is 12 or 1300 feet long, and most picturesquely situated between the two flanking hills at the end of the valley. The mountains on all sides are composed of heaped-up masses of granite, and the hill to the south against which the bund abuts on that side, cannot be less than 1,500 feet high.

The bund has a solid stone facing on both its front and rear slopes, and differs very much from all other I have seen, not alone in its height, but the manner in which the work has been executed, being quite straight and workmanlike throughout. The immediate object of my inspection was with reference to the sluice, which was reported out of order and for which an estimate had been framed. This I, however, found to be erroneous, and but a trifling amount of work required.

I may now conclude this report by mentioning that the only matter of much importance which further required my attention was the so-called Nundidroog ghaut, situated north of the hill, and on the provincial road leading through Chickballapoor to Colar. It has hitherto been so steep as to prove an effectual bar to through traffic. Though a good sum of money will be required to correct its defects, I was enabled to select a line, which on being worked out will give sufficiently easy gradients.

R. H. SANKEY.

No. XVI.

A G R A F O R T .

*Report of a Special Committee, assembled by order of HIS EXCELLENCY
THE COMMANDER-IN-CHIEF, to consider the question of the improve-
ment of Agra Fort.*

PRESIDENT.

Brigadier St. G. D. SHOWERS, C.B.

MEMBERS.

Colonel F. TURNER, C.B., Bengal Artillery, Agent for Gun Carriages.

Lieut.-Colonel A. CUNNINGHAM, Bengal Engineers, Chief Engineer, N. W. P.

Major J. H. MAXWELL, Bengal Engineers.

Capt. J. D. CAMPBELL, Bengal Engineers, Superintending Engineer, N. W. P.

Agra, 26th January, 1860.

The Committee proceed to take into their consideration, the following subjects, as appear to them indicated in the instructions, namely:—

1st.—Strengthening the fortification as it at present stands.

2nd.—Formation of outworks as affecting the Jumma Musjid and Tripolya, and the construction of detached posts.

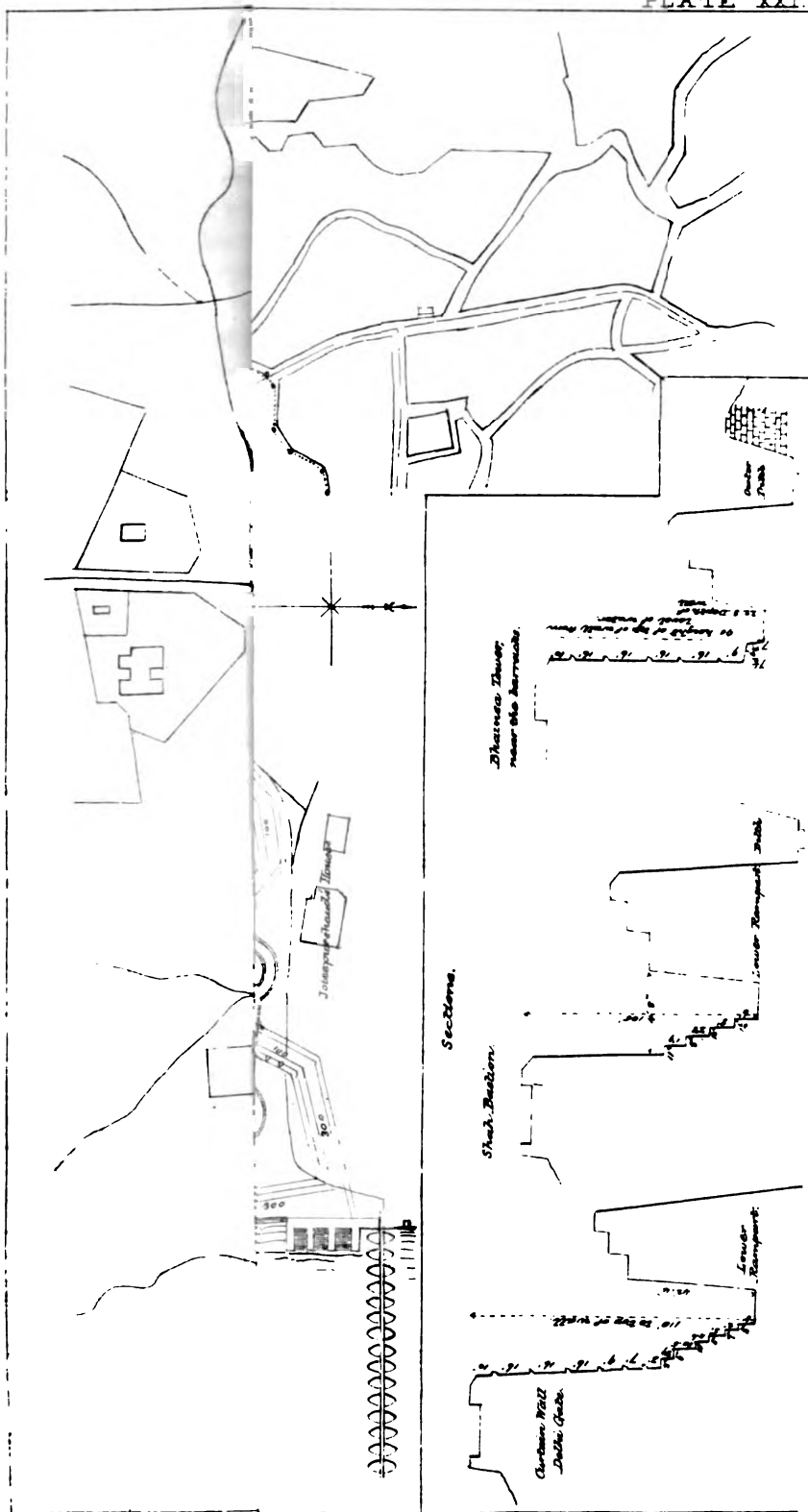
3rd.—The levelling and clearing of the ground immediately under the walls of the Fort.

The Committee having discussed these several subjects with plans before them, and having inspected the ground and position, proceed to report as follows.

The chief defects of the Fort of Agra are the following:—

I.—The deficiency of flanking defences.

II.—The want of a glacis to cover the scarp walls.



III.—The great height of all the batteries above the country, and the consequent plunging and defective nature of the fire, which is ineffectual at short ranges.

IV.—The inequality of the ground on all sides, and the dangerous vicinity of the city on the north and west faces, affording cover to an enemy, to within breaching distance of the walls.

The Committee beg to offer the following suggestions, with a view to lessen, or entirely remove, the serious defects above noted.

I. As to the *deficiency of flanking defences*, we are of opinion that these may be effectually improved by the construction of works in connection with the fort itself, namely,

First.—Earthen bastions outside the corner towers on the river face.

These bastions should be completely isolated from the *fausse braie* by ditches, and be connected with the body of the place by gates. One of these gates, (for the bastion at the north-east corner,) already exists in the northern curtain close to the Shah Boorj tower; and another (for the south-east bastion) exists on the river face of the out-work of the Ummur Singee gate.

These bastions will be so disposed as to afford flanking fire not only to the river face, but also to the north and south fronts, respectively. They will also cover the two weakest points of the fort, which a besieger would be sure to select for attack (and one of which, the south-east tower, was that of Lord Lake's attack). Further, in conjunction with the Water-gate bastion in the centre of the river face, (which will subsequently be noticed in detail,) they will cover with their fire all the ground on the opposite side of the river, which an enemy, contemplating attack on that side could occupy with his batteries, as it is within range from 600 to 1,200 yards.

The proposed north-east bastion also completely covers all approaches to the bridge on both sides of the river, and assists in the flanking defence of the works which are proposed for the Jumma Musjid, within a range of 700 yards.

The new bastion on the south-east provides defence on the line of approach from the direction of the Taj. It also sweeps with its fire, within easy range the two principal ravines on the south side, and covers the approach to the Ummur Singee gateway.

Second.—The conversion of the Water-gate and contiguous bastion

(which at present form part of the lower fort on the river side) into a Horn work, cut off from the lower fort, and connected with the body of the place. This work will cover the Water-gate, and complete the flanking defences of the river face. It will also afford direct fire on the opposite side of the river; it will cover the approach to the bridge from the other side, and co-operate with the flank bastions in the general defence of that front.

The Committee are of opinion that the new works, above described in general terms, will suffice for the protection of that part of the fort.

Third.—For the flanking defences on the land side, the following works seem fully sufficient.

On the north covering tower, No. 9, should be constructed a Counterguard with flanks, for the purpose of affording flanking fire right and left on the northern face. Any more salient work would be objectionable, as advancing the defences towards the city, already too near. The communication with this will be from the *fausse braie* by a bridge across the ditch.

At the north-west corner are the Chowk, the Tripolya and the Jumma Musjid, covering the approach to the Delhi gate. These buildings must either be removed or occupied. If removed, a work of some description to afford flanking fire must be erected on their site. The Committee, however, think it would be more advantageous to occupy them, by forming them into a permanent outwork, which may be thus effected.

The Tripolya, (a small walled enclosure connecting the Chowk with the Jumma Musjid,) with one side of the Chowk, and a portion of the rear wall of the court of the Musjid, must be removed, so as to throw open the interior of the Musjid to the fire of the place. The side walls of the Chowk must be prolonged to connect it with the Musjid. The standing portion of the rear wall of the court of the Musjid can then be formed into a 2-gun battery, which will flank the proposed counterguard and new bastion on the north. The Musjid itself is also capable of being turned into a very formidable battery. Five embrasures may be pierced through its western wall, which is 11 feet thick, and very solidly built, and two in each side wall of the mosque itself. The side walls of the court-yard will also afford positions for several guns, which on the south side will most effectually

sweep the main road to the Delhi gate, as well as much of the low broken ground to the south-west of the Fort. The battery on the west will command a large ravine which would otherwise afford excellent cover for an enemy's approach.

As the piercing of the embrasures through the western wall must be a work of time and labor, it should be begun at once. The embrasures themselves may then be closed by thin screen walls, and the building itself thrown open for the use of the Mahomedan population, as convenient access can be had by the two gateways in the side walls. These gateways would be closed by sandbags, or other effectual means, on any emergency; and if desired, they can always be closed by the strong iron covered doors at present in them.

The Chowk likewise should be made part of the position, by covering its wall with a glacis, leaving the existing road to form the bottom of the ditch, which must also be carried round the Musjid.

It is necessary, however, to note that the houses of the city actually touch the north west corner of the Musjid, and are quite close to the building on other sides, so that to admit of this being retained as an outpost it becomes absolutely requisite to remove a portion of these suburbs, at least to the extent of 200 yards. A greater open space, if it could possibly be obtained, would, in the opinion of the Committee, be most desirable, and in accordance with military principles.

To obtain flanking fire on the south-west front of the Fort advantage should be taken of the high ground immediately to the west of the Ummur Singee gate, on which to throw up a strong ravelin with flanks, of a permanent character, to be connected with the place by a *caponiere* and covered passage leading into the main ditch.

The faces of this work will be swept by the guns of the body of the place, and they will themselves command by their fire the broken ground to the west and south of the Fort. Its flanks will cross fire with the batteries of the Jumma Musjid and the new bastion on the south-east.

Between the high ground on which it is proposed to make this ravelin and the Fort, runs one of the principal lines of drainage of the city and cantonments, which should be converted into an outer ditch, to be enfiladed by the flanks of the ravelin, which will be rendered more secure by throwing stockades across, on the prolongation of the flanks.

II. With regard to the second defect; *the exposed state of the scarp wall of the ditch, and general defectiveness of the glacis, and in many parts the total want of one*, it should be stated that at present the counterscarp wall is generally at least five feet too low for the efficient protection of the scarp wall of the ditch, and the earthwork of the glacis is not even carried up to the top of the existing wall, so that one-third, and in places, one-half of the wall being visible, a practicable breach might readily be formed by the enemy's batteries from a distance. To obviate this important defect the Committee strongly recommend, that the counterscarp wall should be raised and the glacis properly formed and completed.

III. With reference to the third point; *the defective nature of the fire from the body of the place, owing to the great height of the wall*, the Committee beg to recal the recommendation of the Committee of Engineer Officers, assembled in 1857, that the walls should be lowered; and to suggest instead, that embrasures should be opened in the curtain walls, on the ground level of the Fort, wherever available; and that the only guns on the high towers be of large calibre, on pivot or traversing platforms, and confined to the most salient towers. These pivoted guns on the towers will assist the flanking fire afforded by the proposed new works; and the demi-casemated batteries of the curtains will, at a much more favorable level, (about 25 feet below the present towers,) protect and cover the ground in their fronts by direct fire. The great height of the walls, the Committee consider a decided advantage, as it precludes the possibility of escalade; and even when breached, the height will still offer a formidable obstacle, almost an insurmountable one, if the ground behind the breach be properly retrenched.

IV. The Committee desire to remark on *the broken nature of the ground around the Fort*, and on the immediate neighbourhood of buildings, which would afford perfect cover to large bodies of hostile troops in close proximity to the walls, and thus give them the means of establishing their breaching batteries unseen.

On the northern side, the broken ground consists of the *debris* of that part of the city which was thrown down during the outbreak. The Committee recommend that the *debris* on this side should be formed into a second or outer glacis. As this is the weakest side of the fort, on account of the cover afforded by the houses of the city,

this advanced glacis will be of considerable advantage, as it will more effectually screen the main wall, and so prevent a besieger from establishing his batteries under shelter of the city houses, and force him to advance to the crest of the glacis by the usual process.

On this side there are immediately under the walls two houses left standing, which it will be necessary to remove; also a wall several feet high defining the limit of the fort lands on the city side. The rubbish may be thrown into a sunken road close by, which will thus be brought up to the general level.

On the south-west side leading down from Boileaugunge to the Delhi gate, there is a sunken road which can only be seen to any extent from the Jumma Musjid. The steep side of this road towards the Fort should be sloped off so as to expose the whole line to the view of the place.

On the south side, the broken ground is far more intricate and extensive. Here also the same general principle should be followed of sloping off the mounds from the fort outwards, so as to present a succession of glacis, and expose their whole extent as much as possible to the view of the fort.

With regard to the most prominent of these mounds, it may be necessary to occupy some of them by light field works, so as to command as far as possible the uneven ground in their front. These works should consist merely of a light parapet and ditch open to the rear; but their exact forms and positions can only be determined when the permanent improvements of the fort are decided upon. As the new defences are to be chiefly earthworks, and as very extensive levelling will also be required, it appears to the Committee that it might be more cheaply and expeditiously effected with the aid of some companies of the Corps of Sappers and Miners.

In the event of the removal of the Arsenal from Delhi to Agra, and with reference to the increased armament rendered necessary by the enlargement of the works, it appears to the Committee that provision should be made for more extensive magazines for powder. They therefore take leave to suggest the open square in the middle of the Meena Bazar as the safest and most central position for that purpose. The place proposed is 114 feet square, already sunk upwards of 20 feet below the level of the surrounding ground, and would afford room

for capacious magazines which could only be reached by vertical fire.

The *Armament* of the Fort should, in the opinion of the Committee, be as follows:—

On each of the high towers,* (which if not sufficiently strong, should be made so,) there should be one 8-inch shell gun, on a pivoted or traversing platform, which will command, to a wide circuit, all the broken ground and houses.

From the great height of these towers, it will be easy to afford cover to the artillerymen when working the guns, and the Committee consider that this armament will be ample for these towers, the fire from which from ordinary guns on account of their great height, would be very ineffective.

There should be embrasures pierced through the main walls in as many of the curtains as will admit thereof; and these batteries should be armed with 18 or 24-pounder iron guns, as most available. As the ordnance in these batteries would be partly under cover, and particularly well defiladed, it would be economical to mount them on iron carriages. The Committee anticipate that batteries of the above nature should be made in the curtains† to contain about five guns each, forming a total of 40 guns.

The nature of the ground around the fort, renders vertical fire from mortars very desirable, and the Committee would point out the following sites as good positions for batteries:—

First.—In the south-east angle of the Fort near the Jehangir Muhul, from which shells may be thrown into the broken ground on the south and across the river;—a *second* battery might be placed near the present barracks; and a *third* on the grand parade.

These positions would be taken up, on the necessity occurring, but mortars of the heaviest calibre, for the armament of the place, should be specially retained in the fort.

The Committee would limit the armament of the *fausse braie* to the formation of batteries in the bastions of the outworks in front of the gateways; as in any other parts the *fausse braie* is so narrow, and

* Nos. 1, 2, 4, 6, 7, 10, 11, 13.

† The curtains, one on each side of the Ummur Singee gate, and one on each side of the Delhi gate—also to the right and left of the Futeh Boorj on the north, and the curtain of Ummur Singee outwork, and one on the water face where found practicable.

the main walls so high, that the batteries would be untenable from the splintering of the stones under the enemy's shot.

The ordnance should be as follows :—

At the Ummur Singee gateway, three guns and one howitzer, in each bastion.

At the Delhi gateway, a similar armament.

The armament of the new works outside the Fort, should be as follows :—

For the two new bastions on the river face :—

IN EACH BASTION,	1	8-inch howitzer,	}	per flank.
	1	24-pounder gun,		
	1	8-inch howitzer,	}	per face.
	2	24-pounder guns,		

For the Counterguard north front, two 24-pounders in the east flank, to sweep the face of the proposed new bastion. One howitzer, 8-inch, and one gun in west flank, to cover the Jumma Musjid and city.

For the Jumma Musjid outwork. For the front, three guns to sweep the ravine, leading right upon it and the neighbouring suburbs, and two guns in each of the three remaining sides.

For the Ravelin in the south-west part field guns and howitzers only are deemed necessary. The faces and flanks should be pierced with embrasures for ten or twelve pieces, say two in each flank, and three or four in each face.

ABSTRACT OF ARMAMENT.

<i>Body of the place.</i>	{	8-inch shell guns in bastion,	8
		Siege iron guns in casemates,	40
		13 and 10-inch mortars,	12
<i>Fausse braie.</i>	{	Siege iron guns, 24-pounders,	12
		8-inch howitzers,	4
<i>River bastion.</i>	{	24-pounder iron guns,	12
		8-inch howitzers,	4
<i>Counter-guard.</i>	{	24-pounder iron guns,	8
		8-inch howitzer,	1
<i>Jumma Musjid.</i>	{	24-pounder iron guns,	5
		8-inch howitzers,	4
Total Iron Guns,			105
<i>Ravelin.</i>	{	9-pounder brass field guns,	8
		24 " " howitzers,	4
Total Brass Guns,... ..			12

with a proportion of field guns, and 5½-inch brass mortars available; as circumstances may demand their use.

From the Secretary to the Government of India, with the Governor General, to the Secretary to Government, N. W. Provinces, P. W. Department.

Benares, 8th December, 1890.

SIR,—The Governor General having had before him the report of a Committee, convened under orders from this department in December last, on the improvement of the defences of the Fort of Agra, with reference to the contemplated removal to that place of the arsenal establishments from Delhi, has come to the conclusion that the great cardinal object of reducing to the smallest dimensions all strong places, the retention of which is a necessity so long as we retain India, has not been sufficiently kept in view by the Committee.

His Excellency is of opinion that the outworks proposed by the Committee, are objectionable as rendering it necessary to maintain a larger garrison, and being in themselves a source of weakness rather than of strength.

The irregular ground outside of the Fort, should, as recommended by the Committee, be sloped off, so as to present a succession of glacis, and expose the whole extent as much as possible to the view and fire of the fort.

A glacis and covered way should be formed; the counterscarp being strengthened by counterforts where necessary, to make it support the additional weight of earth.

The Jumma Musjid should neither be destroyed nor occupied, but mined so as to admit of its being blown up in case of necessity. Embrasures, not concentrated in batteries, but scattered, should be pierced in the walls, so as to give a fire at a lower level than from the top of the walls.

To carry out the above measures, the Military Department has been this day requested to move His Excellency the Commander-in-Chief, to place a company of Sappers under an intelligent officer, at the disposal of the Superintending Engineer, and I am to request that His Honor the Lieutenant Governor, will have the goodness to authorize the Superintending Engineer to allow the officer in question to draw

funds to the extent of one thousand rupees per mensem, from the Executive Engineer, for laborers to be employed under the supervision of the Sappers, and for materials and miscellaneous expenses connected with the works. He should of course be required to furnish proper accounts, and to report progress of work.

I am further to request that the Public Works and Civil Officers may be called upon to submit estimates of the cost of removing Jotee Persad's house, situated on the northern side of the fort, and for effecting a clearance round the Jumma Musjid.

A report is likewise required from the Superintending Engineer, as to whether space could be found in the fort, to erect two or more earthen cavaliers, on which the garrison could, in case of need, place batteries which would enable them to return the fire of assailants, after the masonry walls should have been so injured as to be incapable of bearing guns.

A further report by the Superintending Engineer is requested, as to the armament that will be necessary for the fort, with reference to the above contemplated arrangements.

The Committee have selected the Meena Bazar, as the site for the powder magazine. This has the approval of the Governor General, but the estimate for the work may be deferred until the arrangements in regard to the ordnance magazines in the Agra fort, shall have been settled in the Military Department, so as to define the accommodation to be retained for that purpose.

C. H. DICKENS.

No. XVII.

MACHINES FOR RAISING WATER.

Calculation of the labor, and cost of raising water by the different machines employed in India by the Natives. BY SERGEANT J. WEBSTER, *Assistant Master, Thomason College.*

THE heights assumed for raising the water in each case are those for which it is believed the several machines could be most generally and usefully employed.

The value of the modulus and the useful effect in each case are assumed after due consideration of the structure of each machine and the amount of spillage or waste.

1. THE BEAM AND BUCKET.

(One man employed.)

Water raised 16 feet.

Content of bucket = $\cdot 45$ cubic feet = 2·8 gallons.

Average time of raising the bucket = 20 seconds.

Number of discharges per minute = 3.

Discharge per minute = $3 \times \cdot 45 = 1\cdot 35$ cubic feet = 8·4 gallons.

Discharge per hour = 81 cubic feet = 506 gallons.

If we take the useful effect or discharge at 90 per cent, we get—

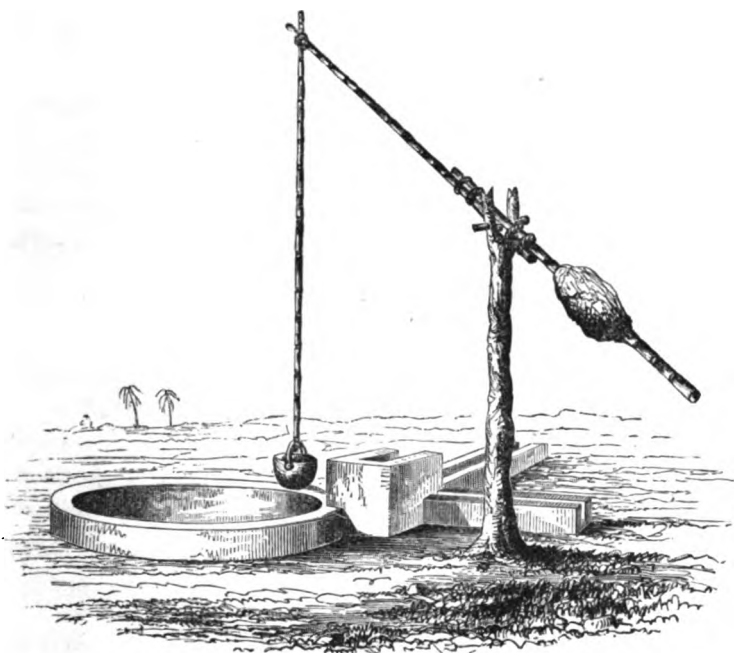
Actual discharge per hour = 72·9 cubic feet = 455·4 gallons.

2. BALING.

(Two men employed.)

Water raised 5 feet.

Deliveries in each minute = 20.



THE BEAM AND BUCKET.



BALING.



One delivery = $\frac{1}{4}$ cubic foot = 2.1 gallons.

Delivery per minute = $\frac{1}{2}$ cubic feet = 42 gallons.

Delivery per hour = 400 cubic feet = 2520 gallons.

If useful effect = 75 per cent., then—

Actual discharge per hour = 300 cubic feet = 1890 gallons.

3. THE SINGLE MÔT.

(One man and two bullocks employed.)

Water raised 40 feet.

Speed of bullocks = 2 miles an hour.

Space gone over by the bullocks at one lift = 80 feet.

Content of bag = 3 cubic feet = 18.75 gallons.

Weight of water raised at each lift = 187.5 pounds.

Time required for bullocks in turning = .4 minute.

Speed of bullocks per minute = $\frac{5280 \times 2}{60} = 176$ feet.

Therefore time required to pass over 80 feet = $\frac{80}{176} = .45$ minute;

and time required for one lift = $.45 + .4 = .85$ minute.

Number of lifts per minute = $\frac{1}{.85} = 1.18$.

Discharge per minute = $1.18 \times 3 = 3.54$ cubic feet = 22 gallons.

Discharge per hour = 213.6 cubic feet = 1320 gallons.

Useful effect = 70 per cent.

Actual discharge per hour = 149.5 = 924 gallons.

Taking the modulus = .9 and the weight of the rope and bag = 42 pounds, the required traction which the bullocks have to overcome is

= $\frac{187.5 + 42}{.9} = \frac{229.5}{.9} = 255$ pounds; and one bullock = 127 pounds.

4. THE DOUBLE MÔT.

(One man and bullock employed.)

Water raised 40 feet.

Speed of bullocks = 2 miles an hour.

Speed of bullocks per minute = 176 feet.

Diameter of barrel = 3 feet.

Diameter of bullock walk = 16 feet.

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Length of bullock walk $= 16\pi = 50.2$.

Number of turns of bullock per minute $= \frac{172}{50.2} = 3.4$.

Turns required for drawing up the bag $= \frac{40}{3\pi} = 4.25$.

Time required for drawing up the bag $= \frac{4.25}{3.4} = 1.2$ minute.

Time for disengaging the barrel and lowering the bag $= .2$ minute.

Total time for raising the bag $= 1.4$ minute.

Content of bag $= 3$ cubic feet $= 18.75$ gallons.

Discharge per minute by one bag $= \frac{3}{1.4} = 2.1$ cub. ft. $= 13.4$ gallons.

Discharge per minute by 2 bags $= 4.2$ cubic feet $= 26.8$ gallons.

Discharge per hour by 2 bags $= 252$ cubic feet $= 1608$ gallons.

Useful effect $= 65$ per cent.

Actual discharge per hour $= 165.8$ cubic feet $= 1045$ gallons.

Space moved over by the bag at one revolution $= 3\pi$.

Space moved over by the bullocks at one revolution $= 16\pi$.

Ratio of power and weight $= 3 : 16$ or $1 : 5.3$.

Weight of water contained in two bags $= 375$ pounds.

Weight of bags and ropes $= 85$ pounds.

Total weight to be raised $= 460$ pounds.

Taking the modulus $= .7$, we get—

Work applied $= \frac{460}{.7} = 657$ pounds.

Required traction $= \frac{657}{5.3} = 124$ pounds.

5. THE SINGLE PERSIAN WHEEL.

(One man and two bullocks employed.)

Water raised 40 feet.

Diameter of driving wheel $= 4$ feet.

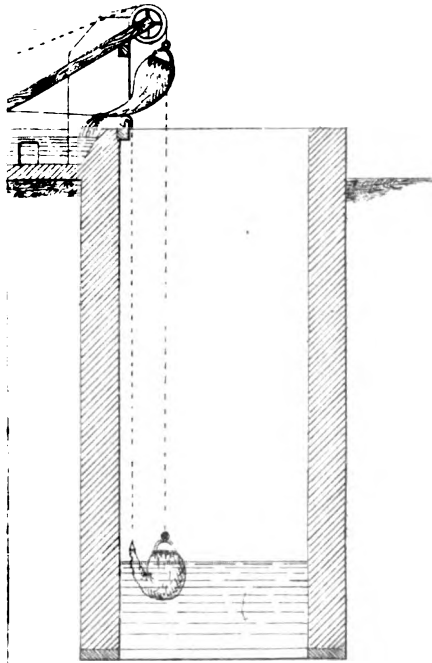
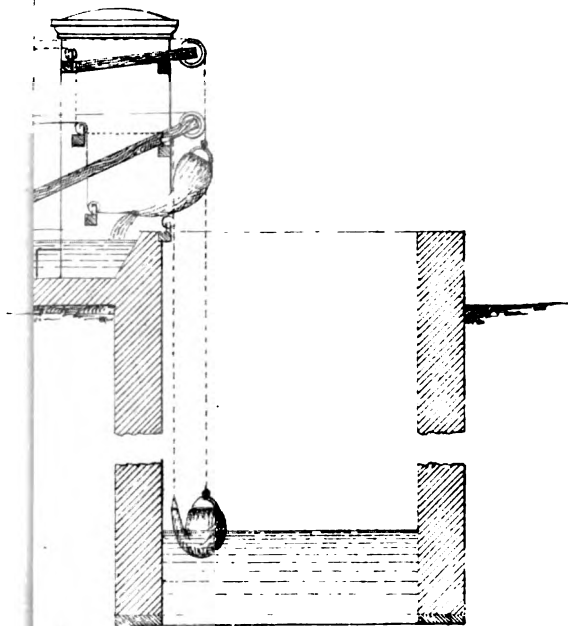
Diameter of bucket wheel $= 4$ feet.

At each turn of the bullocks, 6 buckets are emptied, and assuming the content of each bucket $= \frac{1}{3}$ cubic foot, we have—

Discharge at each turn $= \frac{2}{3} = \frac{2}{3}$ cubic foot $= 4.7$ gallons.

Length of bullock walk $= 20\pi = 62.8$ feet, and speed of bullocks $= 2$ miles an hour, we get—

Speed of bullocks per minute $= 176$ feet.



J. C. Coe, lith.



Number of turns per minute = 2·8.

Discharge per minute = $2·8 \times \frac{1}{4} = 2·1$ cubic foot = 13 gallons.

Discharge per hour = 126 cubic feet = 780 gallons.

Useful effect = 55 per cent.

Actual discharge per hour = 69·3 = 429 gallons.

Buckets are 2 feet apart.

Number of buckets required = 40.

Weight of buckets = 80 pounds.

20 buckets being always full, the weight of the water they contain
is = $\frac{20 \times 62·5}{8} = 156$ pounds.

Weight of rope = 22 pounds.

Total weight to be raised = 258 pounds.

Space moved over by the buckets at one revolution = 4 π.

Space moved over by the bullocks at one revolution = 20 π.

Ratio of power and weight = 1 : 5.

Modulus = 0·6.

Work applied = $\frac{258}{0·6} = 430$ pounds.

Required traction = $\frac{430}{5} = 86$ pounds.

TABLE SHOWING THE COMPARATIVE PERFORMANCE AND COST OF THE ABOVE MACHINES IN RAISING WATER TO THE SAME HEIGHT (40 FEET.)

The expense of a laborer is put down at 2 annas and of a bullock at 4 annas per diem. Duration of work per diem = 8 hours.

No.	Methods.	Stages.	Useful effect per cent.	Discharge per hour.		Discharge per diem.		Ratio of discharges.	Employs. Men.	Daily ex- pense, Annas.	Quantity of water raised for one rupee.		Remarks.
				Cubic feet.	Gallons.	Cubic feet.	Gallons.				Cubic feet.	Gallons.	
1	Beam and bucket,	2.5	90	29.07	181.4	232.5	1451.5	1	2	4	980	5806	{ Discharge increased with decrease of height.
2	Baling,	8	75	37.5	236.2*	300	1875	1.29	4	8	600	3750	Ditto.
3	Single Persian Wheel,	1	55	69.8	429	554.4	8432	2.4	1	2	10	887	{ Discharge the same at any height.
4	Single Môt,	1	70	149.5	924	1196	7392	5.1	1	2	10	1911.8	{ Discharge increased with decrease of height.
5	Double Môt,	1	65	165.8	1045	1326.4	8360	5.7	1	2	10	2096.6	Ditto.

The cost and wear of the machines are not taken into consideration.

* Being 4th of the quantity raised 5 feet high as computed at p. 172.

J. WEBSTER.

No. XVIII.

SOHAN BRIDGE—LAHORE AND PESHAWUR ROAD.

Designed, and now being constructed by LIEUT.-COLONEL ALEXANDER
TAYLOR, C.B., R.E.,

To The Chief Engineer and Secretary to Government Punjab, P. W. D.

Murree, 7th May, 1862.

SIR,—I have the honor to submit a revised design and estimate for a Bridge over the Sohan river. The work proposed is entirely of masonry, and is less expensive than a bridge having masonry piers and timber superstructure with the same width of roadway and same waterway.

The area drained by the Sohan at the site of the bridge is about 573 square miles, and is very compact in shape. The greatest depth of the river in floods is 15 feet, and the mean velocity about 8 or 9 feet per second. The slope of the bed is at the rate of 14 feet per mile. The calculated mean velocity is 13 feet per second. The discharge calculated from cross sections of the stream, is in extreme floods about 91,000 cubic feet per second, which is equivalent to about $\frac{1}{4}$ of an inch over the entire catchment basin. The bed of the river exposed to view, consists of boulders, water flows all the year round, and is never less than 1 foot in depth. The true bed of the river is no doubt the hard red clay of the country, over that may be expected a layer of blocks of conglomerate, and over that some 12 or more feet of boulders.

In the design proposed, the foundations of the drop walls, and of the piers and abutments are all carried through the boulders and conglomerate blocks, and rest on the hard clay.

At the site selected for the bridge, the river is rather wide, being over 1000 feet, while a few hundred feet higher up, the width does not exceed 750 feet. (*See accompanying plan.*) The clear waterway of the bridge is 945 running feet.

The excavation of the foundations in accordance with the design now submitted is being vigorously proceeded with, and I hope that a good deal of the foundation masonry will have been executed by the beginning of the rains. The excavation is now $11\frac{1}{2}$ feet below water, and the influx of water is under 80 cubic feet per minute, while we have means ready to pump out double that quantity. At 11 feet we have met with the tops of some conglomerate blocks which renders it probable that the depth to the clay bottom assumed at 16 feet will suffice.

The tramway bringing stone from the quarry is in full work.

The Governor General has already expressed his approval in regard to the leading features in this design, that is, the width of roadway and the substitution of masonry for timber. For foundation work, the present and the next months are very valuable, and this coupled with the foregone approval to the change in design, has induced me to push on with the work in anticipation of final sanction.

The cost of a timber bridge without any flooring was estimated at 4,50,000 Rs.

The cost of the masonry bridge with flooring, and in all respects complete is estimated at 4,28,271 Rs.

Early intimation of sanction to this design is requested, that arrangements may be made for the supply of the large number of bricks that will be required.

REPORT.

The original design consisted of 10 spans of 100 feet each. The superstructure was of timber on masonry piers, and the bridge was not floored. The design now submitted consists of 15 spans of 63 feet each, entirely of masonry and the bridge is floored throughout. It is less expensive than the original design with the same waterway, and same width of roadway.

SPECIFICATION.

The foundations to rest throughout on the clay bottom of the river. The masonry below the flooring to be of coursed rubble, the faces not

to be dressed. The floor to consist of large blocks of stone well fitted, and the end stones to be of the largest size and cut to fit closely.

From the floor to the spring of the arches the masonry to be of the best coursed rubble in large blocks with dressed faces. The imposts to be accurately cut.

The arches, spandrel walls, and superstructure of parapets to be of best brick-work. The cornice to be of cut stone. The surface drainage of roadway to be discharged through the crown of each arch, by an iron pipe just clear of the wheelguard.

The entire surface of the roadway to be metalled with broken stone.

The stone to be used is sandstone, from the quarry on the Leh Nul-lah, and none but the very best quality of stone is to be put into the work.

ABSTRACT OF ESTIMATE.

		R.	A.	P.
1,56,694	Cubic feet cut brickwork, at Rs. 85 per 100, - - -	54,842	9	0
21,924	" cut stone masonry, at Rs. 50 per 100, - -	10,962	0	0
8,04,271	" rubble masonry in superstructure with dressed faces, large blocks, at Rs. 25 per 100, - - -	76,067	7	0
8,24,844	Cubic feet rubble masonry in foundations, at Rs. 22 per 100, - -	71,465	7	0
22,03,500	" excavation for foundations in boulders and water, at Rs. 20 per 100, - - - - -	44,070	0	0
61,00,000	Cubic feet excavation in drainage cuts, partly dry and partly in water, at Rs. 9 per 100, - - - - -	54,900	0	0
15,522	Cubic feet boulders for metalling, at Rs. 2 per 100, -	310	4	0
15,522	" " to be broken, at Rs. 8 per 100, - -	465	7	0
15,522	" " " consolidated, at Rs. 1 per 100, - -	155	2	0
15	Centerings, at Rs. 1,600 each, - - - - -	24,000	0	0
	Pumping and pumping machinery, - - - - -	60,000	0	0
29	Iron drainage pipes, 4 inches thick, at Rs. 22 each, - -	638	0	0
	Probable loss on ironwork prepared in furtherance of original design being one-third of cost, - - - - -	10,000	2	0
	Total, - - - - -	4,07,877	6	0
	Contingencies at Rs. 5 per cent., - - - - -	20,393	8	0
	Grand Total, - - - - -	4,28,271	0	0

A. TAYLOR, LIEUT.-COLONEL,
Superintendent, Lahore and Peshawar Road.

No. XIX.

REPORT OF THE OPERATIONS OF THE GREAT TRIGONOMETRICAL SURVEY OF INDIA, DURING 1862-63.

By MAJOR J. T. WALKER, R.E., *Superintendent G. T. Survey.*

To the SECRETARY TO THE GOVERNMENT OF INDIA, *Military Department.*

Dehra Doon, 1st September, 1863.

SIR,—I have the honor to report the progress of the Trigonometrical Survey during the past official year.

In accordance with the sanction of Government, I proceeded, in the autumn of 1862, to Vizagapatam to measure a Base line. Vizagapatam is situated nearly on the same parallel of latitude as Bombay; and is the point where the Bombay longitudinal series, when extended eastwards to the Madras coast, will terminate. This series of triangles will form, with the Great Arc Meridional, the Calcutta Longitudinal, and the coast series, a vast quadrilateral figure, circumscribing the meridional series of triangles which are required as a basis for the interior topographical details. Base lines had been measured several years ago, by Colonel Everest, at Beder, Seronj, and Calcutta, the S.W., N.W., and N.E. angles of this quadrilateral. One more Base line remained to be measured, which, for considerations of symmetry it was desirable to place in the vicinity of Vizagapatam.

Captain Basevi, the officer in charge of the coast series, being located at Vizagapatam, was directed to select the site. After several trials, owing to the difficulty of carrying a straight line, several miles in length, so as to avoid the numerous irrigation tanks with which this district is studded, he eventually succeeded in finding a suitable line

on the undulating plain between the military stations of Vizagapatam and Vizianagram, at a distance of about fifteen miles to the west of the port of Bimlipatam. The ground was chosen before the commencement of the rainy season of 1862, when trenches were dug to carry away the expected rain-fall during the monsoon, and every precaution was taken to keep the line dry. But when Captain Basevi took the field early in October, he found that the rains had been so heavy, that the surrounding tanks had been converted into lakes, and the line lay submerged under a sheet of water, in some parts as much as sixteen feet deep. By great exertions the water was drained off into adjoining ravines. A portion of the line was ready for measuring, on my arrival in December, and the remainder had become fairly dried by the time it was reached, in the course of measurement.

The apparatus employed, consisted of a set of compensating bars and microscopes, on the principle of those designed by Colonel Colby, for the Ordnance Survey of Great Britain, which had been constructed under the superintendence of Colonel Everest, by whom they were brought out to India in 1832. This apparatus has been employed in measuring three Base lines on the great arc, two at the north and south extremities of the Calcutta meridional series, and two at the extremities of the Indus series. The length of these bases has, in each instance, been determined in terms of ten foot standard bar A the unit of measure of the Indian survey.

At the time this standard was constructed, it was believed that the length of a well made iron bar, supported by rollers at its points of least flexure, might be considered invariable for any given temperature. But, of recent years, there has been a growing tendency to doubt the invariability which has hitherto been assumed. Series of comparisons made by the Ordnance survey show there is much probability that the texture of an iron bar changes gradually in the course of years; for the factors of expansion obtained from groups of comparisons made at intervals a few years apart, differ from each other by larger quantities than are due to errors of observation. It is preferable, therefore, to employ several standards, constructed of different metals, than to trust to the integrity of a single bar.

To ascertain whether our standard has altered in length, it would be necessary to re-measure the whole, or part, of one of the Base lines

which were first measured after the arrival of the bar from England. I wished to obtain some light on this subject, by re-measuring certain short sections of the Calcutta Base line, the extremities of which were originally indicated by permanent marks. But, on examining the positions of the section mark-stones, I found that, though concealed from view, there had been a regular thoroughfare over them, for many years, of carts and elephants, as well as foot passengers; consequently, they must, in all probability, have been disturbed, and they cannot be safely referred to, to decide so delicate a matter as the constancy of the standard.

Disappointed at being baffled in my efforts to investigate this matter, by any simpler and shorter process than the re-measurement of a whole Base line, I determined to mark the intermediate section stations of the Vizagapatam Base as permanently as the extremities, in order that any future enquiry regarding the length of the standard, at the time of the measurement of this Base line, may be conducted without greater labor than the re-measurement of a short section.

It has been well said, by one of the greatest living authorities on scientific matters, that "the ends of a Base line should be guarded with religious veneration." In this country they are liable to be viewed with mingled cupidity and dread; the natives sometimes fancy that money is buried below, or they superstitiously fear that the Englishman's mark will cast a spell over the surrounding district. In either case, the mark is liable to be destroyed, as has already happened at the Seronj Base line.* To ensure the protection of the ends of the Vizagapatam Base, I have had substantial domes of cut stone masonry built over them, without any openings, so that, before the marks can be reached, the domes must be pulled down, which will be so laborious, that the police should be able to hear of and arrest the perpetrators, before they have had time to harm the marks.

* On this subject, the following extract is taken from a letter by Colonel Sir George Everest, C.B., to the President and Council of the Royal Society, dated 8th April, 1861:—

"The natives of India have a habit, peculiar to human beings in that state of society, of attributing supernatural and miraculous powers to our instruments, and the sites which have been occupied by them. In cases of death, or any other natural visitations, they often offer up prayers to those sites, and if the object of their prayers be not conceded, they proceed to all sorts of acts of destruction and indignity towards them: nay, as in all cases where it was practicable, my station marks were engraved on the rock, *in situ*, they have been known to proceed in bodies, armed with heavy sledge hammers and beat out every vestige of the engraving."

Captain Basevi and the Assistants of the Coast series party, shared in the measurement of the Base line, which occupied about two months. The length of the line is six and a half miles. It was divided into three verificatory sections, which were subsequently checked by two series of triangles, one on each flank of the base, to test the measure of each section against the others. These tests were satisfactory; for the extreme difference between the measured length of the whole base, and its computed length by triangulation from either section, has been found to be *one inch*. The comparison of the measured length, with the computed value brought down by triangulation from the Calcutta Base line is singularly satisfactory, for the error of the computed value is only *one quarter of an inch*, though the triangulation embraces a distance of four hundred and eighty miles, much of it passing over flat plains which are covered with dense forest and jungle, and very difficult to work through.

On the completion of the Base line, Captain Branfill was deputed to connect it with the principal triangles of the Coast series, and to execute the verificatory triangulation between the sections. Meanwhile, Captain Basevi proceeded, by my instructions, to make a reconnoissance of the neighbouring territories of the Rajah of Jeypore.

It is a singular fact that, in the vicinity of the British stations of Vizagapatam and Vizianagram, and within sixty miles of a coast which has been frequented by British traders for upwards of a century, there is an extensive tract of country, subject to a friendly Rajah, of which less is known, than of districts occupied by hostile tribes along the frontier of our recently acquired Punjab Provinces. A glance at any map of the Madras Presidency reveals a great blank in our geographical knowledge, in the tract of country which lies parallel to the coast, and N.E. of the Godavery river. Its deadly reputation appears to have been a bar alike to the explorations of the curious and scientific, and to the visits of sportsmen. No regular survey of it has ever been attempted; the few places given in the map seem to have been obtained from native information, for they are generally exceedingly erroneous.

A reconnoissance of this tract was required for our own operations, in the extension of the Bombay Longitudinal series to Vizagapatam. As any reliable information regarding land so little known might be expected

ted to be of much value and general interest, I was much gratified when Captain Basevi volunteered to reconnoitre this *terra incognita*; though, at the sametime, I could not but feel apprehensive for his safety in a country so deadly, for his route would have to pass through dense jungle, in which it would be necessary for him to preserve his reckoning by the troublesome process of traversing, which, under such circumstances, is very laborious, and entails the necessity of performing the greater part of each day's march on foot. The inevitable exposure to be thus undergone is very great, in a tropical climate, and when the district to be traversed is known to be exceedingly feverish and unhealthy, no small amount of courage is needed, to prompt a man to volunteer for such a task.

Captain Basevi took with him one European Assistant, Mr. O'Neill, and a few natives. He himself, fortunately escaped with a slight attack of fever, but Mr. O'Neill suffered severely, and has not yet recovered, and the natives of the party were also, more or less incapacitated by fever, so that but for the assistance afforded by the Rajah of Jeypore, the operations would have been stopped almost at their very commencement. The results are, a good preliminary map of Jeypore, which has been forwarded to the Surveyor General, to be lithographed and published; a report by Captain Basevi, giving details of his route, and a general description of the country; several valuable astronomical determinations of latitudes and longitudes, and barometrical determinations of heights; also memoranda of various other routes, the details of which were obtained from native information. In consideration of the great value of Captain Basevi's services, he has been permitted to proceed to Europe on furlough for one year, during which his appointment will be kept open for him.

During the summer of 1862, the field season of the Kashmir survey party, the triangulation made great progress to the east of Léh, and stations were fixed on the Chinese frontier, from which a number of peaks in Tartary were determined. Some of these were more than one hundred miles distant, and will materially aid in the construction, from native information, of maps of districts into which the surveyors will probably be unable to penetrate. Several of the stations observed from, were over 20,000 feet in height above the sea, and Mr. Johnson visited one peak of a height of no less than 21,072 feet, but, owing to a very heavy fall of snow, was unable to observe from it.

A great many points were fixed in the Pangkong district. The whole of Astor was triangulated, and several peaks were fixed to the north of Gilgit; none of these were of any great height, the highest being only a little over 19,000 feet. The natural difficulties of the country were at first much enhanced by bad weather, which came on with the heavy rains in the southern and outer Himalayan range. Notwithstanding these circumstances the out-turn of work has been good, and the general progress very satisfactory, the total area of the triangulation being about 10,500 square miles, and of topography 10,400 square miles, on the scale of four miles to the inch.

The Topographical operations made good progress, though not so great as would have been the case had all the assistants retained their health. Unfortunately two of them, on entering the higher ranges, broke down completely, and a third had to leave off work early in the season. The ground sketched was generally very elevated and barren, the surveyors' chief difficulties arising from the want of provisions and firewood, and sometimes even of fresh water. The plane table sketches required for the map of Little Tibet have been completed, and lodged in the head-quarters office at Dehra. A glacier, about twenty miles in length, was discovered by Mr. Ryall at the head of the Nubra Valley. Some large glaciers were also found in the neighbourhood of the Nanga Parbat.

I fully concur in the testimony which is borne by Captain Montgomerie, to the great zeal with which these arduous survey operations have been carried on by all the assistants under his orders. The good fortune of success has hitherto attended all undertakings executed under the superintendence of this officer.

There is much reason to expect that, if the snows are not unusually heavy, and if most of the surveyors keep in good health, the remainder of the country to be surveyed in and around Kashmir and Ladak, will be completed during the next field season. Captain Montgomerie has made every effort to persuade the Maharajah of Kashmir to allow one of our surveyors to go to Gilgit, and has obtained a half promise to this effect. Possibly the fear of being called to account, should any harm happen to a European in his territories, causes the Maharajah to hesitate to sanction an undertaking which might be somewhat perilous. He informed Captain Montgomerie that, during the late winter, his

troops in Gilgit had been sleeping: no exacter information could be elicited than what is suggested by this metaphor. If, as Captain Montgomerie thinks likely, the sleep was that which knows no waking, the Sikh garrison of Maharajah must have been massacred by the hill tribes, in which case there is little hope of our surveyors being soon able to penetrate into Gilgit.

The eastern frontier party, under the charge of Mr. C. Lane, Chief Civil Assistant, has been employed, throughout the field season, in Independent Tipperah. At the end of the preceding season, this triangulation had reached a point to the south of Cherra Poonjee, on the confines of Tipperah, where the British boundary retrogrades westward to a considerable distance, so that the triangulation would have had to make an extensive circuit, in its onward progress to Chittagong, had the operations been required to be kept within the British boundary. Fortunately, Mr. Buckland, the Commissioner of Chittagong, had sufficient influence with the Maharajah of Tipperah to induce him to consent to our operations being carried across his territory, on the direct line to Chittagong.

Mr. Lane proceeded, in the first instance, to Agartolla, the chief town of Tipperah, where the Maharajah resides; and there he succeeded in securing the friendship and good-will of the prince and his court to an extent to justify the expectation, which was subsequently realized, of obtaining their cordial assistance and co-operation. Mr. Lane deserves much credit for the tact he has displayed in cultivating amicable relations with the barbarous races that inhabit the hill country of Tipperah, who have long been a terror to the industrious population of the plains within the British frontier. Mr. Lane has sent a valuable report on the portion of Independent Tipperah traversed by himself and assistants during the past field season.

The east Calcutta longitudinal series party was formed on the 1st September, 1862, and placed under the charge of Lieutenant Thuillier. The object of this series is to become the basis for the surveys of the districts of Nuddéah, Jessore, and on, *via* Dacca, to the eastern frontier along a parallel of latitude slightly north of Calcutta. The publication of the sheets of the Indian Atlas, which embrace these districts has long been delayed for want of this triangulation.

The party proceeded from Dehra Doon, by steamer and railway, to

Calcutta, where they took the field in November on the termination of the rainy season. Operations were commenced at Chinsura, on a side of the Calcutta meridional series. Much assistance was derived from a carefully executed Map, prepared in the Surveyor General's Office, by which Lieutenant Thuillier was enabled to lay out his lines so as to pass through a minimum amount of property. In working through forests and jungle, it is usual, in the first instance, to cut a narrow glade, in a perfectly straight line, through all intermediate obstacles, in the direction of the required station; when this trial line has been carried over a distance of eight to ten miles, the ground beyond is carefully reconnoitered for a suitable site, to which a line is cut from a convenient point in the trial line; thus two sides and the included angle of a triangle are given, with which data it is easy to ascertain the direct line between the two stations, which is then cleared to obtain mutual visibility. Owing, however, to the valuable nature of the property through which the triangles were carried, it was necessary to run a traverse along each line, with numerous intermediate bends, to avoid houses and orchards. In clearing the final line, great caution was requisite to prevent any tree from being cut down needlessly, a matter of some importance in Bengal, where every tree is more or less valuable, and has to be paid for. These circumstances greatly increased the labor of the preliminary operations, and protracted them over a longer period than is usual.

Further delay was caused in building the principal stations. These are usually, towers, with a central pillar, four feet in diameter, of burnt brick and lime masonry, surrounded by a platform of unburnt bricks and mud, fourteen to sixteen feet square, the whole raised to a height of twenty to forty feet, according to the nature of the obstacles to be overlooked. This structure has been adopted on account of its cheapness, and the rapidity with which it can be constructed; it has hitherto been found to be well adapted to our requirements. But it appears to be inapplicable to the rainy and moist climate of eastern Bengal, where unburnt bricks rarely have an opportunity of drying sufficiently to be safely used, in raising a structure of such necessarily large dimensions. At one of Lieutenant Thuillier's stations, in consequence of the employment of damp materials in the unburnt brick-work, and constant and heavy falls of rain during the construction, the building gave way

under the weight of the instruments and observatory tent. Fortunately, the large theodolite was packed in its case, and received no injury, but the season was too far advanced for the tower to be rebuilt before the setting in of the monsoon, and as the mishap occurred in the first polygon of the principal triangulation, and there were no more towers ready in advance, the out-turn of work, as measured by the area triangulated, is unusually small, though much valuable experience has been gained, and there is every reason to hope that there will be a full out-turn of work next season. The design of the tower stations will have to be altered to suit the climate of eastern Bengal; in lieu of the present solid mass of earthwork, it will be necessary to build a masonry wall around the central pillar, to support the observer's platform.

The Rahoon meridional series, under the superintendence of Mr. H. Keelan, First Assistant G. T. Survey, was brought to a termination during the last field season, by being extended southwards until it joined the Great Longitudinal Series of Triangles, connecting Calcutta and Karachi. The meridional distance triangulated is sixty-nine miles, by thirteen principal triangles, arranged in polygons, for mutual verification, and covering an area of 1,603 square miles.

This series has taken six years to accomplish. It was commenced by Mr. Logan, late first Assistant G. T. Survey, but has been chiefly executed by Mr. Keelan. It is double throughout, the triangles being arranged in successive quadrilaterals and polygons of remarkable symmetry. Its meridional length is 457 miles; the principal and secondary triangles cover an area of 23,620 square miles. The computations and maps connected therewith will be completed by the 1st October, when the party will be transferred to the districts on the meridian of 84° , between Sumbulpoor and the east coast. The total cost of the operations, up to 1st October, will be about rupees 2,01,609, which gives a rate of rupees 8-8-6, or about 17 shillings per square mile.

The field operations of the Gurhagurh series, on the meridian of Umritsur, were brought to a termination at the end of season 1861-62, when it formed a junction with the series of triangles on the same meridian which had been brought up by Captain Rivers as far as Ajmere, from the Great Longitudinal series. By the 1st October, 1862, the recess computations and charts were completed, and the party was avail-

able for transfer elsewhere. This series has taken five years to complete; the greater portion has been executed by Mr. George Shelverton. Its meridional length is 557 miles; the area covered by the principal and secondary triangles, 19,096 square miles; the cost, rupees 1,08,212, which gives a rate of rupees 5-10-8, or about 11 shillings per square mile.

The Sutlej series follows the left bank of the Sutlej from its junction with the Indus, near Mithunkote, to a side of the Gurhagurh series, near Ferozepoor. It was commenced towards the close of field season 1860-61, by Lieutenant Herschel, and was completed last season by Mr. Shelverton. It is single throughout. The recess computations will be completed by 1st October, when the party will be transferred to the meridian of 80°, to execute the required triangulation between Jubbulpoor and Madras. During the past field season the triangulation extended over a distance of 112 miles, covering an area of 1,366 square miles. A very creditable amount of secondary triangulation was also executed. The total cost of the series, up to 1st October, the date of its completion, will be about rupees 80,743; the total area covered by the triangulation is 8,142 square miles, thus giving a rate of rupees 9-14-8, or nearly 20 shillings per mile.

The Bombay party, under the superintendence of Captain Haig, Royal (Bombay) Engineers, having completed the triangulation in northern Bombay, was deputed to execute a series of triangles to the south of the parallel of Bombay, on the meridian of Mangalore. While the preliminary operations and selection of stations were proceeding, Captain Haig marched to the origin of the Bombay longitudinal series, with a view to making this series double throughout, by adding flank stations, so as to form polygons in parts where there were only single triangles. On reaching the ground, it was found that the ends of the Beder Base line were, fortunately, in good preservation. Three of the advanced stations had, however, been completely destroyed. Captain Haig judiciously determined to triangulate the series anew, as far west as the Mangalore meridian. The revision having been executed with a much superior instrument to that employed in the original triangulation, the value of this portion of the Bombay Longitudinal series is very greatly enhanced.

Having completed this revision, Captain Haig was proceeding with the principal triangulation on the meridian of Mangalore, when an un-

toward accident brought his operations to an abrupt termination. The large theodolite was set up for observation on the tower station of Palwan, when, without any previous warning, the tower gave way on one side, causing the fall of the instrument and observatory tent, whereby the instrument was so seriously injured that it is incapable of being again used, until it has been repaired by the makers in England. Fortunately, the horizontal circle, the most valuable portion, appears to have escaped injury, but the vertical circle was destroyed, and the injuries are such that the instrument cannot be repaired in this country. Capt. Haig convened a Court of Enquiry to report on the circumstances; the proceedings of the Court have already been submitted to Government. The Court came to the opinion, in which I entirely concur, that the fall of the tower was occasioned by the sudden and unexpected sinking of the ground below, and that no blame is attributable to Captain Haig or any other person, for the mishap.

Captain Haig had already turned out a very excellent season's work, comprising thirty-two principal triangles, covering an area of 6,625 square miles, and extending over a length of 260 miles, whereof 66 appertain to the Mangalore meridian, and 194 to the parallel of Bombay.

The Spirit Levelling operations were carried on by Mr. Donnelly, Civil Second Assistant, under the superintendence of Lieutenant Thuillier. The party accompanied me to Calcutta, to receive the necessary instructions regarding the programme of the season's operations, which could not be decided on until I had obtained reliable information regarding the Railway levels between Calcutta and Agra. I had hoped to be able to incorporate these into our work, so as to avoid the labor and expense of carrying a line of levels all that distance. During the previous field season, a connection had been made, at Agra, with the Railway levels brought up from Calcutta, and the G. T. Survey levels, brought up from the mean sea level at Karachi. The two sets of results differed by about twenty-four feet, and it was hoped that all difference would disappear, on connecting the Railway datum, the site of Howrah Dock, with the mean sea level of the Bay of Bengal.

That level had already been closely ascertained, by a series of tidal observations taken at Kydd's Dock, and subsequently verified by others taken at Kejiri, from the description of which (*vide* foot-notes) it is evident that the mean sea level of the Bay of Bengal may be considered

to be known, to within a few inches of the truth.* On connecting the

* The following description of the connection of Kydd's Dock with the mean sea level of the Bay of Bengal is taken from a Report, dated 1st November, 1854, on the Calcutta Meridional Series, by Colonel Waugh, Surveyor-General, and Superintendent G. T. S. :—

" A register of the tides in the river Hoogly is regularly kept at Kydd's Dockyard, near Calcutta, the height of each successive tide being referred to a fixed datum line or zero which is the bottom or sill stone of the dock, and therefore an object of invariable character.

" A transcript of the register of the tides for two years, viz., from May, 1846, to April 1848, having been obtained from the Marine Department, a monthly abstract of mean tide was deduced therefrom.

" The waters of the ocean could maintain a constant level if undisturbed by the action of the sun and moon. La Place has demonstrated that this level is a mean between the highest and lowest state to which the surface of the ocean is reduced by the attraction of those bodies. This mathematical truth is corroborated by observations made on open coasts, from which it results that the mean of high and low water for two consecutive tides represents, very nearly, the level of the sea, and that the average for a lunation is constant within a very small quantity."—*Fide* Professor Whewell's Report, Vol. VII., British Association's Report.

" An examination of the abstract of monthly mean tides will, however, show that considerable irregularity exists in the river Hoogly, the monthly means differing as much as six and a half feet. Now if the annual average be considered as the true level of the sea, it would follow that for some months, consecutively, the mean height of the river is two and a half feet below the sea level, a conclusion which is altogether inadmissible.

" The lowest monthly mean tide occurs about February and March, when the fresh water in the river is lowest, and strong Southerly winds do not prevail. The mean tide rises gradually, as the river rises during the south monsoon, until it attains its maximum in September or October, at which time the monthly mean exceeds that of February by no less than six feet. This rise is, obviously, the effect of accumulation, produced by inundation in the Valley of the Ganges, and the force of the S.W. wind, which dams up the freshes in the long and narrow channel of the river.

" It has been remarked by Colonel Cheape, Chief Engineer, in his memoirs, dated April, 1835, that the surface of the Salt Water Lake, wherein the rise of the tide is almost imperceptible, would on account of its wide expanse, represent very accurately the level of the sea with which it communicates. He also observes that Captain Taylor's levels indicate that the surface of the lake in the dry season is 3 feet 4·3 inches below the mean state of the river. This result corresponds very nearly with the mean tide of the river itself, which in February is 2 feet 5 inches below the level of the annual mean.

" Colonel Cheape further states that the periodic rise of the surface of the lake in the wet season is ten inches. Now, the contemporaneous rise in the mean tide of the river has been shown to be six feet, and as the cause of these elevations is precisely the same, though the effects are in the ratio seven to one, the greater rise in the river can clearly be attributed only to the narrowness of its channel compared with the bay : it is probable that a considerable portion of the rise of ten inches in the surface of the lake is also due to accumulation ; so that, although a rise may be supposed to take place in the level of the sea at the head of the bay, during the continued pressure of the S.W. monsoon, still, that elevation must be much less than what takes place in the lake, where the effect of this rise is increased by the narrowness of the channel, and the influx of fresh water during the inundation.

" It has been shown, that if the annual average of mean water be taken as the sea level, it would lead to the inadmissible conclusion that in the dry season, the average level of the river at Calcutta is twenty-nine inches below the sea, with which it freely communicates. It has also been shown that the surface of the great Salt Water Lake, in the dry season, is on a level, or nearly so, with the mean tide of the river at the same time. It is likewise manifest that the periodic rise of mean tide during the monsoon, to the extent of six feet in the river and ten inches in the lake is occasioned by local causes, independent altogether of the true level of the sea, which is a constant level, and these causes, I appears, operating in narrow channels are capable of producing exaggerated results in the proportion of seven to one, showing clearly the fact of accumulation. Hence the conclusion is inevitable, that the lowest monthly mean tide of the river, observed in February and March, represents the nearest approximation to the actual sea level, and that the rise of mean tide at Calcutta during other months may fairly be ascribed to disturbing causes of an inland character, altogether independent of the true and constant level of the ocean. The variable character of the disturbing causes is shown by

Railway levels with Kydd's Dock, it was found that there still remained

the fact that the monthly means of corresponding months, for the two years differ considerably, except in the months of February and March, the monthly mean tides of which are very accordant.

"Proceeding upon this principle, I have used the following observations to refer the datum line in Kydd's Dock to the sea level :—

Mean tide February, 1847, above datum as measured on gauge,	...	...	8.11 feet.
" March, " " " " "	...	...	8.45 "
" February, 1848, " " " "	...	...	8.48 "
" March, " " " " "	...	...	8.50 "
" February, 1850, " " " "	...	...	8.28 "
" March, " " " " "	...	...	8.62 "
" February, 1851, " " " "	...	...	7.94 "
" March, " " " " "	...	...	8.36 "

Mean, ... 8.343 feet

"Correction for error of graduation on gauge by Mr. Bedford's measurements, 0.576 feet.

"By tides measured at Calcutta in February and March, mean sea level above datum, ... 8.576 feet.

"Again, in the years 1850 and 1851, Mr. Bedford, the Marine Surveyor, took a series of tidal observations at Kejiri, and connecting this point by a series of levels with Kydd's Dock, found the datum line at the latter point is 9.07 feet below the sea level. Mr. Bedford's observations, from which this result is derived, are as follows :—

MEAN LEVELS OF THE RIVER'S MOUTH AT KEJIRI, AT NEAP TIDES, FOR THE YEARS 1850 AND 1851, EXCLUDING THE SOUTH-WEST MONSOON.

Months.	Highest Low Water.		Lowest High Water.		Mean.	
	Feet.	Inches.	Feet.	Inches.	Feet.	Inches.
1850.						
January,	5	0	11	9	8	4½
	4	0	11	9	7	10½
February,	5	6	11	0	8	3
	4	9	11	6	8	1½
March,	6	0	11	0	8	0
	4	9	12	0	8	4½
April,	6	9	11	0	8	10½
	4	9	12	6	8	7½
May,	6	9	12	0	9	4½
	5	3	13	0	9	1½
June,	6	6	13	3	9	10½
	6	0	14	9	10	4½
November,	7	0	13	3	9	7½
	4	9	13	0	8	10½
December,	5	9	11	9	8	9
	4	6	12	3	9	4½
1851.						
January,	4	6	11	9	8	1½
	4	3	11	0	7	7½
February,	4	3	11	3	7	9
	5	0	10	3	7	7½
March,	4	9	11	0	7	10½
	6	3	11	9	9	0
April,	5	3	12	9	9	0
	7	0	10	6	8	9
May,	5	6	12	6	9	1½
	7	0	12	9	9	9
June,	6	0	14	6	10	8
	6	9	13	3	10	0

a difference of about twelve feet between the Railway and the Survey height of Agra.* On discussing this subject with the Chief Engineer of the Railway, I ascertained that there were several breaks in the Railway

			feet. inches.
" Mean height of sea level above the datum line at Kejiri, ...	...	...	8 9-75
" Datum line at Kejiri above that of Kydd's guage, ...	...	...	0 2-38
" Sea level above the datum line of Kydd's guage, ...	...	...	9 0-63
" Which reduced to decimals of a foot, becomes, ...			9-053

" Which differs from my determination by half a foot; but, if the tides at Kejiri for February and March be alone taken into account, at which period the inland waters flowing seaward are lowest, the result would agree with that derived from my discussion of the tides at Calcutta to about one inch."

* Mr. Donnelly reports that he was much delayed by the discrepancies which were found between his levels and those of the Railway. They entailed the re-measurement of two sections, one fifteen, the other twenty-six miles in length. In the first, the discrepancy was five feet; in the second seventeen and a-half feet. Mr. Donnelly and his Assistant re-measured both these sections, and obtained results differing from their first results by only -032 of a foot in the first instance, and -043 in the second, clearly shewing that the error did not lie in their work.

In the course of the Field Season, Mr. Donnelly laid down nine G. T. S. Bench-marks, fixed two G. T. S. Trigonometrical Stations, and connected one hundred and forty-one points, principally Railway mile-stones, Bridges, Bench marks, and Station Platforms.

COMPARISON OF RAILWAY AND G. T. SURVEY LEVELLED HEIGHTS.

Names of Railway Stations and Bench-marks.	G. T. Survey.		Railway.	G. T. S. — Railway.	Remarks.
	Height above Mean Sea Level	Height above Howrah Dock Sill.	Height above Howrah Dock Sill.		
Serampoor, ...	+ 30-910	+ 32-852	+ 32-231	+ 0-322	Level of Rails.
Pundooa, ...	+ 42-398	+ 54-031	+ 54-140	+ 0-100	Do.
Dymaree, ...	+ 66-697	+ 78-331	+ 78-260	+ 5-070	Do.
Burdwan, ...	+ 100-325	+ 111-968	+ 107-260	+ 4-698	Do.
Kanoo Junction, ...	+ 121-439	+ 133-172	+ 128-250	+ 4-922	Do.
Gooskarrah, ...	+ 110-948	+ 122-137	+ 118-257	+ 3-887	Do.
Beddiah, ...	+ 132-270	+ 143-903	+ 147-250	+ 5-663	Do.
Bulpoor, ...	+ 166-635	+ 171-268	+ 167-256	+ 4-018	Do.
Ahmadpoor, ...	+ 134-213	+ 145-846	+ 142-250	+ 3-596	Do.
Cynthes, ...	+ 168-330	+ 179-963	+ 176-250	+ 3-713	Do.
Dullarpoor, ...	+ 143-709	+ 155-362	+ 151-231	+ 4-112	N. W. Plinth of Station-house.
Rampoor Haut, B. D.,	+ 116-810	+ 128-143	+ 124-960	+ 3-483	Square Pillar in centre of Line, opposite Booking-office. Level of Rails.
Pakowr, ...	+ 104-392	+ 116-025	+ 112-250	+ 3-775	
Teenpahar, ...	+ 103-770	+ 115-422	+ 109-250	- 13-838	
Tillinghuree, B. D., ...	+ 110-900	+ 122-583	+ 115-830	- 11-906	Square Pillar on Line to E., marked D.
Do. ...	+ 96-838	+ 108-271	+ 121-090	- 12-809	Heel Stone of Gateway, W. Gate of Fort N. side, original B. D.

levels, that, in consequence of the pressure of other work, there had been no opportunity of preparing a correct and true section of the whole line, and that it was contemplated to re-level the line, as soon as the Engineers had leisure to do so. I decided, therefore, on deputing the levelling party to re-level the line of the Railway, and connect all the Trigonometrical Stations within reach thereof.

Mr. Donnelly made good progress, and accomplished two hundred and forty-two miles of first-class levelling,* forty-one of which had to be re-levelled, on account of large discrepancies which were found in the Railway levels. The operations had reached the vicinity of Bhagulpore, when Mr. Donnelly was compelled, by severe illness, to close work.

During the year under review, I was called upon to collect all the available data of levels, existing in the Public Works, Railway, and Survey Offices, all over India, in order to reduce them to a common datum. As a first step towards this desirable measure, I have published a volume of Tables of Levels, based on the Spirit-Levelling operations of this Survey, and reduced to the mean sea level of Karachi harbour, as their datum. Additional volumes will be published as soon as possible. They will enable Officers of the Public Works and Railway Departments to reduce their levels to the mean sea, by connecting them with the nearest Bench-mark, or Station of the Trigonometrical Survey. In most instances, however, the business of connecting will probably devolve on the Survey Department. At present, we have only one Levelling party, which is employed in Bengal; I therefore submitted a project for the formation of other parties, to carry on operations, simultaneously, in the Madras and Bombay Presidencies, as the only means of speedily accomplishing an operation, of which the practical value will be greatly enhanced by early completion. Unfortunately, financial reasons have interfered to prevent this proposal from being sanctioned.

I now proceed to report on the Astronomical Observations for the determinations of the Latitude and Longitude of the Andaman Islands, which were instituted on a representation by the Superintendent of Port Blair, that the erroneous positions assigned to some of these

* With an Assistant levelling the line, independently, behind him, station by station, after the method described in the published volume of Tables of Heights.

Islands, in the published Charts, endangered the safety of ships sailing between Calcutta and Singapore. Under the orders of Government in the Home Department, the Surveyor General had deputed a Surveyor, Mr. Nicolson, to conduct the necessary observations, the superintendence of which was subsequently transferred to the Trigonometrical branch of the Survey.

Mr. Nicolson started from Calcutta early in December, 1861, to reconnoitre the Coco and Andaman Islands. He found that, in order to take a complete Series of Astronomical Observations at the Great Coco, it would be necessary to have a steamer placed at his disposal for some weeks, to keep up his communication with Port Blair, and bring the necessary supplies for his party.

About this time, a communication was received from the Bombay Government, representing that there was as much doubt about the accuracy of the position of Port Blair, as of that of the Coco Islands. Under these circumstances, it seemed advisable that Mr. Nicolson should begin operations by fixing Port Blair, in order that the proposed operations might be commenced at the place where the greatest facilities for their execution existed.

The inaccuracy of the present Charts of the islands lying between Sumatra and Burma being admitted on all sides, it appeared necessary, in the absence of any regular survey of those islands to fix, by astronomical observations, the positions of Acheen Head, Port Blair, the Great Coco, or the Preparis Island, and an island in each of the other groups intermediate between Acheen Head and Cape Negrais. It is believed that the relative positions of the mutually visible islands of each group are already correctly shown on the Charts; consequently, by determining the absolute position of a point in each group, it would be possible to rectify the existing Charts, without making a general re-survey.

Mr. Nicolson, having completed his reconnoissance, returned to Calcutta in February, 1862, by which time one of the large 8-foot astronomical circles of the Trigonometrical Survey had been got ready, and a portable observatory, with rotating dome, constructed for the observations. There was no good astronomical telescope available in the stores of the Mathematical Instrument Department; consequently, Mr. Nicolson was directed to take all his observations, whether of

occultations, eclipses, or moon culminations, with the telescope of the astronomical circle, which he could point to any part of the sky, through the aperture in the rotating dome of the observatory. Owing, however, to the small number of occultations and culminations which occur monthly, and the risk of losing some of them in cloudy weather, Mr. Nicolson was directed to base his observations for Longitude chiefly on the measurement of lunar zenith distances, for which the astronomical circle is well adapted. He was supplied with an astronomical clock, and all other necessary instruments, from the Calcutta Observatory.

In May, 1862, Mr. Nicolson had set up his observatory at Port Blair, and was ready to commence observations. Unfortunately, the season of fine weather had then nearly terminated; the monsoon set in with unusual severity, nights favorable for observing were few and far between, and, consequently, several months elapsed before the whole of the necessary observations for Latitude and Longitude were completed. The work was further impeded by the delays attendant on postal communication between Calcutta and Port Blair, making it very difficult for me to exercise that degree of supervision over the operations, which their delicate and difficult nature required.

By the end of 1862, Mr. Nicolson reported that he had taken a sufficient number of observations to fix the position of Port Blair; he, therefore, applied for a vessel to be placed at his disposal to enable him to proceed to fix the positions of the Great Coco, and other islands. Owing to postal and other delays, it was not until the end of February, 1863, on my return from Vizagapatam, that I learnt from the Marine Department that no vessel was available, nor could one be got ready before the fine weather season would have terminated.

From the same communication I also learnt that the Secretary of State for India had ordered a complete Maritime Survey of the Andaman Islands to be executed. Being then in Calcutta, I went to Captain Rennie, the Secretary to Government of India, Marine Department, and was informed that, under instructions from the Admiralty Hydrographer, it had been determined to find the differences of Longitude between the various groups of islands, chronometrically, by a battery of thirteen or fourteen chronometers.

The circumstances under which it was originally proposed to fix a

series of positions by astronomical observations had thus entirely altered. The complete Maritime Survey, which has been ordered by the Right Hon. the Secretary of State for India, renders further astronomical observations unnecessary. The determinations of differences of Longitude, which are the only really difficult portion of the work, can be done chronometrically by the Marine Surveyors, with much greater rapidity and economy, and, probably even with greater accuracy, than by the best astronomical observations for absolute Longitude.

Consequently, in March last, I desired Mr. Nicolson to restrict his operations to taking as many more observations for the determination of the Longitude of Port Blair, as could be obtained before the setting in of the monsoon, and then to return to Calcutta. He reached the Presidency in June, and has ever since been employed in reducing his observations. They consist of 32 lunar culminations, 136 lunar zenith distances, 130 transits of clock stars, and 162 meridional zenith distances of stars for Latitude, observed up to the 12th March, when the astronomical clock met with an accident, and Mr. Nicolson was afterwards obliged to employ a chronometer. His subsequent observations are, consequently, not as valuable as the earlier ones; they consist of 9 culminations, 64 lunar zenith distances, and 36 clock stars. The whole of the Latitude observations have been reduced, and found exceedingly satisfactory. There has not yet been leisure to reduce more than a few of the observations for Longitude, but the results obtained hitherto are satisfactory. The final resulting Longitude will be communicated for publication in the *Calcutta Gazette* as soon as ascertained. It should serve as an excellent datum for the proposed Maritime Surveys, and save the expense of a series of voyages between Madras and Port Blair, which would otherwise have to be incurred to obtain a good chronometric determination of the Longitude of Port Blair.

THE OUT-TURN OF WORK EXECUTED BY EACH PARTY DURING THE FIELD OPERATIONS OF THE OFFICIAL YEAR 1862-63, IS SHOWN IN THE FOLLOWING ABSTRACT:—

Statistics.	Kashmir Series.	Coast Series.	Balei Series.	East Calcutta Longdial Series.	Rahoon Meridional Series.	Eastern Frontier Series.	Bombay Party.	Total Out-turn of Work.
Principal Triangles,	..	19	29	4	13	16	32	113
Average error of Principal Triangles in seconds,	..	0°.94	0°.43	0°.44	0°.46	0°.48	0°.89	0°.65 average.
Observed Azimuths,	..	1	1	..	2	..	1	5
Secondary Triangles with all three Angles Observed,	..	10	132	..	16	..	32	190
Area of Principal Triangulation, square miles,	..	256	1,366	220	1,608	884	6,625	10,954
Area of Secondary Triangulation, square miles,	10,500	..	4,316	..	950	263	1,510	18,189
Area of Topographically Surveyed, scale 4 miles = 1 inch, square miles,	10,400	..	..	..	..	..	..	10,400
Intersected Points,	..	12	112	..	18	22	110	274
Length of Principal Triangulation in miles,	..	..	112	20	69	49	260	490
Secondary	..	..	340	..	72	..	100	512
Miles of rays cleared between Principal Stations,	..	..	300	253	159	..	..	712
Towers built for Principal Stations,	..	..	11	5	5	..	2	23
Platforms	..	12	..	..	6	17	44	79
Platforms built for Secondary Stations,	..	..	95	..	..	..	..	95
Length of Triangulation laid out in advance in miles,	..	..	..	45	..	77	150	272
Principal Stations selected in advance,	..	..	..	8	..	17	86	61

The Computing Office has been employed in a variety of preliminary operations, which are necessary to form the basis of a general reduction of the whole of the principal triangulation of this Survey, which will shortly become necessary, now that almost the whole of the triangulation of the tracts of country comprised in the great quadrilateral figure connecting Calcutta, Karachi, Attok, and Purnea, is completed. Though the triangulation has been executed with the very best instruments, and though the system of observation which was introduced into this Department by Colonel Everest, is more rigorous and accurate than that of any European Survey, it is evident that, in consequence of the vast length of each Series, and the imperfections which necessarily attend whatever is the work of human hands, each Series generates a certain amount of error, which becomes apparent as linear error on the termination of the Series on a measured Base line, while on the close of a circuit formed by two Meridional Series, and the portions of the connecting Longitudinal Series at their extremities, it produces errors of Latitude, Longitude, and Azimuth. The dispersion of these errors in such a manner as to obtain the most probable results of the whole, giving its due weight to each fact of observation, and taking into consideration the bearing of every such fact on all the rest, is a matter of great intricacy and difficulty, on which it will be necessary for me to consult with the ablest mathematicians of the present day in Europe, before deciding on the system to be finally adopted. Meanwhile, the necessary preliminaries for the eventual calculations are being carefully elaborated by Lieutenant Herschel, to whom I am indebted for numerous very valuable suggestions, and for co-operation as cordial as it has been unintermittent.

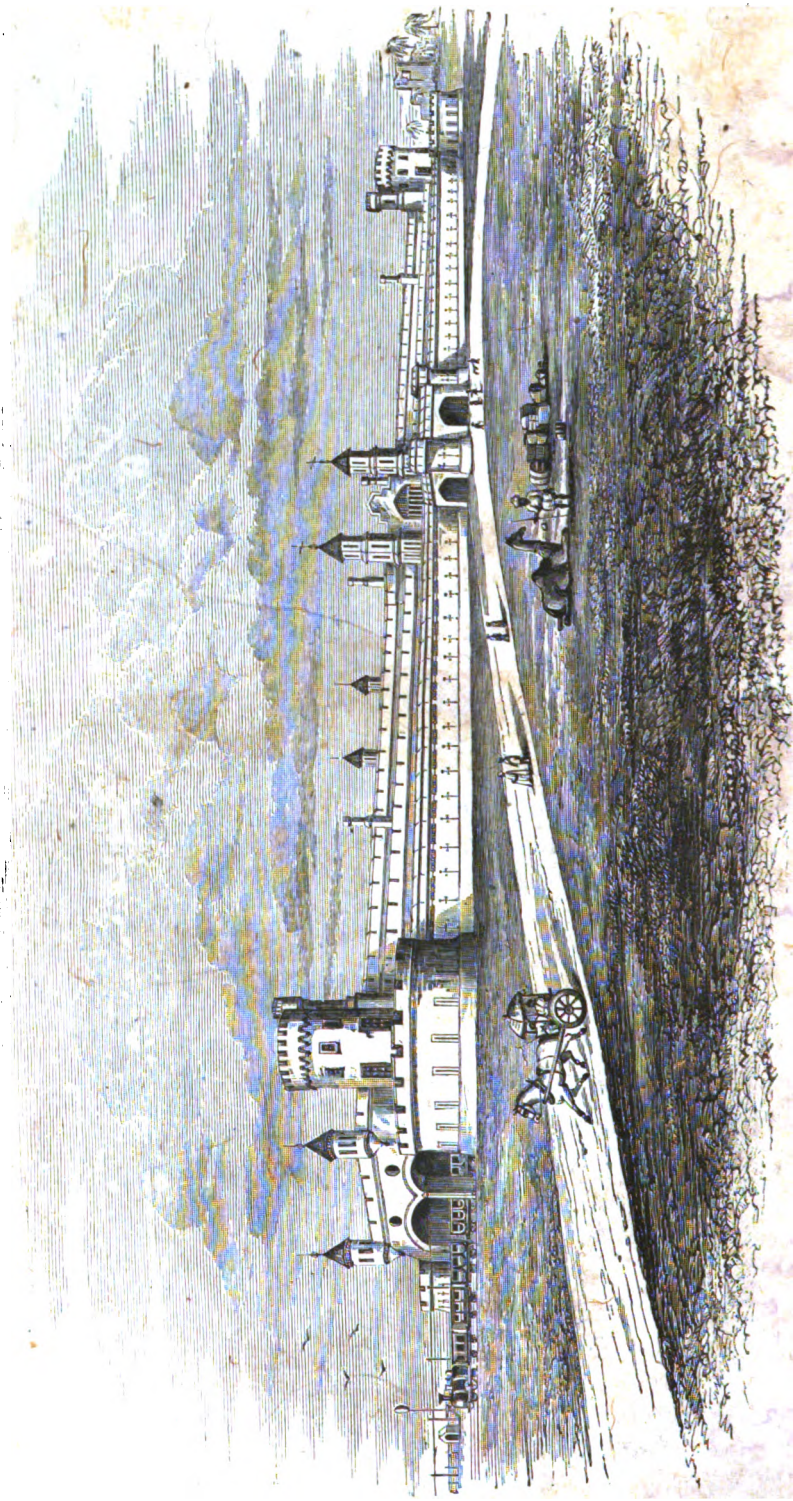
While the practical operations of this department may be confidently pronounced to be of a superior order to similar operations in any other part of the globe, it must, on the other hand, be admitted, that the theoretical applications, for the reduction of the triangulation, have not kept pace with recent improvements in geodetical science, which have been introduced into some European Surveys. The method which has hitherto been employed for reducing the observed angles, so as to satisfy all the equations of condition of each figure, though a great improvement on any previous method, has had, in its turn, to give way to the subsequently discovered method of minimum squares. The algebraical

solution of the equations necessary to satisfy the condition that the sum of the squares of the errors shall be a minimum, is by no means difficult, but hitherto there has been no practical adaptation of it in this Survey, chiefly owing to the pressure of other and more urgent business, on those alone capable of dealing with the subject. Much progress has, however, been recently made in this direction, and I am indebted to Lieutenant Herschel for devising methods of calculation, which will enable the reduction of our figures to be effected, according to the new and rigorous system, by native computers possessing little more than a knowledge of arithmetic, with even greater facility than the less refined methods of reduction, which have hitherto been employed.

The Drawing Office has been chiefly employed in compiling Maps of the dominions subject to the Maharajah of Kashmir, from the plane table sheets sent in by Captain Montgomerie. A new Chart of the Triangulation of this Survey, up to date, has also been prepared, and a Chart to illustrate the volume of Tables of Heights recently published; both these Charts were lithographed in the Office of the Surveyor General, Calcutta. Nine original preliminary Charts of the triangulation, in various parts of India, have been prepared, in duplicate, for the use of the Surveyor General's Office, and the Geographer to the Right Hon. the Secretary of State for India. The Photographic apparatus is also being usefully employed in copying and reducing Maps, and in furnishing preliminary copies for current use, until the originals are engraved and published. Owing, however, to the small establishments at my disposal, the photography is necessarily restricted to the short period of the recess of the Kashmir party, three to four months, when the services of our best Photographer, Captain Melville, are available for their management.

In the Instrumental Department, great advantages may be expected by the appointment recently made by the Right Hon. the Secretary of State for India, of an Officer, Colonel Strange, to superintend the construction of the new Great Theodolite, and various astronomical instruments, which are being prepared in England for this Department. When they are received in India, we shall be in a position to undertake the necessary operations for ascertaining our Longitudes, in connection with the Observatory at Greenwich, by means of the Electric Telegraph, which is now brought across from the Mediterranean to India.

J. T. WALKER.



Wood Engraving Dept. Thomson (Lille).

LAHORE RAILWAY STATION.

ANGLO-INDIAN ARCHITECTURE.

THE revival of Architectural taste which has sprung up within the last twenty years in England, is slowly but gradually spreading to India, and within the last few years more than one handsome church, railway station, or other public building has been erected, which would do no discredit to any European capital. This improvement has certainly not come before it was wanted. Until very lately we did not shine in designing public or private buildings at home; witness the heterogeneous rows of suburban villas in the neighbourhood of London, or the unmitigated monotony and ugliness of many of our modern streets. But we certainly surpassed ourselves in India, and succeeded in inventing a style of building, (irreverently known as the Military Board style,) which for ugliness beat everything that ever was constructed by man.

Who does not know the sense of desolation that comes over one at first sight of some of our Indian cantonments; the straight and dusty roads, the rows of glaring white rectangular barracks, the barn-like church, differing only from a barrack in the presence of a square tower and classical (!) portico, the Roman Catholic chapel ditto, only smaller and with bright green doors all round.

Then the houses evidently built after the model of the barracks, unless when the genius of the builder had displayed itself in a profusion of bright colors on the external walls, arranged in such startling contrast that the dāk horses were very apt to shy at passing it.

If we go inside matters are not much better. High bare white-

washed walls, a barn-like roof, with perhaps a dirty ceiling cloth shaking in the wind, a dilapidated plaster floor and square holes cut in the wall doing duty as doors and windows. One exception alone is there to this puritanical simplicity, in the fire-place, which is evidently an offspring of the genius of the native mason, and consists of a grotesque mass of ornaments which would perhaps be more effective if unblackened by the smoke from the ill-constructed chimney.

The general reason assigned for such a state of things is—1st, The requirements of the climate; 2nd, The necessity of economy. But the cogency of either argument must be altogether denied. There can be no doubt that a thoroughly airy and well ventilated building may be made just as ornamental as one which is adapted for a cold climate only; and that a small amount of money expended in judicious ornamentation will scarcely affect the total cost of the building. The real reason has been undoubtedly a want of taste and knowledge, and now that such deficiencies are beginning to disappear, it is hoped and believed that the beginning of an improved state of things has arrived. It must I think be allowed that the true principles of architectural construction for buildings in the East, which are to be used by men habituated to an entirely different climate, have not as yet been discovered; a Mosque for instance has a pleasant temperature both in winter and summer, while a Gothic Church in India is as a rule either very hot or very cold. I do not say that Gothic Churches are unsuitable to India, but only that they are so as we now build them. In the same way many of our houses with lofty rooms, numerous openings and thin walls, are far less cool and pleasant than native houses, low and badly ventilated as they are, with thick walls and few doorways. I do not say that we ought to live in native houses, but simply that we have not as yet hit upon the right way of constructing our own.

Treating of Architecture as distinct from mere building, it is an art, not a science, and therefore does not fall under exact rules of

instruction ; one consequence, of which is, that while Engineering advances and improves, Architecture stands still and copies.* We make better roads and bridges now than in the 15th century, but we have hardly got beyond copying their churches ; and until there is a reformation in this respect, it is hopeless to expect that we shall have an Architecture adapted to the peculiar circumstances of Anglo-India. It is not intended here to propound any original ideas on the subject of Anglo-Indian buildings, lay or ecclesiastical, but merely to offer a few hints for improvement in matters of detail which may be useful to those called upon to design and erect buildings in India.

First, as to the style of our dwellings in the Upper Provinces. As above hinted, it is doubted whether the present style is not radically unsuitable to the climate. In a hot and damp country, especially if near the sea coast, numerous doors are certainly required by which the cool breezes may sweep through the house, and hence verandahs are necessary to shade the doors from the direct glare of the sun. But where, as in Upper India, it is necessary during the fierce dry heat of April, May, and June, to exclude the hot air altogether by night as well as by day, the fewer doors there are the better, and ventilation should be secured through the roof. In the cold weather, the paucity of doors would add much to the comfort of the house, and verandahs might perhaps be altogether dispensed with. The thin walls which now get so thoroughly baked that they continue to radiate heat by night and day for months together, should be made twice their present thickness, or better still, might be double. Upper storied buildings are perhaps more suitable to Lower than Upper India, unless the upper rooms are used solely as dormitories, but considerations of expense will generally bar their adoption. In many parts of the country perhaps the old Eastern style of building, round an open quadrangle in the centre might be adopted with

* See a late article in the Quarterly Review, on the Progress of Engineering Science,

advantage. This open court paved with marble or stone, filled with fragrant shrubs, and with a fountain and tank in the centre, is characteristic of most of the dwellings of the wealthy throughout Syria and other Eastern countries, and is indeed common enough in native houses in India. Perhaps some one will work the idea into a tangible shape.

Next, let us protest against the indiscriminate use of plaster so generally applied to buildings of all kinds in India. In most cases it is simply used to conceal bad masonry, and every plastered building looks shabby in a few months after being constructed. It is expensive and adds no strength to the work. Brick masonry if well executed has a beauty of its own, and with well made bricks, well-bonded, and with fine joints, there can be no meaning whatever in hiding the material. Some excellent specimens of brick masonry have been lately erected* in Upper India, but improvement is required in the manufacture of bricks before this kind of work can be executed to the best advantage, otherwise the dressing and chipping of the surface entails much labor and removes the outer skin of the brick, which is the most durable part and is best fitted for resisting atmospheric effects. The use of the pug-mill, a careful choice of mixture of earth, and perhaps the employment of machinery in moulding would ensure the requisite degree of excellence. By the employment of colored bricks in the exterior mouldings very good ornamental effects might it is believed be produced. Plaster must still be used for the interior surfaces of walls, and where the best kinds of lime plaster can be afforded, perhaps no better material can be wished than the smooth polished surface thereby produced. But if inferior plaster be used, why daub it invariably with the lime whitewash, which comes off on the clothes and produces a most wretched and shabby effect? Wherever chalk can be obtained it is little dearer than lime, looks much better, does not whiten your coat every time you lean against the wall, and

* The new Government School-house at Umritsur, built by the Municipal Engineer, W. Gordon, Esq., and the new Lahore railway station, described in the present number, are excellent specimens.

takes the common coloring matters well. Of these the *neila tutya*, (sulphate of copper,) the *peoree*, *soorukh*, and *Mooltanees muttee*, are well known in Upper India; and good shades of blue or green, yellow, red, and buff, are produced from them; but let them be mixed with chalk, not lime, as is usually done, and use a sizing of glue or rice-water. There is a popular but ill founded objection against the use of paper for walls. In a damp climate like Bengal it would not do, but in the dry Upper Provinces there is no reason whatever for not employing it.

Will somebody invent a new material for roofs in India? Slates we have not, except in one or two out of the way localities. Galvanized iron we cannot get. Tiles get broken and look ugly, and are leaky. The ordinary flat terrace roof leaks also, and is very heavy. A trussed roof with a very slight pitch, (say 10°), and covered with flat bricks and lime terrace is about the best we know, but is very far from being what it should be.

But our floors are worse. A lime floor looks very well when just finished, and for a private house answers its purpose fairly; but for a building like a barrack it is soon cut up, is unhealthy, (the dusty particles flying about engender opthalmia,) and impossible to repair satisfactorily. A plank floor is expensive, perishable, and warps from the extreme changes of the climate. The best floors hitherto made are those of flat brick or brick-on-edge. But why should not this method be improved upon in public and private buildings? Excellent colored and glazed tiles are made in the Punjab and other parts of India, and hexagonal or diamond shaped flooring tiles of white and blue or black look very well, and ought, if properly made, to wear well. The glaze is objectionable as making the floor slippery and apt to chip or wear off, but why should we not use the unglazed encaustic tile now employed so largely in England by Minton and other manufacturers? No better floor could be devised for a private house in the hot weather than one of colored tiles, laid in an ornamental pattern, and which would enable us to dispense with carpet or matting. I have little doubt that if a

manufacture were started on a line of railway, the speculation would pay excellently; and I would recommend the idea to Government for the new public offices at Calcutta, Allahabad, and elsewhere. I believe the requisite materials exist in plenty throughout India, and nothing is wanted but the requisite skill and capital. One other material may be named for floors, viz., gypsum, or plaster of Paris, (sulphate of lime,) which abounds in some parts of India, as for instance, the Dehra Doon. It is excellently adapted for floors, cornices, and other interior parts of buildings, and is capable of being made into highly ornamental forms.

Fire-places and chimney-pieces must be left to the taste of the builder. The exceedingly ugly square upper windows may be replaced by circular ones, especially if the doors have circular fan-lights above them. For both doors and windows colored glass may be used with great advantage to the comfort of the room, and the *diaphane*, or imitation stained glass, is both economical and pretty.

Punkahs may be decidedly improved. The kind generally known as the Bombay punkah, consisting of a single bar of wood with a heavy deep fringe, is decidedly superior to the abominable white-washed rectangle which invariably disfigures every room in Upper India. But if the latter shape is preferred as giving more air, at least let it be colored or covered with ornamental paper; let the fringe be of good material and color, and above all, clean; and let the ugly thick white cotton ropes be replaced by thin colored cord or wire.

Enough has been said for the present or we might still declaim against mud walls of compounds, ugly rows of out-houses, hideously ornamental gateways, &c. But as it is to be hoped a more refined taste is in progress, it may be sufficient to urge the subject on the attention of those whom it may concern.

J. G. M.

No. XX.

THE LAHORE PASSENGER STATION, PUNJAB RAILWAY.

PLAN, Sections and Elevation are given of the above building, of which the Engraving on the Frontispiece presents a general view. I have been disappointed in not receiving the Estimate and Specification.

The Lahore Railway Terminus is about 400 yards distant from the Delhi Gate of the city, on the site of the old Sikh Cantonment of Naolucka, amongst the ruins of the ancient city. Great difficulty and expense were incurred in getting in the foundations of the various Station buildings, owing to the depth of these ruins over the firm soil below.

The buildings sanctioned, and either completed or in hand, are the Passenger Station, Goods' Shed, Workshops, Carriage Sheds, and Locomotive Stables. In designing the Passenger Station, it was thought advisable to give it a defensive character, as far as possible, and to arrange the defences so as to require but a small garrison. Hence the Fort-like appearance of the present structure.

The material employed is brick throughout; the outer surface being carefully dressed with very close joints. It would be difficult to find better masonry anywhere. The roofs are of pukka terrace on trusses of low pitch, except those over the platforms, which are to be of galvanized corrugated iron. The floors are all of brick-on-edge, set very close, and dressed smooth. The timber employed everywhere is deodar, from the forests of the Punjab Himalayas.

The entrance archways at either end of the building can be closed when necessary by heavy sliding doors.

The building was designed by Mr. Wm. Brunton, late Chief Engineer of the Punjab Railway, and has been, I believe, chiefly executed under the superintendence of Mr. E. Baines, District Engineer, and the Architect of the Lahore Exhibition.

J. G. M.

Railway.

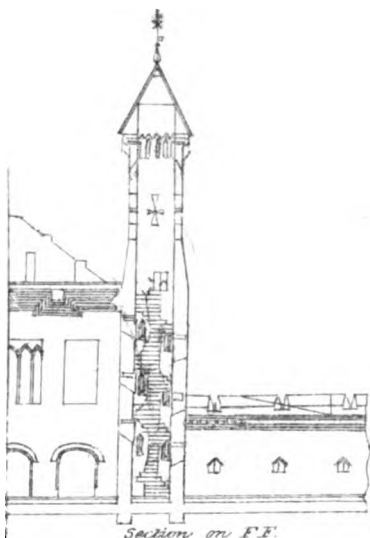
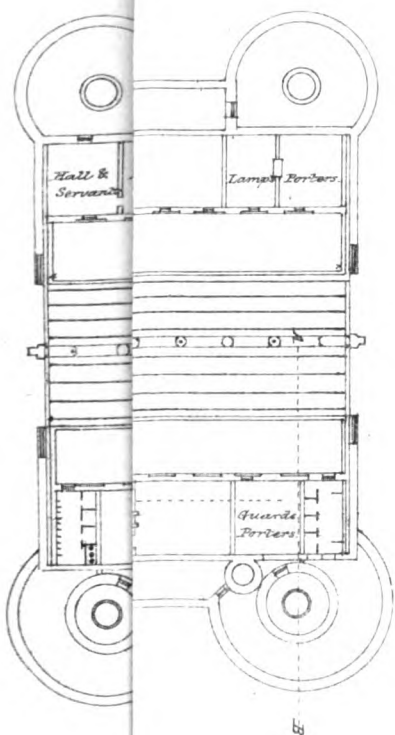
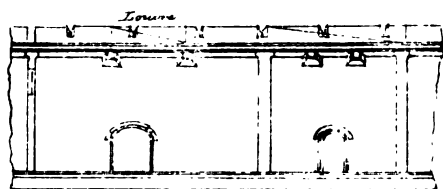
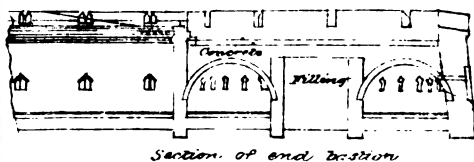
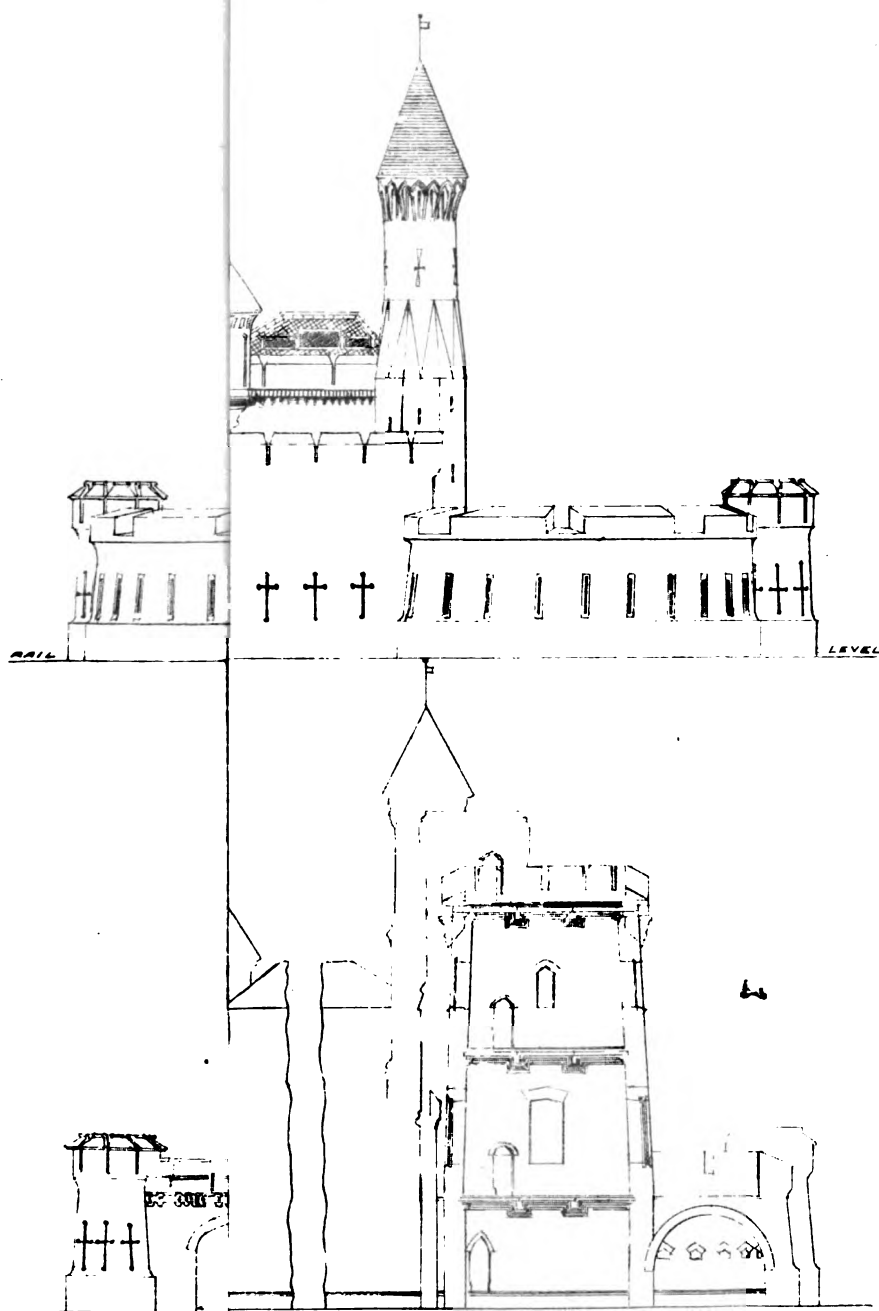


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Half Section on line A.B. on Plan

No. XXI.

BOAT AND PONTOON BRIDGES.

[Government having called for Reports on the best form of Boats to be used in Boat bridges, and on the comparative merits of Boats and pontoons, the following Reports were submitted by three of the officers consulted.]

From R. J. CLARK, ESQUIRE, Exec. Engineer, 5th Division, Grand Trunk Road, to Superintending Engineer.

Agra, 15th July, 1862.

SIR,—In reply to letter from the Secretary to Government, N. W. P., requiring a report on the best form of boats to be used in boat bridges, and also whether pontoons are not more suitable, and in the end more economical; I have the honor to state, that, if a bridge of boats was preferred, I should consider the following alterations required in a native boat to adapt it for bridge purposes.

Instead of the broad flat bow of the native boat, the bow should be gradually rounded off from the straight side, by gradually bringing the side planks to meet at the stem; as by pointed bows the boats would offer less obstruction to the current, and cause less wear and tear in the moorings.

Instead of the simple beams across the native boat, by which alone the sides are tied together and supported, I would have a series of strong frames across the boat, fitting, and secured to, the sides and bottom,

having one upright in the centre, and two sloping struts between the top and bottom pieces; these frames would keep the boat in shape, and distribute the weight of the roadway equally.

I have noticed that in native boats, as now used, with the roadway beams laid on the sides, or able to take a bearing on them, the sides get all the weight, and usually bulge outwards, and as soon as the boat has grounded, the bottom bulges upwards in the centre considerably; also a heavy weight passing over the side of the boat causes great undulation in the roadway.

As to the fixing of the roadway, for the reasons above stated, I consider that to make a roadway over boats as rigid as one over cylindrical pontoons, the points of support for the roadway beams should be as near as possible to the centre of the boat; this might be effected by a longitudinal bearer notched down to the frames abovementioned, in the centre of the boat, and raised a little above the sides, to enable the beams to work clear of them, but this plan would increase the expense, longer beams being required.

I beg to state, however, that in my opinion cylindrical pontoons are more suitable than boats for bridges, for the following reasons:—

1st. They offer, from their shape and size, less resistance to the current than boats, and consequently, fewer moorings are required; boats fouling the bridge are more easily cleared, and the pontoon bridge is the least liable to be carried away by sudden floods.

2nd. They are more secure against the weather, being entirely covered in, whereas boats require continual attention in the rains to keep them clear of water, and this would be against the durability of the boat as compared with the pontoon.

3rd. I consider that there is less undulation in the roadway of a pontoon bridge. Pontoons being narrow, the bearing of the roadway beams is from centre to centre of the beams, or nearly so, and a weight passing over is supported at once by the whole buoyancy of the pontoon; whereas in boat bridges, as the roadways are, I believe usually laid, viz., with two sets of working joints over each boat, a weight passing over must depress one side of a boat considerably before reaching its centre where the whole buoyancy of the boat takes effect.

4th. Most bridges are partly made over a sand bank. When the river falls after the rains, the bed is frequently altered and the bridge settles

down on the sand unevenly, and with steep slopes in places. If the bridge is on cylindrical pontoons it can be at once cheaply adjusted by digging the sand from under the pontoons without any carpenter's work. Boats can only be lowered the same way at great expense, and then they are so imbedded in the sand as to be liable to be sunk by any sudden flood, or otherwise the roadway must be packed up, which involves expensive carpenter's work and hindrance to the traffic; the same adjustment is required at any change of the level of the water at other times. This was found to be a continual source of expence when boats were used in the Agra bridge.

5th. As to durability, I have no means of ascertaining the difference between boats and pontoons in this respect, but the pontoon being more protected, ought to last the longest. The pontoon would stand, being placed on a dry sand bank for eight months in the year better than a boat. When the under side of a pontoon is nearly worn out, it might, with little expense, be reversed, and it would last nearly as long again.

6th. I am unable to state the comparative cost, but I imagine the cost of a boat or pontoon would be nearly equal. The cost of a pontoon at Agra would run from 900 to 1,000 rupees, and I do not think a boat sufficiently large for bridge purposes could be obtained for less. In some situations where wood could be obtained, cheap boats might perhaps be made cheapest, but I think that generally pontoons would be as cheap. They could be made quicker and are much easier to move about than boats.

R. J. CLARK.

MEMO. BY THE SUPERINTENDING ENGINEER.

I think the Executive Engineer has submitted good reasons in the foregoing letter in favor of pontoons as compared with boats, to which may be added, that pontoons when built in compartments, must always be safer than boats of the ordinary kind, and cannot be burnt. Such boats seem to have only the advantage of being more easily obtained when time is an object.

With regard to cost, the market prices of the larger class of boats seem to vary from 600 to 1,000 rupees, according to size and locality, and there could not be much difference in the cost of a pontoon bridge of each kind.

Pontoons, moreover, can be more easily transported over roads, if occasion should require, either for commercial or military purposes; and iron, which is properly protected, will, I think, last longer than timber, with less leakage from alternate wet and dry conditions.

J. D. CAMPBELL.

*From CAPTAIN D. LIMOND, R.E., Exec. Engineer, Cawnpore Division,
to Superintending Engineer.*

Cawnpore, 1st September, 1862.

SIR,—I have the honor to acknowledge the receipt of your memo. and to observe after due consideration, that I am of opinion pontoons are very much to be preferred.

The boats at present in use, form an excellent bridge; with the strongest flood running, there is hardly any motion. This of course arises from a great super-abundance of buoyancy, entailing extra strain on the cables, and forming a great obstacle to the free passage of the current. I am afraid the existence of this bridge has had a great deal to say to the erosion of the bank up-stream, regarding which I have written you demi-officially.

Long, narrow flat-bottomed boats, similar to English canal boats would not have this objection, but they are not free from the main one, which in my opinion most decidedly turns the scale in favor of the iron pontoon.

The Ganges is in a very different state during the cold and hot seasons and the rains; there always must be tracts of sand to cross during the former seasons; I cannot explain on paper the difficulty and inconvenience during the period of transition. If the boats are left aground they rapidly deteriorate; in short there are two periods of the year, the duration of each entirely dependent on the river, when it is impossible to keep the communication in a satisfactory condition, boats being used as the means of floatation. If pontoons on the other hand be used, they can be allowed to ground, the roadway subsequently levelled by excavation of the sand below them, or, they can be rolled

away with the greatest facility, and communication transferred to the sand bank. The removal of boats is not so easy, nor can such be done with the speed pontoons could be taken out. Large pontoons with ten or twelve feet bays should be used, in preference to the smaller or military class.

I had lately an opportunity of inspecting the pontoon bridge at Agra; the roadway is more level and superior to that on the Cawnpore bridge, for regular scantlings and means of floatation exactly similar, are used throughout its length.

The pontoons are allowed to ground, but a level roadway is secured by excavating the sand beneath them.

This course would not be so easy of execution with large boats, added to which iron pontoons do not apparently deteriorate by being left aground, while wooden boats certainly do. At the same time, I beg to bring to notice that the cost of construction of such a bridge over the Ganges at Cawnpore would be as follows—

110 pontoons with the superstructure approximately 1300	
each, cost Rupees,	1,43,000
or in round numbers one and a half lacs of rupees,	

Cost of Boat Bridge.

Average number of boats during hot and cold seasons, 35,	
for eight months, at an average of Rs. 35 per mensem, . . .	Ra. 9,800
Average number of boats during the rainy season, 60,	
at Rs. 35 per mensem,	Ra. 8,400
Average establishment for eight months at Rs. 300, . . .	„ 2,400
Average establishment for four months „ 750, . . .	„ 3,000
Interest on Rs. 31,000 expended on iron anchors, at four	
per cent,	Ra. 1,240

Total Ra. 24,840

To this add the cost of re-construction before the rains, the renewal of the down-stream temporary anchors, the interest on the expenditure on superstructure, and it is feared that little will remain of the toll proceeds, viz., 2,543-12-0 monthly, aggregating, Ra. 30,525

The risk of accidents remains.

D. LIMOND.

From LIEUT. J. ECKFORD, R.E., *Deputy Superintendent, Roorkee Workshops, to Superintendent General of Irrigation.*

Roorkee, 30th July, 1862.

SIR,—In reply to your letter, No. 858, I beg to enclose a letter which I have received from Mr. Campbell, whom I requested to inspect and report upon the Agra Pontoon Bridge. There is no need for my informing you, what weight I should give to Mr. Campbell's sense and practical judgment in a question like that which we have to consider; and I, too, would recommend the round pontoons for the following reasons:—

We are asked by Colonel Morton to decide between boats and pontoons; I do not know exactly how to define the latter, or where the difference between the two commences, but in the discussion which took place on the first establishment of the British Pontoon equipage, the *open* boat was absolutely and totally condemned, though opinions varied as to whether the pontoon should be of a boat shape or the present service pattern, which is cylindrical. We are now, however, treating of pontoons which are to be used for a very different object to military ones, and the arguments which apply to the latter will not hold as regards the former. The shape and size of military pontoons are mainly fixed by their facility for carriage, facility in handling and launching, and facility for being rowed when the bridge is broken into rafts. What we wish to arrive at is the cheapest form of pontoon adapted for a good permanent bridge for the heaviest traffic, taking into consideration that although the main part of the bridge may be permanent, the pontoon must be handy enough and with a sufficiently light draft of water to come quickly into place as the river rises, foot by foot, and submerges the low sandy ground, which generally covers a mile or two of its banks.

The size of the pontoon must in great measure depend on the place it has to be used at; a very heavy pontoon might be used on the Jumna at Calpee, where the river is one unbroken sheet, while at Cawnpore, where a low sandy island full of creeks intervenes between the Oudh and Doab banks, a lighter pattern must be adopted for the temporary parts. This point must be determined mainly by the Executive Engineer, and from the long experience which the present

Executive at Cawnpore, has had, the question could not be in better hands.

Wooden boats have only their cheapness in first cost to recommend them; wood is a peculiarly perishable material in India, and the boats built are notoriously weak and frail. Look at the superstructure of the Agra bridge, and think of an 8½-inch square beam being rack-lashed down to the thin bulwark of an ordinary boat, while to build a good strong boat with proper knees, and her timber strongly fixed together, would in the present state of the timber market, and with such carpenters as are to be got, be dearer than cylindrical pontoons at Boorkee. From actual experience on a bridge of boats, I can re-echo all Mr. Campbell's objections to the Delhi bridge; the water falls rapidly and before the two or three boats can be got out, (which form the small bridge over some creek,) the end of the creek has silted up, and the boats cannot be removed; they lie there to rot, their seams start from the heat, and the roadway over this part is lowered a foot or two, which if not made of short kurries, tied to the boat with hemp lashings, would inevitably break the main beams. Mr. Campbell says that the Agra practice, where the men dig under the pontoon and let it deeper into the sand, and again pack it up when necessary, is perfectly successful in keeping a level roadway. You will see the difference between getting to the bottom of a 5 foot round pontoon, or to the bottom of a 15 feet beam flat-bottomed boat, (which is a small boat,) and this is one of the two main reasons in favor of the narrow cylindrical shape. The applicability of this practice to Cawnpore should, I think, be first referred to the Executive Engineer there.

Looking on iron then as the cheapest material, perhaps not at first, but certainly in the end, (Mr. Campbell has not stated in his report, but has informed me that some of the pontoons have been in use for eighteen years,) the arguments for a boat shaped pontoon are, her less resistance to the current from her fine bow entry, and that should the bridge ever be displaced you have a serviceable boat. Neither of these reasons can for an instant be put in competition with those for a cylindrical one, namely, the superior facilities for keeping the bridge level, by being able to get underneath the pontoon, and its superior cheapness. An iron boat has to have her sheets rivetted to angle iron framing; this framing is expensive and troublesome to

set up, it requires careful workmen, and the constant supervision of the designer, while the curved plates of her bow and stern entries, require bending and rebending from unskilled natives, before they can be got to the proper curve.

A cylindrical boiler on the other hand is about the most straight forward work a man can do, every rivet of it can be given out to piece work, and it requires no inside framing; on these two reasons, therefore, of greater facility in keeping the bridge level, and a very great saving in prime cost, I would prefer the cylindrical shape.

From A. CAMPBELL, Esq., Special Assistant Engineer, to LIEUTENANT ECKFORD, Deputy Superintendent, Canal Foundry, Roorkee.

SIR,—I beg as requested by you to report on the pontoon bridge at Agra, and also to state my own views on the subject of pontoons *versus* boats, for river bridges.

The Agra bridge is supported on cylindrical sheet iron pontoons; the total length of the ordinary pontoons is 30 feet 8 inches; the middle part is 5 feet 8 inches in diameter, for a length of 22 feet. The ends are egg shaped, the thickness of the sheet iron is $\frac{3}{4}$ " and the sheets are rivetted together with $\frac{1}{2}$ inch rivets, spaced from 2 to $1\frac{1}{2}$ inches apart from centre to centre. Each pontoon has a man hole, and a small hole for the mooring chain; the mooring chains vary, but are in general long linked chains $\frac{1}{2}$ inch diameter. No anchors are used, their place being supplied with blocks of stone.

The pontoons are spaced 18 feet apart from centre to centre; on the pontoons, and resting on a timber saddle, the longitudinal beams are placed, the two outside and the centre one being $8\frac{1}{2}$ inches square, with four intermediate ones $8\frac{1}{2}$ inches deep, by 5 inches broad, making in all seven beams; upon these beams, the planking consisting of one thickness of 3 inches sal is placed. The width of this roadway or planking is 26 feet; it is spiked down to the longitudinal beams at each outside edge of planking. Both above and below runs a longitudinal stringer of sal 7 inches wide by $2\frac{1}{2}$ inches thick; this is bolted together with wrought iron bolts; on the top of this, posts spaced 6 feet apart are stepped; between the posts run two lines of long linked $\frac{1}{2}$ inch chain.

Inside the pontoons are placed props of wood to stiffen the pontoons.

To allow boats to pass up and down, there are two pontoons each four feet longer than the ordinary ones, on which are arranged two crabs with hinged platforms. These are raised, the whole removed to one side, and returned when the boats have all passed. The arrangement acts very well, but I think might be improved by the substitution of gearing, and wench handles, for the present handspike drum.

The whole of the bridge was in good order, the undulations from the level were very slight, and everything seemed to be well looked after.

I afterwards saw the bridge of boats at Delhi, and a more striking contrast could scarcely be imagined. The road was a series of ups and downs; most of the boats were rotten, and had settled down in the sand till their bottoms had bulged up half way; a great number were so firmly fixed in the mud that in the event of a heavy flood coming, they would not rise and would of course be swamped; I believe that shortly before, 15 boats were carried away. Some that I saw had their beams, to which the mooring rope was attached, half rotten through, while the ropes themselves were in many places covered with fungi, and looked in the same state.

From the inspection it was very evident that the road could not be kept so easily in line as a pontoon one; it was impossible to dig away the sand from under one of the large bottomed boats; some of the boats were very much up at the head and down at stern, owing to the earth under the stern being washed away, and the only means of partly rectifying it could be by raising the roadway. Perhaps the great difference between the state of the two bridges is owing to the one being under the Executive Engineer of the roads, and the other under the Deputy Commissioner, but still I am firmly convinced that the pontoon bridge is in every respect superior to a bridge of boats for a permanent bridge over a large river.

I have very few remarks to offer in regard to alterations from the present Agra bridge, but perhaps the substitution of iron beams for the wooden ones would be an improvement in the end, as also I think would be the laying down of broad plated tramways which would bind

the planking together and prevent it from rising, and so get rid of the grass that makes the draught so heavy in wet weather. The tramway would require to be of roughened plates to prevent the feet of the bullocks from slipping.

If the pontoons were made in Roorkee, our price for each of the same size and thickness of iron, as the ones at Agra, would be Rupees 800.

Iron Pontoon Bridge for the Fyzabad and Allahabad Road, to be made up in the Roorkee Workshops. Designed by A. CAMPBELL, Esq., C.E., Special Assistant Engineer.

SPECIFICATION.

Pontoons. To be of boiler plate $\frac{3}{8}$ inches thick, total length 80 feet; diameter 5 feet 8 inches, parallel for 22 feet; the pontoon to be divided into three water-tight compartments by means of iron bulkheads. The bulkheads to be of sheet iron $\frac{3}{8}$ inches thick. At the upper end of pontoon, a crab with surging barrel to be placed, the crab to be worked by means of ratchet and upright lever, something after the manner of a windlass on board-ship; the working handles will unship.

Pontoon Brackets. Will be placed as shown in drawing, the girders will be bolted to these, and the brackets themselves bolted to the pontoons by six bolts.

Girders. The girders for supporting roadway will be 18 feet long 1 foot 2 inches deep; the web $\frac{3}{8}$ inches thick, and the angle iron $2" \times 2" \times \frac{3}{8}"$, there will be six in the width of roadways.

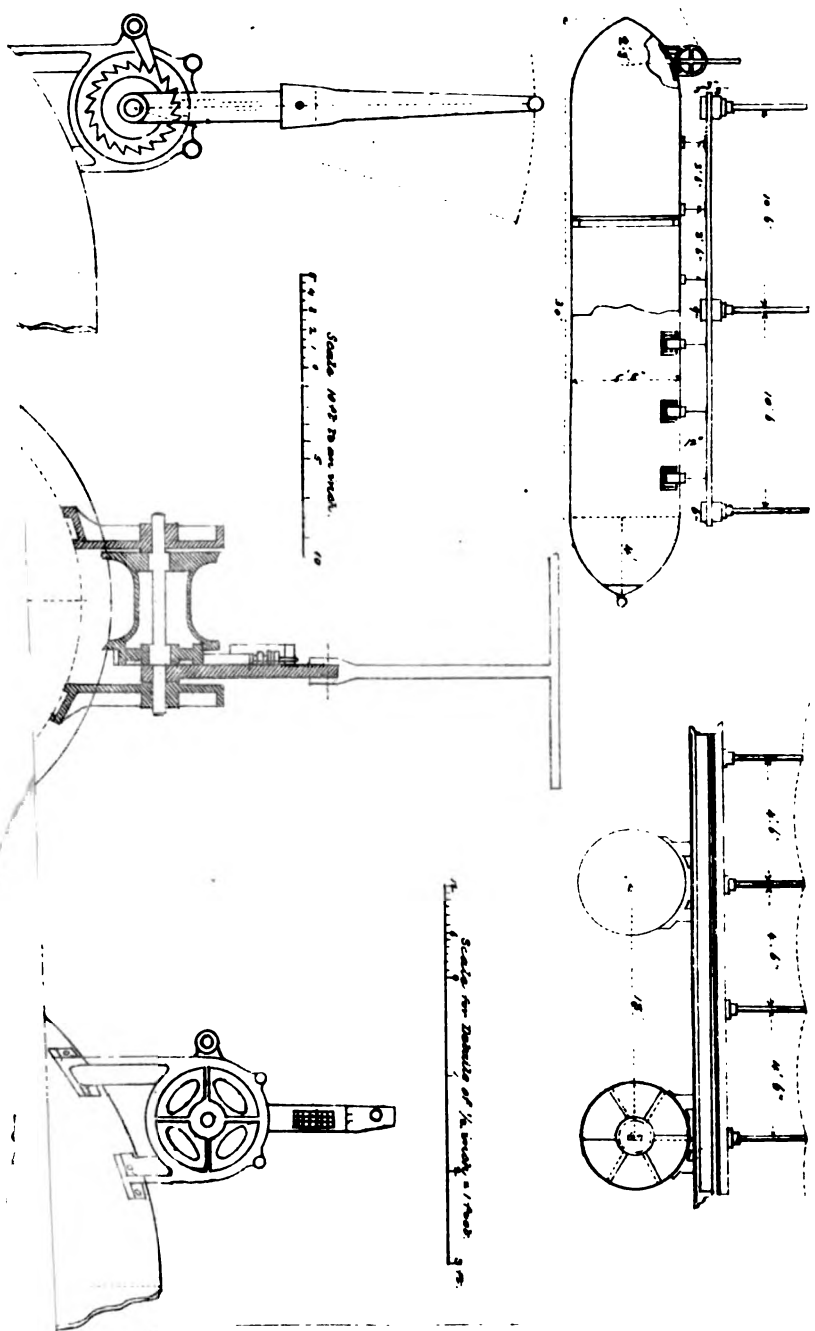
Anchors. Anchors and chains to be supplied, the chains to be $\frac{3}{4}$ inches diameter, and 80 feet long, to be BB short-link crane chain.

Roadways. To be of 8-inch planking bolted to the girders by $\frac{3}{4}$ -inch bolts, and also fixed at centre and ends by stringers 8 inches thick; the roads to be guarded by angle iron standards with cast-iron shoes and two rows of long linked chain $\frac{3}{4}$ inches diameter, the chain to be fixed to the angle iron standards by means of bolts.

Painting, &c. The pontoons and chains to be tarred; the other

BOAT AND PONTOON BRIDGES

Iron Pontoon Bridge
 for the Pynead and Allahabad road



wrought and cast-iron work to receive two coats of the best oil paint.

ESTIMATE.

Detail.	Quantity.	Rate.	Amount.
	M. S. C.	RS. A. P.	RS. A. P.
36 Plates 6' 0" × 2' 0" × $\frac{1}{8}$, . . .	40 20 0		
20 " 4' 0" × 2' 0" × $\frac{1}{8}$, . . .	15 0 0		
2 End Plates, 15" dia. × $\frac{1}{8}$, . . .	0 28 0		
6 Plates 6' 0" × 2' 0" × $\frac{1}{8}$, bulkheads,	6 30 0		
	62 33 0	8 8 0	534 0 9
Rivets 3156,	3 6 0	20 0 0	63 0 0
Punching holes, 6820,			18 12 0
Workmanship, including establishment,			200 0 0
Tarring,			4 3 3
Total for one Pontoon,			815 0 0
Bracket for fixing girder to Pontoon,	0 34 0	9 0 0	7 10 5
6 Bolts $\frac{1}{2}$ " dia. 2' long,	0 1 6	42 0 0	1 7 1
Total for one Bracket -			9 1 6
BEARING GIRDER, 18' LONG × 1' 2" DEEP.			
3 Plates 6 × 1' 2" × $\frac{1}{8}$,	2 0 0		
2 Strips 10" × 6" × $\frac{1}{8}$,	0 3 2		
	2 3 2	8 8 0	17 10 3
72 Feet of angle iron,	4 4 0	8 0 0	32 12 9
84 Rivets,	0 8 10	2 0 0	4 5 0
250 Rivet-holes,			0 8 9
Workmanship,			5 4 0
Total for one Girder,			60 9 2
RAILING STANDARD.			
4 Feet of 2" × 2" × $\frac{1}{4}$ " angle iron,	0 6 0	8 0 0	1 3 4
Cast-iron shoe,	0 6 0	9 0 0	1 5 8
4 Bolts $\frac{1}{2}$ " dia. 10 $\frac{1}{2}$ " long, ogee nuts,	0 1 7	28 0 0	1 0 0
2 Bolts $\frac{1}{2}$ " dia. 11 $\frac{1}{2}$ " long and nuts,	0 0 12	40 0 0	0 12 0
Total for one Standard,			4 5 0
BOW AND STERN CRABS.			
2 Crab cheeks,	2 10 0		23 4 0
1 Barrel,	2 4 0		21 6 6
1 Barrel spindle,	0 12 8		7 14 0
1 Pin for pall,	0 3 8		5 6 0

Detail.	Quantity.	Rate.	Amount.
	M. S. C.	Rs. A. P.	Rs. A. P.
1 Fall,	0 2 8		8 3 9
2 Distance bolts $\frac{1}{2}$ ",	0 3 8		4 6 0
1 Lever,	0 17 0		11 9 8
1 Fall piece,	0 2 6		2 11 9
8 Bolts for fixing do. 1" dia. 8' long,	7 0 0		4 6 0
Fitting up and fixing,			5 12 4
Total for one set of Crabs . . .			90 0 0
Pattern, painting, &c.,			2 0 0
Handle for crabs,	0 16 0	20 0 0	8 0 0
$\frac{3}{4}$ " Chain for pontoon, 80 feet,	1 32 0	22 0 0	40 0 0

A B S T R A C T.

Detail.	Quantity.	Rate.	Amount.
	M. S. C.	Rs. A. P.	Rs. A. P.
66 Pontoons, each,		815 0 0	53,790 0 0
66 Set of brackets with bolts for do., each set,		108 0 0	7,128 0 0
66 Crabs, with fixing bolts, each, . . .		90 0 0	5,940 0 0
66 Anchors, each,		20 0 0	1,320 0 0
66 Anchor chains, 80 feet long, $\frac{1}{2}$ " each,		40 0 0	2,640 0 0
402 Girders, 18 feet long,		62 0 0	24,924 0 0
804 Standards for chains, with fixing bolts,		4 5 0	8,467 4 0
6 Chains, 1,200 feet long, each, . . .		500 0 0	3,000 0 0
800 Bolts, $\frac{1}{2}$ " diameter, 10" long, for stringers, per md.	11 20 0	20 0 0	230 8 4
3200 do. $\frac{3}{4}$ " do. 4" long for planking, per maund,	7 20 0	25 0 0	187 8 0
800 Washers for $\frac{1}{2}$ " bolts, each, . . .		0 0 8	12 8 0
6 Handles for working crabs each,		10 0 0	60 0 0
Bilge pumps, each,		30 0 0	390 0 0
Total Iron-work in Bridge,			1,08,089 7 4

No. XXII.

ABBOTTABAD CHURCH,—PUNJAB.

Designed and Constructed by LIEUT. BLAIR, R.E., *Executive Engineer, Hazara.*

REPORT.

THE Church is to be built in a palisaded ravelin on the western front of the proposed new fort at Abbottabad, on the site of the old Kutcherri.

The Church will be built for 150 sittings and in the early English style of architecture.

The cost to be Rs. 15,000, of which the Government grant is 10,000, and the remaining 5,000, have been guaranteed by the Local Committee.

The enclosed design has 1,350 superficial feet for sitting, or allows 9 superficial feet per sitting.

As no sandstone is obtainable in this district, the cornices and other decorations will be plain but massive, throwing deep shadows, for as the Church will have to be built with the hard blue lime stone from the Abbottabad quarry, so for economy sake the decorations have to be simple.

The Church is to be built in the most substantial manner, and will be roofed with a high pitch shingle roof, as this style of roofing is found to be best adapted for this district.

To harmonize with the mountain scenery a wooden spire has been included as a set off to the northern face of this design.

The interior will be plastered with gray plaster in imitation of stone, and will have a high open roof with decorated trusses and furnished

with handsome sittings with poppy head decorations ; pulpit, altar table, &c., of walnut wood.

The rates in this estimate may appear high but are intended to cover the cost of furnishing all portions of the building, with the very best description of workmanship and materials, and it is solely for this purpose that private subscriptions have been given.

SPECIFICATION.

The space for 200 feet square to be levelled and to be spread with 6 inches of gravel.

Foundation and plinth to be of hammer dressed pucca rubble masonry with best lime cement of equal parts of lime, sand and soorkhee.

The superstructure including cornices, mullions, and all exterior work, will be of neatly cut stone dressed on all six sides and set in the best cement of equal parts of lime, sand, and soorkhee, well ground in a mill.

The interior will be plastered with polished grey chunam plaster colored grey with a slight mixture of charcoal, but the cornices and corbels will be left white.

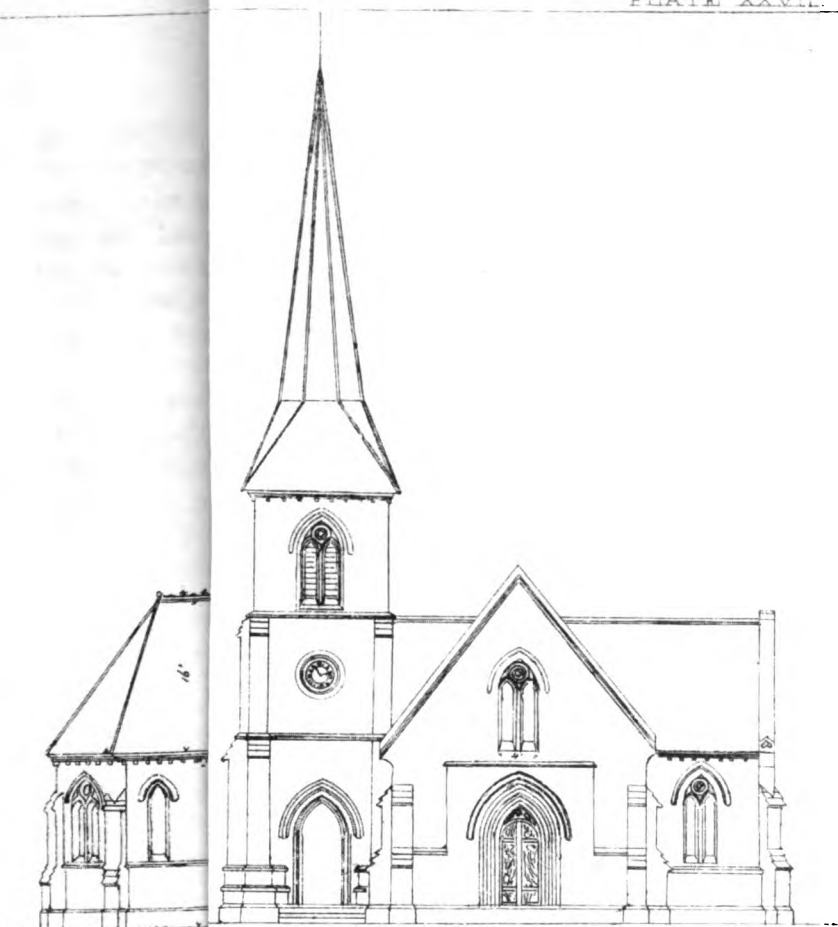
The doors and windows to be made of walnut wood, the former of double (diagonally) 1-inch planking, strengthened with decorated iron hinges, and the windows to be on 6 inches diamond shape framework glazed with ground glass.

The roof to be of treble shingles of deodar wood, 2 feet 6 × 6 inches × 2 inches laid on 2 inches horizontal planking, having a ridge piece decorated with poppy heads.

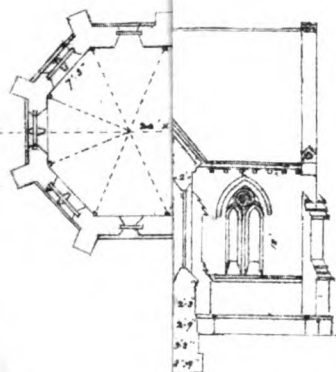
The trusses to be 6 feet 8 inches from centre to centre, of deodar wood of timbers 9 × 6 inches, with lower edges bevelled and decorated ; to consist of principals, collar beam, two braces and an arched brace, with pendant resting on an ornamental corbel ; the principals and pendants are fixed to a hammer beam to give the trusses a fair bearing in the wall ; the whole truss will be braced together with ornamented iron straps and bolts.

The floors of the Church to be of one layer of dressed stone on well rammed earth with 4 inches of well beaten and polished terrace plaster.

Spire.—The roof of the spire to be of double 1-inch grooved planking, supported on a square shaped truss, the octagonal shape being



West Front.



given by the purlins which are 12 × 3 inches and let in sideways into the principals.

The main truss to consist of four principals, 6 × 6 inches at the top, and 12 × 10 inches at the base, with six collar beams, and diagonal bracing of 6 × 6 inches timbers.

The principals fit into an iron cap at the top and are firmly set into massive tie-beams, 12 × 10 inches at the base; besides which to give them greater stability, they will be braced to the flooring beams of the two lower stories, with double beams 10 × 4 inches at each corner, and at the joint with the tie-beam, strong iron knees will be given.

The sittings to be 9 feet long for 5 sittings, of walnut wood, with solid 1½ inch plank sides, decorated.

The altar, pulpit, and altar rails to be of walnut wood, highly decorated, and supplied with cushions of English embroidered crimson cloth.

ABSTRACT.

80,000	Cubic feet earthwork, at Rs. 3 per 1,000, - -	240 0 0	
9,566	Cubic feet foundation, at Rs. 12 per 100, - -	1,148 0 0	
20,572	Cubic feet superstructure with arching and cornice work, at Rs. 23 per 100, - - -	4,732 0 0	
6,281	Pucca gray plaster, at Rs. 71 per 100, - - -	436 0 0	
or 30,138	Cubic feet masonry at Rs. 21-12, about, - -		6,556 0 0
1,827	Pucca flooring, at Rs. 10 per 100, - - -		188 0 0
636	Doors and windows, at Rs. 2-12 per foot, - -		1,733 0 0
5,599	Shingle roofing, at Rs. 24 per 100, - - -	1,844 0 0	
902	Timber work, at Rs. 2-8 per foot, - - -	2,255 0 0	
40	Maunds iron work, including lightning conductor, at Rs 20, - - - - -	800 0 0	
or 5,599	Roofing with spire and scaffolding, at Rs. 78-6, nearly, - - - - -		4,399 0 0

FITTINGS.

150	Seats, at Rs. 6 each, - - - - -	900 0 0	
1	Pulpit and altar, - - - - -	240 0 0	
1	Font, - - - - -	100 0 0	
	Altar rails and chairs, - - - - -	100 0 0	1,840 0 0
			14,211 0 0
	Contingencies, - -		711 0 0
	Total, - - - - -		14,922 0 0

H. BLAIR, LIEUT., R. E.,
Ex. Engineer, Hazara Division.

No. XXIII.

SIND CANAL REGULATORS.

Memorandum descriptive of a Regulator proposed for large Canals in Sind. BY LIEUT.-COLONEL FIFE, R.E.

ONE of the most serious difficulties the Engineer encounters in the management of Canals in Sind, arises from the enormous quantity of silt which enters from the rivers. In the case of the simple Inundation Canals of the country, the silt can be removed by manual labor when the water subsides at the conclusion of the season; though, of course, this annual operation adds enormously to the cost of maintenance. But with respect to Perennial Canals, where navigation, as well as irrigation, has to be maintained throughout the year, the difficulty is more serious. It is true that the nicely adjusted gradient of the Canal, designed by the skilful Engineer of the present day, and the constancy of the stream, permit much less silt to accumulate than must take place in the Inundation Canal, with its ever varying velocity of current, and much of the matter which is now deposited in the bed of the Inundation Canal will be swept into the smallest distributing channels, and even into the fields, by means of the Perennial Canal. But still there is a large quantity of sand borne along by the waters of the Indus which must either be removed from time to time, or prevented from entering the Perennial Canal at all.

The subject of silt traps has often been discussed, and that such an arrangement is feasible needs no demonstration. An extra depth to the Canal at its head sufficient to slacken the velocity of the current, till it allows the heavier particles of sand, but not the finer particles

and the mud, to be deposited, is all that is required. There will be considerable expense in clearing this from time to time, and perhaps some slight inconvenience, but the difficulty may be said to be reduced to an item of annual expense, by means of the silt trap. Dredging may be resorted to, and when the works are on a very large scale the dredging machine might be employed with advantage, as it was many years ago on the Caledonian Canal, where it was found cheaper to let the sand in a cutting fall down to the level of the bottom of the Canal and afterwards to take it up with the dredging machine than to remove it in the ordinary manner from above. The dredging machine in the instance I have alluded to, cut its way through the ground and formed the Canal. Whatever arrangement is made for removing the silt, however, the trap may be said to reduce the silt difficulty to an item of annual expense.

But this annual expense will be considerable; and to prevent the heavy silt entering the Canal at all would therefore be more satisfactory, and with this view I proposed for one of the large Sind Canals the construction of an escape channel, or artificial branch of the river, and the drawing off of the Canal's supply from the escape channel, and not direct from the river in its silt loaded condition. The stream in the escape channel was to be regulated to such a velocity that the heavy silt might be thrown down into the bed and rolled onwards back to the river again, the Canal receiving its supply from the top or surface water after the heavy silt had sunk to the bottom. *Fig. 1.* exemplifies the arrangement described. It should be understood that there is a fall in the river's surface of about $2\frac{1}{2}$ feet between the mouth and tail of the escape channel.

For the purpose of obtaining the Canal supply from the top water and to secure facility in working the sluices, security against accident, and permanency of construction, I proposed making the gates in three pieces (the principle of the Ganges Canal gates) to be worked singly or together as occasion might require, the whole, including guides, to be of iron. This construction will be expensive in the first instance, but its permanency and facility of working will render it perhaps not more expensive than the wooden gates in use, while I believe there are other advantages which will render it very superior to the wooden gates.

A drawing, *Fig. 2*, of one of the gates is attached. The opening to be regulated is 10 feet square, and there are to be 10 in number. The greatest depth of water outside the regulator is to be 21 feet. The pieces of the gate are composed of iron frames, with $\frac{1}{2}$ inch plates over them. The connecting or disconnecting of the three pieces composing each gate is to be effected by means of two bars BB, passing through eyes attached to the different pieces, and with T heads and cross pieces, PP. The connecting or disconnecting is effected by sliding these bars up or down, and then giving them a half turn to either lock or unlock the T heads and cross pieces in the eyes. The handle at the top is parallel to the T head at bottom, and it can always therefore be seen whether the pieces of the gate are locked together or unlocked.

During floods the top piece of the gate only would be worked. When the raising of this piece is insufficient to supply the required quantity of water, the second piece is to be attached and drawn up also. When a still larger aperture is wanted the whole of the pieces are to be taken up. It will, however, only be necessary to lift the whole gate when the Indus is at its lowest level, and when there would be comparatively speaking but little heavy silt in motion outside the regulator, or even at the mouth of the escape channel.

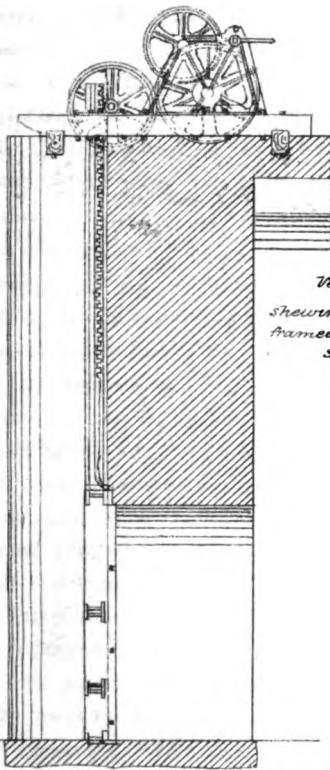
The raising and lowering of the gates is to be effected by two four ton winches. The greatest force even required by theory for weight and friction combined, is about $8\frac{1}{2}$ tons. In this case the river would be standing at 21 feet outside the regulator and the Canal would be empty. The top piece of the gate only would be raised.

A very serious inconvenience in the management of regulators in Sind arises from the enormous quantities of drift trees, bushes, and grass. The trees if large must remain against the regulator, if they should ever be drawn into the Canal entrance, till they can be cut up or withdrawn by means of ropes, but in the daily working of the Narra river regulator, we found the grasses a more serious inconvenience than any thing else. These twist round wood work in such quantities as to render it immovable. I believe that the iron gate with its sharp edges and tremendous weight would destroy all these minor obstacles without difficulty. By alternately raising and lowering the gate very slightly it would cut through grass and break up

SIND CANAL REGULATORS.

Proposed Regulating Bridge at Roree.

Fig. 2.



*Vertical Section
showing lifting racks, guide
frames, lifting bolts, &c.
Scale 1/4 in. = 1 foot.*

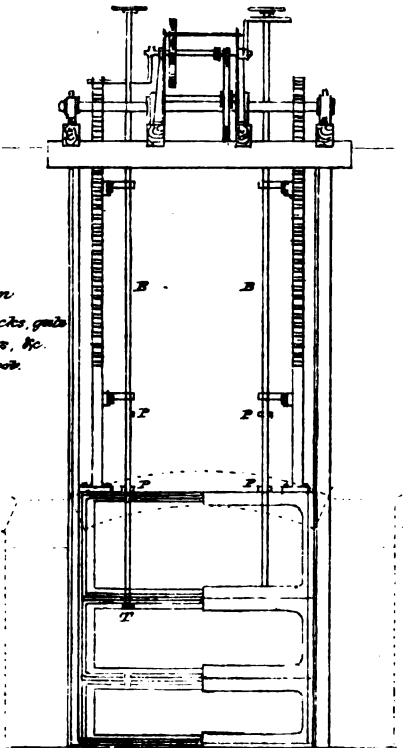
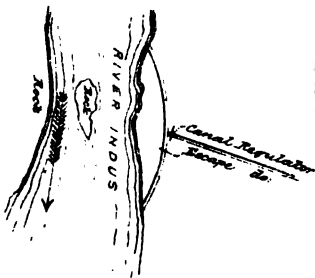
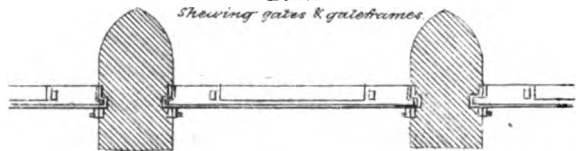


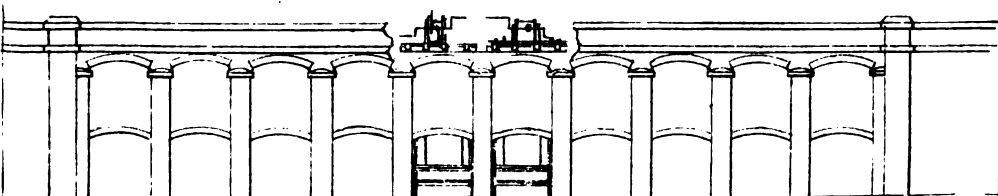
Fig. 1.



*Plan
showing gates & gate frames*



General Elevation.



bushes and branches till they become small enough to pass through the orifice.

I have a plan on a large scale of these gates, and should the construction suit other Canal works, I shall be happy to send a copy to any officer who may wish for one. I have some confidence as to the gates working well in practice, as I consulted a very able engineer, (Mr. Hoskins, the directing engineer to some large iron works on the river Lyne,) who assisted me in the details. I was informed that such gates, with winches complete, would probably cost £2 or £2-10 per square foot of opening. At this rate each gate 10' × 10' would cost £200 or £250.

The subject of the size of openings appears to me to demand some discussion. I have fixed the size in the case given at 10 feet, as it appeared to me convenient as respects the weight of the gates and the power requisite to move them. Each gate with its rack bars and connecting rods will weigh about $3\frac{1}{2}$ tons. The strength is much greater than would be given to a dock gate, in order that there may be less likelihood of accident from any thing striking against them. Small openings in a regulator possess the advantage of very easy working, but the additional masonry piers required, add greatly to the cost, and the flow of the stream is impeded. The advantage of the very small opening however vanishes altogether, when it is necessary to make the covering plates and the framing as secure against a blow from a drift tree or branch as they are in a large gate. The covering plate *must* be thick; hence we cannot calculate on saving material by using very small gates, while the increase in the number of winches for a larger number of small openings would add to the cost.

A large opening possesses one great advantage over a small one if it can only be kept under command. It affords greater facility for getting rid of obstacles brought down by the river. I will conclude by venturing the suggestion that openings should be as large as possible consistent with the easy working of the gates. Those I have proposed are 10 feet by 10 feet, but more able and experienced engineers than myself may be able to show an advantage in making them much larger.

J. G. FIFE.

No. XXIV.

STRIKING BRIDGE CENTRES.

[THE following letters refer to the method of Striking Centres adopted by Captain Mead, in the Morhur Bridge, which was described in No. II. of the Professional Papers.]

From the Superintending Engineer, Southern Division, Bombay.

Poona, 1st January, 1864.

The Superintending Engineer, has the honor to forward reports from the Executive Engineers, Belgaum and Dharwar, on the methods they are now employing for striking centerings of large bridges, as called for by Government.

Both Captain Merriman and Mr. Hart object to the use of sand bags as not possessing sufficient strength, and owing to the settlement which takes place consequent on the alteration of their form when subjected to heavy weight; and both these officers have now adopted sand boxes, which doubtless possess the advantage over sand bags, noted by Captain Merriman in his report.

Although Mr. Hart has hitherto used wooden boxes as being cheaper than iron, he gives the preference to iron boxes, and although Captain Merriman has fitted his cylinders with wooden plungers, he now agrees with the undersigned that the latter, if made of iron, would be an improvement. Lieut.-Colonel Scott thinks it would be a further improvement to allow the sand to escape from *below*, instead of from the sides, of the cylinders, when one hole instead of four would

suffice, and the sand would run out with greater regularity. The cost also of making the cylinders would be considerably diminished.

The Superintending Engineer, is aware that the sand boxes as originally invented by M. Bandemonlin, said to have been perfected by M. de Lazilly, and now used in England, are exactly similar in principle to those prepared by Captain Merriman, but if time and cost can be economised by a more simple arrangement something is gained.

C. SCOTT, LIEUT.-COLONEL, R.E.,
Superintending Engineer, S. D.

To the Superintending Engineer, Southern Division.

Belgaum, 9th November, 1863.

SIR,—I send a drawing showing the arrangements I mean to adopt for striking the centres of bridges on the Belgaum and Kolapoor road; and in the course of a couple of months, I shall have an opportunity of reporting on the same.

I feel confident that success will attend this arrangement, for in one case last season, when I used sand in bags only, there was no failure, though the centres had to be supported with blocks before the key stone was driven owing to the bags having commenced to split from the weight brought upon them during the construction of the arch. In fact, I had to adopt the method used by Captain Mead while the work was in progress, instead of from the commencement. The blocks were eventually knocked away and the centre lowered by opening the mouths of the sand bags.

By having the sand in iron cylinders from the commencement, this double process will not be necessary. The only doubt is whether the sand will run out freely on the doors being opened if it happens to have got into a moist state, but I see no reason why it should not be kept perfectly dry, for the timber piston or plunger fits close into the iron cylinder, which might moreover be temporarily covered so as to prevent any moisture finding its way between the piston and the cylinder.

It will be observed that there are two sets of sliding doors in these cylinders so that the centres may be lowered by degrees, and with more regularity than with sand bags. The doors can moreover be opened and closed at pleasure with the greatest ease.

Of course these cylinders are expensive but they will last for ever when once made up, and their cost can be recovered by charging a small sum for each upon each bridge used.

I do not think I would ever again trust to sand bags alone to support a centre for an arch in progress. I would only use them for the actual operation of striking as in the case reported by Captain Mead.

C. J. MERRIMAN, CAPTAIN, R.E.,
Exec. Engineer, Belgaum and Kolapoor.

To the Superintending Engineer, Southern Division.

Dharwar, 21st November, 1863.

In 1857, when Colonel Kennedy's assistant in Sattara, he suggested to me the use of sand bags as noticed in Weale's Treatise on Bridges. On the Koombarle Ghaut road, when an opportunity presented itself, I carried out his suggestion in the case of a bridge of 40 feet span, and found the method to be both satisfactory and economical.

I submitted a report at the time to Colonel Kennedy.

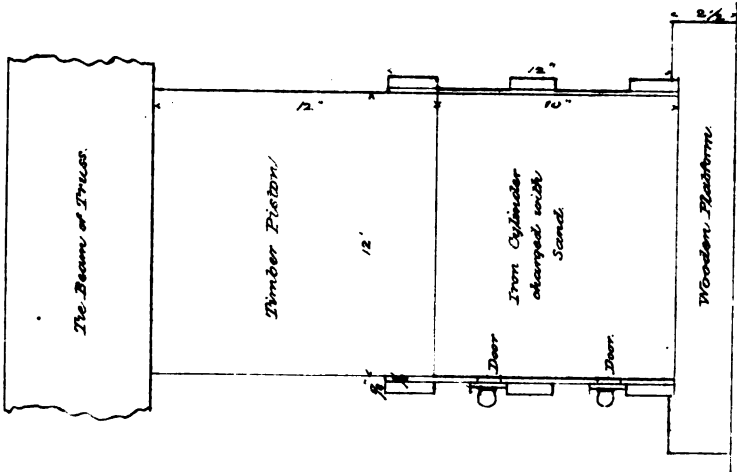
The next opportunity I had of using them was on the Whagary bridge at Nassick, and I mentioned the circumstance in my annual report for the year 1860-61.

The great advantage obtained by the use of sand bags, I found to be—saving of expense and simplicity of arrangement, together with diminution of danger to the work and workmen, at the time of striking the centres.

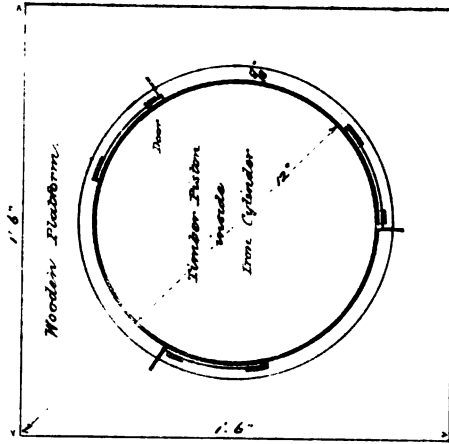
Masonry arches are tried very seriously by the jar produced when wedges suddenly fly home; and sometimes actual injury is produced. Again, the heavy pressure of the superincumbent load locks the fibres of the wood forming them, so firmly together, that no force will start them, and I have seen a wedge broken to peices with a sledge hammer which it had been necessary to use to drive it. Last year two wedges had to be cut out from under the centres of a 30 feet arch, so immovable had they become, whereas the motion of the centres under the use of sand bags is so gradual that the eye can scarcely note the settlement of the frames till the increasing space over the laggings shews that the structure is slowly descending.

STRIKING BRIDGE CENTERS.

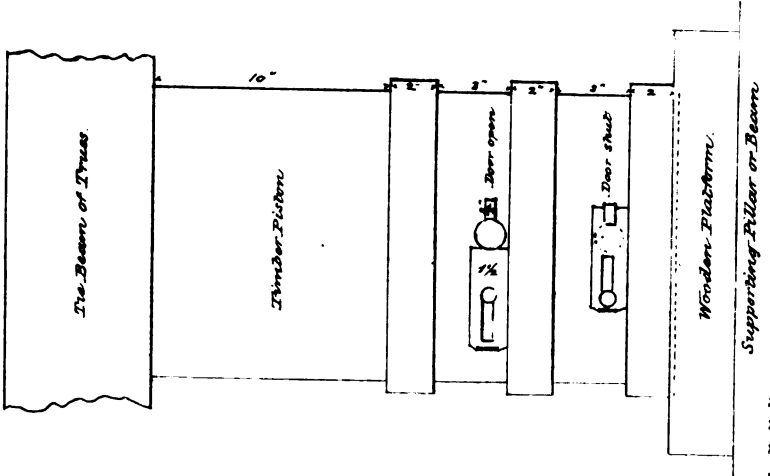
Section.



Plan.



Elevation.



Scale, 1/4 in. = 1 ft.

There is little or no pressure from the sand trying to escape, and the mouths of the bags can be closed without trouble.

I do not describe the construction of the sand bags, because I have come to the conclusion that boxes are very much preferable to bags in practice ; and I have had them made up for use in the bridges now under construction in these districts, and found them to act well.

The disadvantages of bags are the possibility of their bursting, either from decay, or from the attacks of white-ants. There is also a slight settlement which takes place as the load comes on them ; this is due I believe to the stretching of the cloth and the alteration of form, through flattening of the bag. It was always necessary to provide for this, and for accidents, by placing a block of wood between the horizontal beams to relieve the bags of the pressure of the centre till it became necessary to use them. These blocks were easily removed.

Cast-iron cylinders have been used in England lately, and Captain Merriman has had several of wrought iron made up in Belgaum, and will doubtless describe their construction. It is not always possible to get iron ones constructed ; I therefore send you a sketch of the wooden sand boxes I have had made up, but the iron cylinders being much preferable I would recommend their adoption by any one who can get such easily.

JOHN H. E. HART,
Exec. Engineer, Dharwar Division.

No. XXV.

KOHAT FORT—PUNJAB.

From LIEUT. A. W. GARNETT, *Exec. Engineer, Kohat, to Superintending Engineer, Lahore.*

Hungoo, 17th September, 1855.

SIR,—The documents which accompany this Report, are as follows:—

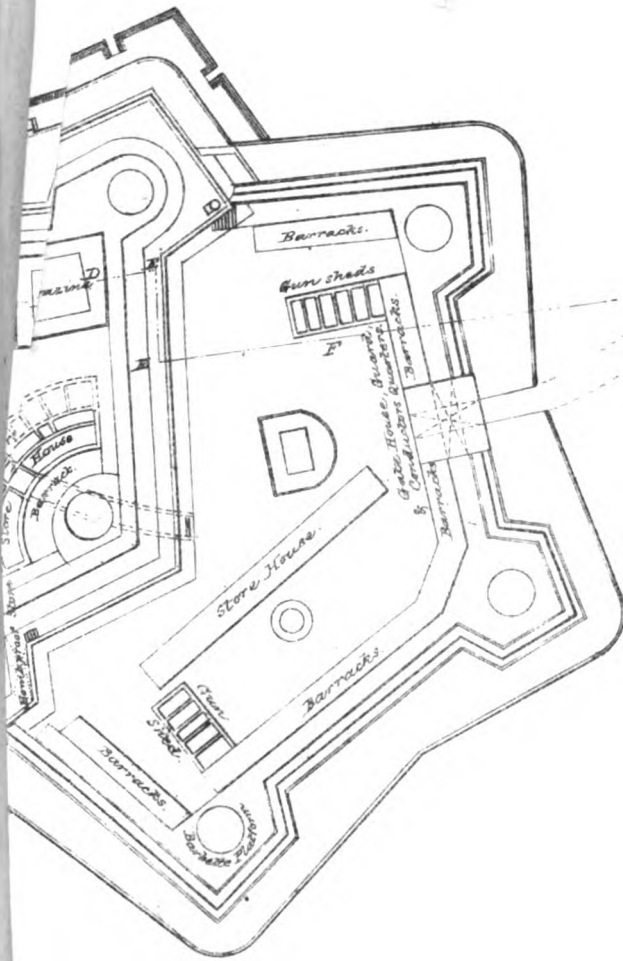
1. Revised estimate of the cost of restoring the Fort of Kohat, with Appendices.
2. Statement of the armament and stores required for the defence of the several works.

To illustrate the above I forward a general plan of the Fort and environs, as they will appear on completion of the works.

To save the trouble of reference to former correspondence, I shall first give a brief retrospect of past operations, after which, I propose to notice the several departures from the original design, which have been found necessary, and the several improvements and additions that have been subsequently recommended, and shall conclude my report by explaining the effect of the above on the quantities and rates of the estimate I have now the honor to submit.

The defences of Kohat first claimed the attention of the Government, immediately after the annexation of the Punjab, and I undertook some repairs to the old works in 1850, by order of the late Board of Administration. During these operations the old walls were found to be in such a state of decay, that no mere patching up could preserve them, and the attempt was abandoned by orders of the Board in April, 1851.

THE FORT OF KOHAT.



T OF P

ral Secta

on AB.

Inter

lower part, 3m

Section a.

157.

E

Secta

157.

OF KOHAT.

2. Sections.

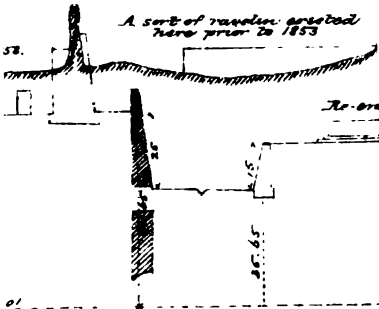
n AB BC CDE EFG

Interior of Lower Fort.

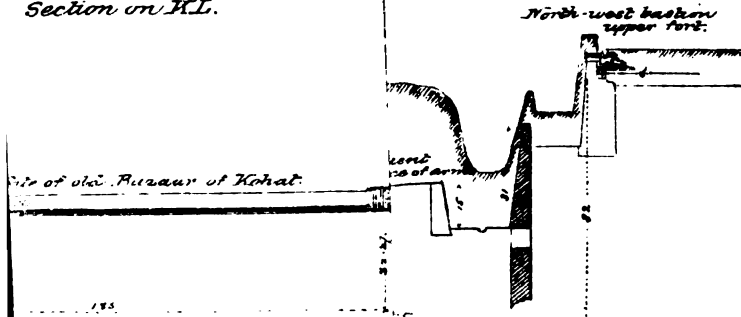
138'
or Fort, South Arm, in each section.

Section on HLI.

*line represents roughly
the works before their re-
s commenced*



Section on KL.



Nothing further was done till March in the following year. In that month, I was called on for an estimate of the probable cost of putting the old Fort in a state of defence. My designs comprised the restoration of the ramparts of the old Fort, and a masonry revetment to the escarp slope of its ditch; the addition of a crown work on its steep south side, and the removal of those portions of the town within 350 yards of the works; also some improvements in the Cantonments. The Government sanctioned an expenditure of Rs. 81,639-3-3, on my rough estimate of the probable cost of the above works, and operations were commenced on the 1st December, 1852. The progress was slow at first; hands were scarce, and all materials had to be prepared on the spot, before masonry works could be undertaken. On the 18th October, in the following year, the Government sanctioned the importation of laborers at high rates of pay, which gave me the command of as many hands as I could employ with advantage. Earlier in the same year, Ensign Basevi's services were placed at my disposal for the supervision of the Fort works. By the end of 1853, not less than 1000 men were employed daily on the Fort, and with the exception of temporary interruptions from rains, nothing occurred afterwards to retard the progress of the works. On the 20th February, 1854, I reported the injuries sustained by the heavy rains which fell in that month. Also the loss of the whole western face and the north-west bastion of the Upper Fort (the eastern face with its two bastions had been previously destroyed by a severe earthquake, which occurred on the 30th July, 1853). On the 25th of May following, the modifications of my original plans, which I considered necessary, and their effect on the cost of the works were explained in my report of that date. The subsequent progress of the works has been fully described from month to month, and rough drawings have been supplied to shew the actual state of the Fort at particular periods. All operations were suspended, agreeably to order, on the 1st July, 1855; and on the same date, I reported the several works which still remained to be completed.

I have alluded to certain departures from the original designs, which I shall now proceed to explain. They are of three kinds—First, Modifications in construction, rendered necessary by difficulties which could not be altogether foreseen or provided for in the rough estimate;

Second, Alterations in design, consequent upon occurrences during the progress of the work, which could not have been previously calculated upon; Third, Additions to meet extra requirements not provided for in the original estimate.

The modifications in construction have been chiefly confined to the foundations of the escarp revetments, and buildings in the Upper Fort. The foundation works were in progress during the Chief Commissioner's inspection in April, 1854, so their nature will no doubt be in his recollection. The arches which support the superstructure of the scarp revetment, are turned on forty-eight piers of masonry, of an average depth of 18 feet, whilst some of them were nearly double this depth. The magazine in the Upper Fort will rest on similar foundations. No provision was made in the rough estimate for works of this description. It has also been found necessary to substitute pukka masonry retaining walls for kutchra ones, at the junction of the Lower Fort, ramparts with the Upper Fort rownee, on account of the great height and weight of the ramparts at these points. I may also here mention that "rubble masonry" has been substituted for "brick masonry" in some cases, to effect a saving in the latter material, and that either "kutchra brick" or "kutchra rubble" has been substituted for the "mud work" of the original estimate, the former in all exterior walls of ramparts, the latter in all interior walls. The "mud work" was partially employed in the Lower Fort ramparts, but it was found to be impracticable to build these walls entirely of mud.

The alterations in design have been chiefly connected with the "relief" of the Upper Fort. The original designs were of course influenced by the existing walls, for the preservation of which they were adapted, but when these walls all disappeared one after another, until nothing was left but the old mound on which they stood, there was no longer the same necessity for carrying up the new "revetments" to such a height. It was too late to alter the plan of them, as the foundations had been partly laid in, but a great improvement was effected by reducing their height, and the height of the whole of the Upper Fort by about 10 feet. Of other alterations, may be named the omission of a fifth bastion, at the angle of the Upper Fort, enclosed in the crown work, and some improvements in the tracing of the galleries.

The additional works to meet extra requirements are the buildings for the Ordnance Department, including quarters for a Conductor, storehouses, and gun-sheds. The interior space in the Fort is so confined, that it is not easy to provide the requisite amount of accommodation for stores of all descriptions. By the arrangements shewn in the drawings, I shall secure the following amount of flooring in the different buildings :—

UPPER FORT.

Bomb-proof buildings, . . .	780	superficial feet.
Storehouses, . . .	10,295	„
Cellars, . . .	3,960	„

LOWER FORT.

Bomb-proofs, . . .	160	„
Storehouses, . . .	2,640	„
Gun-sheds, . . .	2,376	„

The following are the chief additional improvements which are recommended to complete the defences :—

1st. A “ covered way ” is required to the west, north, and east fronts of the Upper Fort. The object of this work is to cover the scarp wall which is now much exposed to view from without, it has also other uses. The glacis of the Upper Fort will be somewhat steeper with this addition, and it will be necessary to turf it or to sow its slopes with grass. This has been provided for in the estimate.

2nd. The parapets are required to be increased to 10 feet in thickness, in both the Upper and Lower Fort. Where the walls are not yet built, as on the two south fronts of the Upper Fort, the necessary thickness will be given to the ramparts to admit of a 10 feet parapet, but in other parts the extra thickness must be given by building out on the terreplein or space left for the passage of the defenders along the ramparts, and the roofs of the barracks along the interior wall must be raised and strengthened, sufficiently to serve as a passage for guns round the Fort.

3rd. The magazine in the Upper Fort will be built in the manner suggested by Col. Napier, during his inspection last spring, *i.e.*, with its floor sunk below the level of the Upper Fort. But with regard to this building, it appears that it will not afford the room now required by the Commissary of Ordnance. I propose giving the additional space

required, by converting a passage in the rownee of the Upper Fort into an auxiliary magazine. This passage was originally intended as part of a postern to communicate with the interior of the Upper Fort, but will be superseded by a more direct and safer communication to be alluded to presently. It is situated in a part of the rownee inclosed in the Lower Fort, in a position very little exposed, and can be rendered bomb-proof easily.

4th. The "postern" leading from the interior of the Lower Fort direct to the interior of the Upper, is a work so much needed, that it should be rather looked on as an omission in the former designs than as any addition to them.

5th. A new entrance in the north front of the Upper Fort, with a bridge and "place of arms," has been provided for in the estimate. The counterscarp or outer wall of the ditch being here 10 feet lower than the rownee, it will be necessary to enter the latter by a postern and steps.

6th. The completion of the masonry revetment, with rownee, &c., round the two south fronts of the Upper Fort has been included in the estimate. The objects, and I may add the necessity, of this work are sufficiently obvious.

7th. It is proposed to reduce the height of the mound and rock to the north of the Fort, so as to bring it as much as possible under the fire of the Upper Fort. This will be explained by the sections.

Lastly. The remaining improvements proposed require no remarks, as their uses are obvious. The following have been provided for in the revised estimate :—

Bomb-proof coverings to wells.

A caponniere to communicate between the Upper Fort and the out-work to the north.

A masonry "traverse" to protect the entrance to the Lower Fort, which will also serve as an expence magazine for the Lower Fort.

Barbette platforms in the bastions.

The great difference between the quantities of work executed, and those estimated for, is partly attributable to the modifications in construction explained before, but more particularly to former omissions. There is a wide difference between estimating for an original design, and

estimating for the restoration of a tottering old Fort. In the one case the measurements are certain, however inadequate the rates may be. In the other they are uncertain, *i. e.*, they depend upon contingencies which no amount of experience can always anticipate. I have explained how the measurements have been largely affected, in one instance, by the great depths to which it was found necessary to penetrate for foundations, how walls which it was intended to retain, disappeared altogether, during the progress of the work, and had to be replaced *de novo*, and how bastions have crumbled away before the protective masonry walls could be built to support them. I may mention in addition, that the adaptation of the new works to the remains of the old Fort, have not only been attended by difficulties, but by considerable danger to the people employed. As to the cost of works, the Government will have been prepared to expect a considerable increase in the charges when sanctioning the advance in the rates of payments, to secure a large supply of laborers. But there are other causes which have tended to make the Fort works more expensive. The confined space in which the bulk of the operations was carried on, the great heights at which some of the works, and the great depths at which others were executed, the losses by rains in this variable climate, not so much by the injuries done to the works as by the interruptions they occasioned, whilst the work people were receiving an uniform monthly pay, were another source of expense. A single day's rain would thus cost 800 rupees, exclusive of the cost of repairing damages. I am aware these are contingences usually supposed to be covered by a small per centage on the amount of the estimate, but instead of adding a twentieth to the cost, they increase it a fifth or thereabouts, in a work like the Fort of Kohat.

With the above observations, I now submit the final estimate for this work, amounting to Rs. 4,06,012-6-7. I ask this sum to complete the defences of Kohat. It includes the cost of all works executed up to the present time, and all additions and improvements that have been recommended, but does not include the cost of alterations in the Cantonments, which should not be confounded with the defensive works, as in the original estimate, and it does not include the cost of ordnance and stores required to maintain the Fort in a defensible state.

A. W. GARNETT.

**STATEMENT OF ARMAMENT AND ORDNANCE STORES REQUIRED FOR THE
FORT OF KOHAT.***

ORDNANCE.									
Ordnance, iron gun, garrison, 18-pounder,	...	...	...	...	...	...	...	...	6
" " " " 9-pounder,	...	...	...	...	...	...	...	...	10
" " " " mortar, 8-inch,	...	...	...	...	...	...	...	...	8
ORDNANCE STORES.									
Axletrees, iron, siege carriage, N. P., spare,	...	...	...	...	...	...	...	...	2
Barrels, bouge, ...	...	...	...	...	...	...	...	...	8
Bars, lifting, gun carriage, ...	...	...	...	...	...	...	...	...	2
Beds, mortar, iron, 8-inch, ...	...	...	...	...	...	...	...	...	9
Blinds, embrasure, ...	...	...	...	...	...	...	...	...	2
Blocks, iron, with B sheaves, double, large,	...	...	...	...	...	...	...	...	2
" " " " single, "	...	...	...	...	...	...	...	...	2
Blue lights, ...	...	...	...	...	...	...	...	...	80
Boilers, copper, medium and small,	...	...	...	...	...	...	...	...	2
" " " " iron, ...	...	...	...	...	...	...	...	...	2
Borax, ...	...	...	...	...	...	...	...	lbs.	8
Boxes for implements, guns, ...	...	...	...	...	...	...	...	...	4
" " " " ammunition, tar and grease,	...	...	...	...	...	...	...	...	} In proportion to stores.
" " " " case shot, 18-pounder,...	...	...	...	...	...	...	...	...	
" " " " fuze, ...	...	...	...	...	...	...	...	...	
" " " " light balls,	...	...	...	...	...	...	...	...	
" " " " signal rockets, ...	...	...	...	...	...	...	...	...	
Boxes nave, brass, for siege carriages, spare,	...	...	...	...	...	...	...	...	4
Brass or gun metal, hammered, ...	...	...	...	...	...	...	...	lbs.,	60
Brushes, painting, large and small, ...	...	...	...	...	...	...	...	...	6
Buckets, wooden, gun, ...	...	...	...	...	...	...	...	...	8
Carriages, garrison, iron, 18-pounder, ...	...	...	...	...	...	...	...	...	4
" " " " wooden 18-pounder,	...	...	...	...	...	...	...	...	4
" " " " iron, 9-pounder, ...	...	...	...	...	...	...	...	...	6
" " " " wooden 9-pounder, ...	...	...	...	...	...	...	...	...	6
" " " " siege, limber, with ES 18-pounder, N. P.,...	...	...	...	...	...	...	...	...	3
" " " " " 9-pounder,	...	...	...	...	...	...	...	...	5
" " " " garrison, wooden, depression, 18-pounder, ...	...	...	...	...	...	...	...	...	2
" " " " " 9-pounder,	...	...	...	...	...	...	...	...	2
" " " " cart, hand or truck, ...	...	...	...	...	...	...	...	...	2
" " " " transport, ...	...	...	...	...	...	...	...	...	1
Cartridges, siege, empty gun, 18-pounder,	...	...	...	...	...	...	...	...	3,600
" " " " 9-pounder, ...	...	...	...	...	...	...	...	...	6,000
Chains, draft, siege carriage, leading, ...	...	...	...	...	...	...	...	...	8
" " " " pole, ...	...	...	...	...	...	...	...	...	8
" " " " transport carriage, ...	...	...	...	...	...	...	...	...	1
" " " " for drag ropes, siege, ...	...	...	...	...	...	...	...	...	16
" " " " locking, siege carriage, ...	...	...	...	...	...	...	...	...	8
Charcoal, ...	...	...	...	...	...	...	...	...	...
Cloth, waxed, new, ...	...	...	...	...	...	...	...	feet,	100
Colors, union, 18' x 12', ...	...	...	...	...	...	...	...	...	1
" " " " 8' x 5½', ...	...	...	...	...	...	...	...	...	1
Composition, greasing,...	...	...	...	...	...	...	...	lbs.,	100
Copper, sheet, thick, ...	...	...	...	...	...	...	...	...	50
" " " " thin, ...	...	...	...	...	...	...	...	...	150

* This list has been given as likely to be useful to the Military Engineer for reference in similar cases—[Ed.]

Draft, equipment, drag ropes, &c., in proportion for 8 siege carriages,	
Engines, water, complete, small,	1
" " " hose, leather, spare,	4
" " " screws,	4
" " " suction pipes,	1
Formers, cartridge, siege gun, 18lbs.,	8
" " " 9lbs.,	5
" " " mortar, 8-inch,	4
Funnels, copper, medium,	8
Fugles, filled, common, 8-inch,	4,000
" " spherical case,	3,200
Gins, large, complete,	1
Gin, falls,	1
Glasses, hour,	1
Gratings, or Garland's shot,	6
Gurrie, bell metal,	1
Half wrought materials, staves for sponges,	24
" " " axletree, beds, for siege guns,	4
" " " felloes, " "	32
" " " naves, " "	4
" " " spokes, " "	32
Heads, rammer, 18lbs. gun,	9
" " 9lbs. "	15
" sponge, 18lbs. "	9
" " 9lbs. "	15
Implements, gun, aprons, canvass, siege gun,	16
" " cartouches, leather, large,	24
" " hammers, with turnscrew,	16
" " " wrench,	8
Implements, gun, handspike, common,	108
" " " iron, mortar,	20
" " " traversing,	10
" " knives, circular siege, sets,	2
" " ladles, copper, siege, ordnance,	16
" " scrapers, for shells,	8
" " sockets, portfire,	48
" " tamping, siege gun, 18lbs.,	6
" " " 9lbs.,	10
" " " mortar, 8-inch,	8
" " tangent scales, complete,	16
" " wadhooks, siege,	16
" " wrenches, iron,	4
Implements, fuze, augurs, hands,	4
" " bags for blowing and bursting powder, 18lbs.,	500
" " " " 9lbs.,	800
" " benches,	2
" " blocks, driving,	2
" " " setting,	2
" " drafts, of sizes,	12
" " engines for drawing,	1
" " gauges, composition or markers,	2
" " knives,	12
" " ladles, composition,	2
" " mallets, driving or setting, large,	2
" " " small,	2
" " pincers, brass or copper,	2
" " roughers, steel,	6

Implements, fuse, setters, common, large, 8-inch, ...	2
" " spherical, case, ...	2
" " vices, hand, ...	2
Implements for proving shells, ...	1
Instruments measuring rods, wooden, ...	6
" " tapes, 100 feet, ...	2
" " perpendiculars, gunners, ...	2
" " quadrants, plumb, ...	2
" " scales, diagonal, brass, ...	2
" " telescopes, ...	1
Iron flat bar and round, ...	160
Jacks, hand, double, ...	2
Lanterns dark, ...	2
" Muscovey, ...	2
Laboratory materials, of sorts, ...	
Light balls, ...	200
Locks, pad, iron, ...	
Match, gun, common, ...	skins, 10
" quick, ...	lbs., 10
Measures, copper, powder, 1 to 8lbs., sets, ...	1
Mortars, brass, ...	1
" pestles, brass, ...	1
Platforms, traversing, wooden 18lbs., ...	4
" gun, complete, ...	8
" mortar, ...	4
Portfires, ...	1,440
Powder, ordnance, service, ...	lbs., 96,000
" musketry, ...	16,000
Quoins, mortar, 8-inch, 2 in a set, ...	8
Quoins, siege, ordnance, ...	32
Rockets, signal, 1lbs. ...	16
Rockets, staves, signal, ...	16
Rope, Europe 8-inch, ...	50
" " 2½-inch, ...	fathoms, 50
" " 2-inch, ...	150
" " 1½-inch, ...	100
Scales, copper, with beams, large, ...	1
" " medium, ...	1
Scale boards, ...	1
" beams, large, ...	1
" " chains, ...	1
Screws, elevating, garrison gun, spare, ...	4
" iron, for woodwork, of sizes, ...	lbs., 50
Shells, spherical, empty, loose, 18lbs., ...	600
" " 9lbs., ...	1,000
Shell, common, empty, loose, 8-inch, ...	3,200
" carcass, filled, 8-inch, ...	80
Shot, case, fixed to bottoms, gun, 18lbs., ...	840
" " 9lbs., ...	1,400
" round, loose, gun, 18lbs., ...	8,600
" " 9lbs., ...	6,000
Sieves, brass wire, medium, ...	1
" " fine, ...	1
" leather tops, ...	1
" receivers, ...	1
Skins, sheep, undressed, ...	50
Sponges, siege gun 18lbs., ...	12

Sponges, siege gun 9lbs.,	...	...	...	...	...	20
" mortar, 8-inch,	...	...	...	...	...	16
Staves, colors, union, large, complete,	...	...	...	...	...	1
" small	...	...	...	...	...	1
Tar and grease, mixed,	...	...	...	...	lbs.,	30
Tools, artificers,	...	...	...	...	...	8
" saws, tenon,	...	...	...	...	...	1
" laboratory,	...	...	...	...	sets,	1
Tow,	...	...	...	...	...	...
Triangles for scales,	...	...	...	...	lbs.,	1
Wads, common,	...	...	...	...	...	4,200
Weights, brass, 28lbs. to 1oz.,	...	...	...	...	sets,	1
" 8oz. to $\frac{1}{2}$ dram,	...	...	...	...	"	1
Wheels, wooden, siege carriage, spare,	...	...	...	...	...	4
Windlass for gin,	...	...	...	...	...	1
Zinc,	...	...	...	...	lbs.,	...

**MISCELLANEOUS STORES, CALCULATED WITH REFERENCE TO ARMAMENT,
AS ABOVE, AND OF A MAXIMUM STRENGTH OF 1000.**

Accoutrements in proportion to 250 stand of small arms,	...	...	...	...	...	24,000
Bags, sand,	...	...	...	...	...	50
Bamboos, 1st size,	...	...	...	...	...	100
" 2nd "	...	...	...	...	...	200
" small,	...	...	...	...	...	...
Boxes, ammunition, common, camel,	...	...	...	...	...	1,200
" tin, for 500 percussion caps,	...	...	...	...	...	600,000
Caps, percussion,	...	...	...	...	...	25,000
Cartridges, ballad, percussion, wall-piece, $7\frac{1}{2}$ drams,	...	...	...	...	...	500,000
" musket, $4\frac{1}{2}$ "	...	...	...	...	...	...
Chests,	...	...	...	...	...	300
Chevaux de frize,	...	...	...	...	...	80
Cloth buntin, blue, red, and white 10 yards of each,	...	...	...	...	yards,	20
Chokers, fascine,	...	...	...	...	...	...
Cloth, linen, old,	...	...	...	...	...	...
Corks,	...	...	...	...	...	...
Cotton wick,	...	...	...	...	lbs.,	10
Formers, cartridge, wall-piece,	...	...	...	...	...	5
" musket,	...	...	...	...	...	10
Iron, country,	...	...	...	...	lbs.,	200
Knives, laboratory,	...	...	...	...	...	10
Lead, pig,	...	...	...	...	cwt.,	30
Ladles, iron, melting,	...	...	...	...	...	2
Line, seizing, common,	...	...	...	...	skeins,	50
Mallets,	...	...	...	...	...	...
Musketry, muskets, percussion,	...	...	...	...	...	250
" wall-pieces	...	...	...	...	...	50
Nails, iron, spike, 7-inch,	...	...	...	...	...	200
" 5 "	...	...	...	...	...	400
" of sorts,	...	...	...	...	...	2,000
Paper, cartridge,	...	...	...	...	reams,	52
Pawlins, waxed, magazine, large,	...	...	...	...	...	2
" small,	...	...	...	...	...	10

Plank, 8-inch, deal,	running feet,	500
" sissoo or saul,	" "	500
Powder, musketry, service,	lbs.,	2,500
Rope, country, 8-inch,	fathoms,	200
" 4½ "	" "	100
Scissors, laboratory,	" "	4
Shells, common, empty, loose, grenade,	...	1,000
Steel, Europe,	... lbs.,	20
Timber, saul or sissoo,	cub. ft.,	250
" fir, "	" "	25,000
Tin, block,	...	20
Tools, artificers, saws, hand,	...	60
Tools, intrenching, axes, felling,	...	20
" " bill hooks,	...	60
" " axes, pick,	...	60
" " shovels, common,	...	50
Twine, country,	lbs.,	30
" Europe,	...	8
Wrappers, ammunition,	...	

**ENGINEER STORES IN ADDITION TO THE ABOVE, CALCULATED FOR A
DEFENCE OF TWO MONTHS, WITH GARRISON AS ABOVE.**

Bags, sand,	24,000
Barrows, hand,	50
" wheel,	100
Buckets, wooden, water,	30
Carriages, cart, hand, or platform,	5
" artificers or store,	1
Jacks, hand, double,	1
Ladders, scaling, 10 feet lengths,	20
Tools, artificers, adzes, carpenters,	15
" " carpenters,	1
" " smiths,	1
" " miners,	1
" " jumpers, miners,	10
" " " smallest,	10
" " levels, ground, square, with bob,	10
" " priming wires, miners,	15
" " saws, hand,	50
" " " cross, cut,	25
" " " pit,	15
Tools, artificers, ladles, miners,	5
" " hammers, sledge, large,	25
" " " small,	25
" " tamping bars, miners,	5
" " stones, grinding, large,	15
" intrenching, axes, felling,	50
" " pick,	350
" " bills, hand,	50
" " hook,	300
" " crow bars, iron,	30
" " hatchets, hand, with handles,	15
" " helves, axes, pick spare,	1,000

Tools, intrenching, sap forks,	15
" " shovels, common,	500
" " miners,	50
" " spades, common,	250

The armament in this statement is that which has been recommended by the Chief Engineer, and the stores are either in proportion to the armament or to the maximum garrison. There are probably some omissions in this statement, and the proportions may not be according to established usage. I should therefore recommend that the matter be referred to the Ordnance Commissariat Department, as soon as the armament is definitively settled. I should like to have some experiments tried with the 18-pounders now in the Fort, to test the capabilities of the ramparts for standing the concussion from the discharge of heavy ordnance before the number of pieces is increased. In the lower Fort, at Kohat, the scarp side of the ditch is maintained at an unnatural slope, (if I may use the term,) by a mere facing of mud bricks. I am not sure that the works built thus will stand the firing of heavy guns until some experiments are made.

A. W. GARNETT.

ABSTRACT OF ESTIMATE.

		R.	A.	P.
54,45,270	Earthwork, excavation, ordinary, at Rs. 5 per 1,000,	27,226	5	7
33,19,483-5	Earthwork, excavation and filling in, at Rs. 7 per 1,000,	23,236	6	2
8,39,493-76	Earthwork, underground excavation, at Rs. 50 per 1,000,	16,974	11	0
12,255	Mud work, at Rs. 8 per 1,000,	367	10	4
1,78,992-63	Pucca masonry brickwork (plain,) at Rs. 20 per 100,...	85,798	8	5
84,715-91	Pucca masonry brickwork (arched,) at Rs. 22 per 100,	18,637	8	0
6,07,499-46	Pucca masonry rubble work, at Rs. 18 per 100, ...	1,09,349	14	5
5,59,687-6	Kucha masonry brickwork, at Rs. 7 per 100, ...	39,178	2	1
2,10,057-81	Kucha masonry rubble work, at Rs. 7 per 100, ...	14,704	0	9
46,917-5	Kucha pucca masonry, at Rs. 15 per 100,	7,037	10	0
s. f.				
10,999-55	Plat roofing, pucca, at Rs. 40 per 100,	4,399	13	1
16,427	Plat roofing, kucha, at Rs. 30 per 100,	4,928	1	7
25,875-44	Pucca flooring and plastering, at Rs. 10 per 100, ...	2,587	8	8
c. f.				
14,082-82	Pucca masonry in wells and staircases, at Rs. 24 per 100,	3,379	14	0
10,800-82	" paved in gun platforms, at Rs. 45 per 100,	4,860	5	11
r. f.				
650	Closed drains, pucca brickwork, at Rs. 2-8 per foot, ...	1,625	0	0
2,000	Open wall drains, pucca brickwork, plastered, at Rs.			
	0-12 per 100,	1,500	0	0
	Carried forward,	3,15,791	8	0

ABSTRACT OF ESTIMATE.—(Continued.)

		R.	A.	P.
r. f.	Brought forward,...	8,15,791	8	0
1,500	Open wall drains, pucca plastered, only, at Rs. 0-5			
	per 100, ...	468	12	0
7,190	Open drains, stone and pucca plastered, at Rs. 0-2-6			
	per 100, ...	1,128	7	0
a. f.				
1,056	Bridge platforms, sissoo timber, at Rs. 2 per 100, ...	2,112	0	0
c. f.				
2,594'26	Fir timber in bridges, blindages, &c., at Rs. 1-4 per foot,	8,242	13	2
364'15	Sissoo timber gates, magazine, &c., at Rs. 2-12 per 100,	1,001	6	7
464	Superficial feet sissoo in gates, 3 inches, at Rs. 4 per foot,	1,856	0	0
3,686'75	" " for timber in doors and windows, at			
	Rs. 1-8 per 100, ...	5,530	2	0
weight.				
6,700	Lbs. iron work in drawbridges, &c., at Rs. 0-4 per lb.,...	1,675	0	0
372	Lbs. copper work in magazine, &c., at Rs. 1-8 per lb.,	558	0	0
a. f.				
8,744'28	Painting, at Rs. 2-8 per 100, ...	218	9	6
7,99,600	Turfing glacis, at Rs. 0-8, ...	3,998	0	0
Total Fort Estimate, ...		8,37,575	10	3

APPENDIX I. OUTWORK.

c. f.				
16,90,000	Earthwork excavation, ordinary, at Rs. 6 per 1,000, ...	10,140	0	0
79,907	Excavation in rock, at Rs. 50 per 1,000, ...	3,995	5	7
780	Pucca masonry brickwork, plain, at Rs. 21 per 100, ...	163	12	10
6,227'51	Pucca masonry brickwork, (arched,) at Rs. 24 per 100, ...	1,494	9	8
38,135'76	Pucca masonry rubble work, at Rs. 18 per 100, ...	6,864	7	0
4,444'94	Superficial feet pucca plastering, at Rs. 12 per 100, ...	538	6	8
290	Superficial sissoo timber in bridge platform, &c., at Rs.			
	2 per foot, ...	580	0	0
3,216	Lbs. iron work in drawbridge &c., at Rs. 4 per lb., ...	804	0	0
Total outwork, ...		24,575	9	4
Total, ...		8,62,151	8	7
Allowance for contingencies, ...		18,107	8	11
		3,80,258	12	6

APPENDIX II.

Compensation for villages pulled down, and various				
property removed, ...		25,701	2	0
Grand Total, ...	Rs.	4,05,959	14	6
A W G.				

From Brigadier NEVILLE CHAMBERLAIN, C. B., Commanding Punjab Irregular Force, to the Military Secretary to Chief Commissioner, Punjab.

Camp Kohat, 30th December, 1856.

SIR,—In compliance with instructions received, I have now the honor to place before the Chief Commissioner my opinion of the works

*of the Kohat Fort, either executed or proposed, as also on its proposed armament.

Before, however, entering into any details, I think I ought in the first place to bring prominently to notice, what I believe the present condition of the Fort to be, and what it still must remain even after it has been strengthened by the addition of the whole of the works now estimated for.

Since Sir Charles Napier first "recommended the repair of the Old Fort as being exactly where it ought to be, and needing very little to make it a perfect protection to the town,"* Rs. 2,71,432-15-2 (including Rs. 25,701 paid on account of compensation) have been expended in fortifying those old remains; and all that portion of the town which formerly afforded shelter close up to the defences of the place, and impeded its fire, has been swept away, and removed out of gun range.

But notwithstanding all these improvements at so heavy an outlay, the inherent defects of the position appear to me to be of such a nature as to forbid the idea of the present work ever possessing those elements of defence which would ever entitle it to the name of a fortress, (unless indeed it were surrounded by a fresh line of works, and the present Fort be viewed, merely as an inner line of defence or citadel,) and as in a question of this nature, government must necessarily depend upon its officers for information, and on so important a subject the real facts cannot be too prominently made known, I feel that I have no option but to state as I have done, what I believe to be the case, leaving it of course to others to confirm or upset that opinion.

If my judgment be correct, there can be no motive for perfecting the defences, further than is necessary to ensure the following objects:—

Firstly. To secure its safety as a dépôt for arms, ammunition, military stores of all kinds, and grain.

Secondly. That it may afford a secure asylum for persons and property on any occasion of the troops having to leave the cantonment unoccupied.

Thirdly. To be able by its fire to defend the town against any descent of the hill tribes in mass.

* "Indian Mis-government," letter, dated 11th March, 1850, to Lord Dalhousie, page 126.

When perusing the remarks I have now to offer upon the Executive Engineer's propositions and estimates, it will be necessary always to bear in mind the opinion I have expressed as to the inherent weakness of the site, and what I conceive to be the object of the Fort, for every thing that I say is of course based on the supposed correctness of those conclusions.

Perhaps my clearest way of explaining myself is to class the proposals and estimates under three headings, viz., Indispensable, Desirable, and Unnecessary; and with reference to the two first named, to distinguish as far as possible the relative importance of each work.

ABSTRACT OF ESTIMATE.

		RUPEES.
INDISPENSABLE.	1 Gates to the upper and lower forts, - - -	653
	2 Completion of the upper fort ramparts and scarp on the south-west fronts, - - -	9,000
	3 Postern between upper and lower fort, - - -	3,724
	4 Levelling the interior of the upper fort, - - -	2,334
	5 Construction of a range of store-houses and barracks, in the south angle of upper fort, - - -	17,300
	Total Rs.	33,011
DESIRABLE.	1 Bridge over lower fort ditch, - - -	1,810
	2 Gun carriage sheds (for ten carriages) in lower fort, -	2,072
	3 Second range of store-houses and barracks, in north and west fronts of upper fort, - - -	29,500
	4 Barbette platforms in all the bastions, - - -	4,860
	5 Completion of covered way to upper fort, - - -	5,400
	6 Completion of glacis of upper and lower fort, - - -	12,000
	Total, Rs.	55,642
UNNECESSARY.	1 Second range of gun sheds in lower fort, - - -	2,000
	2 Masonry traverse and expense magazine in lower fort, -	2,164
	3 Bombproof covering to wells, - - -	13,92
	4 Increasing thickness of parapets lower part, - - -	3,270
	5 Entrance to covered way, north front, - - -	1,000
	6 Lowering of hill to north of fort, - - -	5,000
	7 Out work on hill to north of fort, - - -	24,575
	8 Caponiere between out work on hill and fort, - - -	2,850
	Total, Rs.	42,791

The only works I can recommend to be included in the Budget for 1857-58 are those specified in the first list, and as their necessity cannot I think be questioned, I think they should be commenced upon at once, and completed without delay, for the Fort in its present condition does not fulfil any one of the three conditions I suppose to be required of it.

The works named in the second list, should I think be entered in the Budget for 1858-59; whilst those pronounced by me unnecessary can either be struck out altogether, or be again taken into consideration on the others being completed.

These remarks conclude all that I have to say with reference to "works proposed;" and I will now in as few words as possible proceed to comply with that portion of the Chief Commissioner's instructions which requires it of me to express an opinion on the "works executed."

My ignorance of everything connected with the price of labor and materials, disqualifies me from expressing any opinion as to the cost of the works executed; and having seen the shafts it was found necessary to sink right through, and below the bottom of the mound, (the old site, and around and upon which the upper Fort has been constructed,) before a proper foundation could be obtained for the foundation of the magazine* to rest upon, I have had an insight into the nature of the difficulties, and know how expensive it must have been to overcome them.

Wherever masonry has been used, the works appear to be solid and not likely to suffer from the weather.

The kucha buildings and earthen works were exposed to a very severe and unusual trial last summer, and as a matter, of course, suffered, but perhaps not more than was to be expected. The repair of these works will always call for outlay, and require attention, but much damage and loss may I believe be avoided by plastering the exposed faces at the right moment, and in sufficient time to permit of the mud drying *thoroughly* before the summer or winter rains fall.

In conclusion of this subject I may add, that the bastions of the

* The shafts, 8 in number, were 44 feet deep. The foundations of other portions of the defences are from 35 to 15 feet below the level of the *present* ditch, which had to be sunk 10 feet below its former level. Forty-eight piers, constructed under ground, of an average depth of 18 feet, spanned by semicircular brick-arches, 3 feet thick, support the west, north, and east fronts, comprising a mass of 1,50,000 cubic feet of masonry hid from view.

Lower Fort were in May last subjected to the test of having a few rounds fired from them, from the 18-pounder garrison guns, and stood well; a further trial is necessary before they can be pronounced fit to withstand the concussion of continued firing from heavy ordnance, and this shall be done at an early date.

Twenty-four is the number of pieces* recommended for the armament of the Fort. Assuming this to be the proper proportion for such a work, I would still suggest a modification both of class and calibre; for the transport of so many heavy pieces with proportionate quantity of ammunition and stores, could not be accomplished without considerable expense; and my belief is, that a proportion of lighter pieces would be found equally useful for the purpose likely to be required of them, and they would at the same time possess the very great advantage of being available for use in the field if required.

The following is the armament I recommend:—

<i>Description of Ordnance.</i>					<i>No. of Pieces.</i>	
Iron gun, garrison,	18-pounders,	-	-	-	-	3
" "	9-pounders,	-	-	-	-	3
" " howitzer,	8-inch,	-	-	-	-	2
" mortar,	8-inch,	-	-	-	-	2
Brass gun, field,	9-pounders,	-	-	-	-	2
" "	6-pounders,	-	-	-	-	2
" " howitzer "	24-pounders,	-	-	-	-	2
" " "	12-pounders,	-	-	-	-	2
" mortar, "	5½-inch,	-	-	-	-	4
" " "	4½-inch,	-	-	-	-	2
Total,					-	24

The iron 8-inch howitzers and brass mortars, are in my opinion the pieces most needed, and I advocate their being the first to be despatched. Whether for the defence of the Fort or service in the field, they may be turned to account on this border when other pieces could produce little or no effect. Only in May last, some experiments were made in my presence with the pieces of the Light Field Battery from the bottom of the pass (Kohat), and the result was to establish their inability to afford material assistance if the summit were held by the Afreedies, and the infantry had occasion to possess themselves of it; the 24-pounder howitzer was at last made to throw a shell on to the top of the ridge, but not without having to give the piece undue eleva-

* 18-pounders, 6; 9-pounders, 10; 8-inch mortars, 8.

tion, and then the range was too great for anything like effective practice.

A couple of 8-inch howitzers properly directed would rob the hill of its strength, and save us loss of life ; and the Government, family pensions.

NEVILLE CHAMBERLAIN.

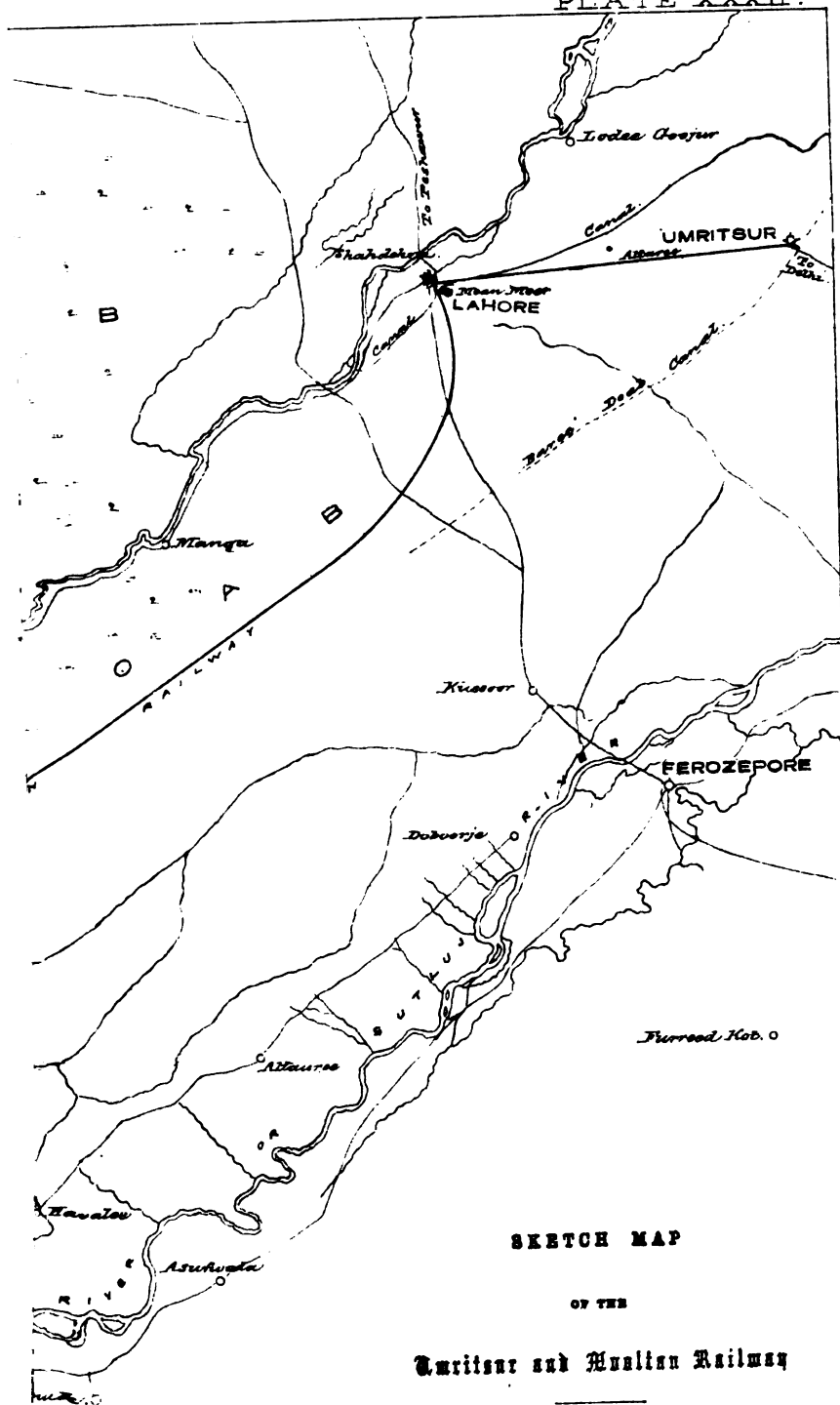
[The Brigadier's proposals were substantially sanctioned by Government, and the work executed in accordance with them.—ED.]

No. XXVI.

UMRITSUR AND MOULTAN RAILWAY.

IN March, 1856, the Scinde Railway Board requested permission of the India House to commence a survey of the country from Moulton to Lahore and Umritsur, with the object of completing the combined system of steam transit by land and water, so long advocated by their chairman. In July, 1856, the permission to conduct the survey was given by the East India Company, and measures taken for its immediate commencement. Of the political and commercial value set on this link in the chain of communication by the local authorities, the following extract from the report from the Punjab Government in 1856, will be sufficient evidence.

“So far as the commercial and material interests of the Punjab are concerned, there is a proposed line from the north-east to the south-west, which is of greater consequence to the country than any public work, or any number of works that could be specified. A glance at the accompanying map will show that Northern India has two natural divisions; *first*, the Provinces of the Ganges and its tributaries; *second*, the Provinces of the Indus and its tributaries. In the first or easterly division, the stream of trade and wealth must ever flow down the valley of the Ganges to the natural outlet of Calcutta. In the second or westerly division, if the power of art and science be brought to the aid of nature, the commerce could follow the direction of the Punjab rivers to the Indus, then down the valley of the Indus towards the rising port of Kurrachee, which is destined to be, to the north-west of India, what Calcutta is to the north-east. To this port would come the products from north-western India, and from the Central Asian countries beyond that frontier; and in exchange for these, the products of European countries. In this same direction, there would



0 1 2 3 4 5 Miles

also arrive the vast quantities of Government stores and material for the military and public establishments in that quarter, and large numbers of European travellers would frequent this line (in preference to the Eastern route), on account of its comparative shortness and proximity to overland passage to Europe.

"For the opening up of this western route, the importance of which upon general considerations is so evident, it is proposed in the first place, to establish communication by rail and steam from Kurrachee upwards to Moultan, just above the point where the Punjab rivers join the Indus. For the first section of this line, a railroad from Kurrachee to Hyderabad on the Indus, a distance of 123 miles, has been undertaken by the Scinde Railway Company.* At first, the line may be continued thence up to Moultan, by steamers on the Indus, to be followed by a railway as soon as it can be constructed; there would then remain to be constructed a railroad from Moultan to Lahore and Umritsur, to join or cross (or rather continue) the great north-western line between Calcutta and Peshawur. It is this last-named railroad, from Moultan to Lahore and Umritsur, which immediately concerns the Punjab; and the Supreme Government have directed complete inquiries on the subject to be made. It will now be proper to state briefly what the advantages and facilities of the line are likely to be.

"The northern terminus of the line will be Umritsur, which is not only the first mart in the Punjab, but also one of the first commercial cities in Upper India. Its merchants have dealings, not only with all parts of India, but also with many parts of Europe on the one hand, and of Central Asia on the other. To this city there come the choicest Asiatic products, the wool of Thibet, the shawls of Cashmere, the dried fruit and spices of Afghanistan, the carpets of Turkey, the silk of Bokhara, the furs and skins of Tartary, the chintzes and leather of Russia. In return for these arrive the piece goods and iron of Europe, the fabrics of Bengal, the sugar of Hindostan and the Punjab. To the same emporium are gathered all kinds of indigenous produce of the Punjab. Of this trade, amounting, according to reliable returns, to three and-a-half million pounds sterling per annum, a large portion proceeds to and from Calcutta by the Grand Trunk Road, another portion to Bombay by difficult and laborious land routes, through Central India and the desert routes of Rajpootana, and a third portion (and

* This line is completed and open, and steamers ply regularly on the Indus. The voyage upwards is still however very tedious.—[Ed.]

at present the least portion)-to Kurrachee, by water carriage on the Indus and its tributaries. Of this traffic, then, nearly all would be diverted to the proposed railroad from Umritsur to Moulton, and thence to Kurrachee. From these parts, most things intended for export would not go to Calcutta, if there were facilities for going to Kurrachee; and of those things destined for Bombay, all would go by the rail to Kurrachee *via* Moulton, instead of the arduous route through Central India. In the same manner all the imports for Umritsur, and other parts of the country between Delhi and the N. W. Provinces Frontier, and the regions beyond it, which now come from Calcutta or from Bombay by land, would proceed to Kurrachee, and thence upwards by rail.

"But besides the noble traffic above indicated, which is of general as well as local interest, there is already a traffic of some magnitude between the Punjab and Kurrachee. So strong is the tendency of trade towards the natural port and outlet, that large quantities of indigenous produce creep and labor in clumsy native craft down the five rivers. In this manner, hundreds of tons of cereals, linseed, sugar, saltpetre, and indigo pursue a tedious way over 400 miles of the five rivers to the sea-board. The water traffic is greatest on the Sutlej, next on the Jhelum, then on the Indus, and lastly on the Chenab and the Ravee. The united traffic of the rivers up and down (by far the greater part, say four-fifths, being down traffic), as ascertained by registration of boats at the junction point, Mithunkote on the Indus, is not less than 700,000 maunds, or 85,000 tons per annum. Now if the rates of carriage by rail should be kept low, so as to attract commodities which can only afford to pay for cheap transit, then it may be certainly presumed, that of the above quantity all that pertains to the Sutlej, the Ravee, and the Chenab, and a part of that belonging to the Jhelum, will be diverted to the Umritsur and Moulton Railway. The present means of navigation being wretched, and the rivers being difficult, the existing water traffic would preferentially take the railway, provided always that the cost of transit be cheap. It is indeed, for the sake of this indigenous traffic that every well-wisher of the Punjab must be anxious to see the day when the rail shall be opened from Umritsur to Moulton. The traffic may be already considerable and promising, but it is now as nothing compared to what it would become, with the advantages of a rail.

"Again, if the advantages, present and prospective, of this line, when constructed, are great, so also are the facilities for its construction remark-

able. Though the country situated above its northern terminus is rich and highly cultivated, yet the particular tract through which it will run is for the most part poor. Between Moulton and Lahore, a distance of 240 miles, the country is a dead level, hard and waste. In the first place, then, there will be no cultivated or inhabited ground to be bought up. The price for the land will be almost nominal. There are no engineering difficulties whatever to be met with anywhere between Lahore and Moulton. The Doab, or country lying between the two rivers Sutlej and Ravee, is elevated in the centre, and the sides slope gently off towards the rivers. From the centre or back-bone of the tract, their naturally run drainage channels to the rivers; consequently, while a road traversing the Doab, near the banks of either river, must cross or be intersected by numerous little streams, a line constructed in the centre would meet none of them. But the railroad would run near the central or dorsal ridge, parallel to the course of the new Baree Doab Canal, and consequently, the line will, perhaps, not meet with any stream whatever. There being no streams, nor depressions, nor elevations, there will, consequently, be no bridges, cuttings, or embankments, on at least four-fifths of the distance. As it approaches Moulton, the line would have to be carried across a few small irrigation canals, and to be partially raised. In short it would be difficult to select, or even imagine, a champaign more suited for the cheap and easy construction of a railway than the country between Lahore and Moulton. Between Lahore and Umritsur the country is fairly cultivated, and generally level. It offers no engineering obstacles. But there would be three or four small streams, and one canal to be bridged. As regards material, the iron would come from England; timber and wood of the best quality is obtainable from the hills by water-carriage; fire-wood exists in the utmost abundance; kunkur would be generally procurable for at least half the distance; masonry would not be much needed; if it were, there are ample facilities for brick-making; the population near the line is sparse, but labor is largely procurable from other parts of this country for any great work.

"The absence of physical and engineering difficulties is indeed most fortunate. For economy and even cheapness of construction will be essential to enable the railway authorities to fix the transit line at low rates. The passenger traffic and the more valuable commodities and products would be considerable, and might bear tolerably high rates. But for a mass of produce great in bulk, but comparatively less valuable, lower rates will be

indispensable. For the goods trains, speed will generally be of less consequence than cheapness of hire. It is upon this condition, namely, that of moderate hire, that the rail may be expected to supersede the native river boats."

*Report from WILLIAM BRUNTON, Esq., C.E., Superintending Engineer,
to the CHAIRMAN and DIRECTORS of the Punjab Railway Company.*

Lahore, 15th June, 1857.

GENTLEMEN,—I beg to forward plans, sections, and estimates for a line of railway uniting the towns of Umritsur, Lahore, and Moulton.

My estimate is for a single line of railway of 5 feet 6 inches gauge, complete with every appliance to render it fully effective, both as regards the carriage of passengers and goods, and the public safety, with sufficient rolling stock, tools, and machinery to work the same, and every way in accordance with the recommendations of the Consulting Engineers of the Indian Railway Companies, sanctioned by the Honourable Court, bearing date, London, March 7th, 1856.

The main reason of my being able, in so short a time, to accomplish your views, is the extraordinary adaptation of the country to railway purposes. No tract I have ever seen, even of much less area, presented so few obstacles.

I have as far as possible chosen the highest ground between the rivers Ravee and Sutlej, in order to keep above the annual inundations, and where this has been impracticable, I have provided such drainage as from the information I have obtained will be sufficient to keep the works perfectly secure in case of floods. I shall personally inspect every portion of the ground during the next flood, in order to be satisfied that I have founded my calculations on correct data.

The working expenses of a line so laid down must of necessity be small. Being nearly level, the consumption of fuel will be proportionally low, and being almost entirely free from curves, the wear and tear of the rolling stock will be trifling in comparison with lines not having the same advantage.

The pay also of natives is about 20 per cent. of that in England for labor of the same description.

I have estimated but not shewn the position of a branch line from the Lahore station to the banks of the Ravee. My reason is, that I wish to see the country over which it must pass inundated (which is the case every year) prior to fixing the most advantageous site for such branch. Which-ever site I decide on, my estimate will be adequate for its construction.

I have consulted the wants of the Mean Meer Cantonment, and have allotted a station at each end of their lines. The stations at Lahore, Umritsur, and Moulton, I have placed more especially with a view to native passenger-traffic, which will be the main source of revenue from passengers; they are also in suitable positions for the delivery and reception of goods.

It is possible (I may say certain) that near each station between Lahore and Moulton, natives will form in time large villages. I should recommend you to make such arrangements with the Honourable East India Company as shall give you the control over the erection of any buildings within, say one mile, from each station; that the villages may be constructed with regularity, and proper sanitary measures taken, as you may be advised by your engineer for the time being.

Over the whole length of the line, timber for fuel is to be obtained in abundance.

At every ten miles along the line, wells will have to be sunk at an average depth of 80 feet, at which depth abundance of water can be obtained. This is a work which should be proceeded with immediately, so as to provide for the wants of the workmen.

The station-houses also should be erected without delay, as they would form head-quarters for my residents, during the construction of the line.

I have formed the line entirely on embankment; I find it necessary, even where the surface of the ground would appear to warrant a cutting. The reason for this is, that in the rainy season any place below the natural surface becomes a pond, if level; and if at an inclination, a bed for a stream.

The quantity of land which will be occupied by the railway and station-plots, will be 1,700 acres, and liberty required to take side cuttings, exclusive of this amount. This quantity provides for a double line of railway.

In my estimate you will perceive I have provided for grassing the slopes of embankments; this may seem an unnecessary expense to parties unac-

six first-class engineers, residents, over certain districts, six second, and six third-class, each first-class having two assistants; one first-class engineer, a good practical man, to take charge of the principal office and drawing department.

The number of inspectors required it is now impossible to state; it will depend on what works are being proceeded with at the same time. These men can be obtained in this country.

I am of opinion that I could complete this line of railway, ready for opening, in four years from this present date, if I have every facility for so doing afforded me.

That the passenger and merchandise traffic are sufficient even now amply to repay the outlay, the statistical reports you already have from the Government officers fully prove, but in my opinion the increase of these sources of profit will be augmented to a degree that it is impossible to calculate, when there is an outlet for the products of the country. At present there is none, the natural result being, that only sufficient for the wants of the immediate vicinity is produced; and, added to its being a source of profit, the present position of India forcibly points to the absolute necessity of rapid communication with all parts of a country made up of so many discordant elements.

As your proposed lines of railway in connection with the river and railway communication to Kurrachee, will form the main artery through which the whole of the traffic from the Punjab must naturally pass, I should, to complete the scheme, recommend that the cost of extending the line from Lahore to Peshawur be ascertained as quickly as possible.

W. BRUNTON.

NOTE BY THE EDITOR.

On the 8th February, 1859, the first sod of the Punjab Railway was formally turned by Sir John Lawrence, then Lieutenant-Governor of the Punjab, and work which had actually begun a short time before steadily proceeded for rather more than a year, when the unfortunate disagreements between the Agent and Chief Engineer of the Railway, which ultimately led to the removal of both, caused great hindrance to

progress. Other unforeseen difficulties also arose. The principal contracts were given to native contractors, who failed in their engagements, not from dishonesty, but from want of experience, and the serious difficulties arising from the great scarcity of labor. Under the able management of the present Chief Engineer, Mr. Joseph Harrison, such difficulties were, however, gradually overcome, but not without having to execute the chief portion of the work by daily paid labor through the District Engineers, and in 1862, the first section of the line from Lahore to Umritsur, 32 miles, was formally opened by the Lieutenant-Governor, and traffic has continued on it uninterruptedly ever since.

A small section, 11 miles long, from the Steam-boat Ghat on the Chenab up to the city of Moultan, was also opened shortly afterwards. Of the 218 miles from Lahore to Moultan, about 170 are already completed, and the whole line will shortly be open.

It would be difficult to find a more extraordinary line, in some respects than the one now described. The country is so flat and open, that, for 114 *continuous miles the line runs as straight as an arrow* down the heart of the Doab, and in the whole distance of 250 miles, there is scarcely a bridge larger than an ordinary culvert. The only exceptions are, where the Railway is carried over two branches of the Baree Doab Canal on Warren's Girders (80 feet span,) at a considerable skew, and across one or two native Canals near Moultan. The gradients nowhere exceed 1 in 600, and are in general much flatter.

The ballast used has been chiefly broken brick from the ruins of old Lahore, which appear to furnish an inexhaustible supply. Brick is the material every where used for all buildings on the line, and the Punjab deodar is the only wood.

Between Lahore and Moultan no place of any size larger than a third rate village is passed, and even the few towns on the bank of the Ravee were too insignificant to necessitate a circuitous route on their account.

The original Estimate amounted to about £6,000 per mile, including rolling stock, but it is believed this has since been increased. All material and stores from England were shipped to Kurrachee, and thence brought by native boats or steamer up to Moultan or Ferozepore, whence they were carried by land on to the line—the Ravee being nearly unnavigable.

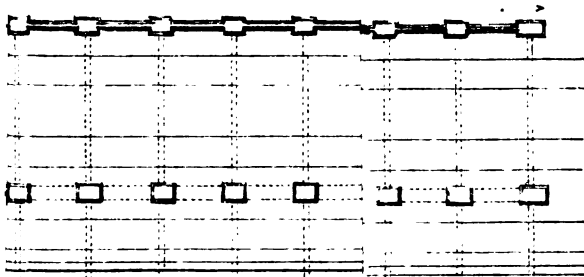
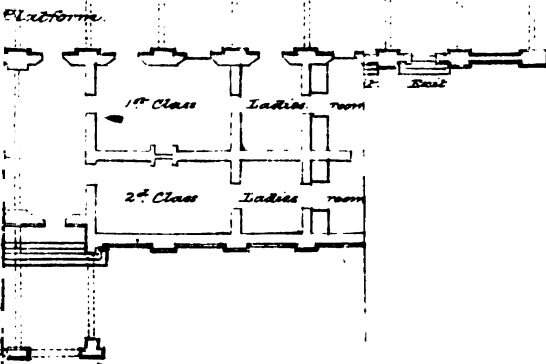
The Rails are very light, weighing 66lbs. only, to the lineal yard, but as low speeds and cheap rates are intended, the weight thus saved where

carriage was so difficult, more than compensated for any supposed disadvantage of using rails lighter than usual. Owing to the difficulty of procuring sleepers, 40 miles of Greave's Patent Permanent Way have been imported and laid down.

A view of the Lahore Station is given in the Frontispiece, and a Plan and Elevation of the Umritsur Station are here added.

The continuation of the line from Umritsur to Delhi has been sanctioned, by which a junction will be effected with the East India Railway, and the line is now being marked out. I hope to be favored with some details of the works on this line (a very interesting one in an Engineering point of view) so as to be able to communicate them in an early number.—J. G. M.

Punjab Railu



No. XXVII.

SCANTLINGS OF TIMBERS—MYSORE.

By Major R. H. SANKEY, R.E., Assistant to Chief Engineer.

THE want of Tables of scantling for beams and trusses having been experienced in this department, the accompanying, which are applicable to the most generally useful of the indigenous Mysore timbers, are now by desire of the officiating Chief Engineer, circulated for future adoption in all roof designs.

With timbers differing so much in relative strength and elasticity, it would have been a tedious undertaking to frame a set of tables for each; a general and somewhat arbitrary classification has therefore been adopted, which, within the limits assigned, will be found sufficiently accurate for all practical purposes, while at the same time allowing of one set of tables answering for all.

From Table No. I, it will be observed that the classification has been determined by the value of $E = \frac{L^3 W}{bd^3 \delta}$ in each case; class No. I embracing all timbers, the value of E for which has been found by experiment, to range from 4,000 to 4,500; class No. II, those ranging from 3,500 to 4,000; and class No. III, from 3,000 to 3,500.

Although arbitrary, this is a sufficiently near approximation to the truth, as an increase or decrease of 500 in the value of E, is very nearly represented by the difference of the scantlings, assigned to the spans next above and below.

In using the Tables, first ascertain from No. I, to what class the timber belongs; if of the first class, take out the required scantling directly

opposite the given span, whether for terraced or pent roofing; if of the second class, take the scantling assigned to the next greatest span; and if of the third class, take that of the next greatest again.

Thus, if it be wished to ascertain the correct scantling of a teak wood girder for a terraced roof, 20 feet span, the girders being placed at 10 feet from centre to centre, take out the scantling under a span of 21 feet in Table No. III, which gives $16'' \times 11\frac{1}{2}''$. Were on the other hand, the timber Sumpenggee, or Poon, the scantling would be $16\frac{1}{2}'' \times 11\frac{1}{4}''$, or that under a span of 22 feet; the timber being third class.

It is not proposed here to explain the nature of the experiments undertaken for ascertaining the values of E for each timber, or give in detail the calculations made for fixing the scantlings required to sustain given weights of roofing, the following brief observations will therefore serve all present purposes.

The formula employed is the ordinary one $E = \frac{L^3 W}{bd^3 \delta}$ for rectangular beams; (L) being clear length of beam in feet between supports; (W) weight in lbs. of roofing spread equally along the beam, and determined by actual experiment for each description; (b) the breadth of beam in inches; (d) depth ditto, and (δ) the deflection assumed at .05 of an inch for every foot in length.

Now if (a) be taken as the side of a square beam, and (W) be substituted for $\frac{1}{4} W$, which is equivalent to the weight suspended from the centre, the above formula becomes $E = \frac{L^3 W}{a^4 \delta}$ hence $a = \sqrt[4]{\frac{L^3 W}{E \delta}}$.

The value of E being given in this equation, for any known timber, the side of a square beam capable of supporting the weight (W), with the deflection of $\frac{1}{40}$ of an inch to the foot, is easily found by logarithms.

In calculating the present tables, the value of E was taken throughout, as that given by the late Conductor Skinner, in his valuable work on Indian and Burman timbers, for Pegu teak, viz., 8,840; it will therefore be obvious that sufficient provision has been made for ordinary purposes, by transferring this and other timbers of equal strength, to the second class—or in other words assigning to them scantlings which would suffice for timbers, the elasticity of which is about 500 less than that ascertained by experiment.

Having found the value of (a) for a square beam, an assumption has to be made, to ascertain the dimensions of a corresponding rectangular one.

By the pr to its diagonal; hence $d = b\sqrt{2}$ and as $a^2 = b d^2 \therefore b$

$= \frac{a}{\sqrt{2}}$ ables have been calculated from the above formulæ.

54

R. H. SANKEY.

MENT PUBLIC WORKS.

Tp.		Remarks.																								
LAT. Inga CAN. Xyn- TEL. Jamd Tant valy	This table gives the characteristics of the most generally useful timbers, for the Department in Mysore and Coorg, there are a great many others, however, which promise well, and should be employed as occasion offers: of these the following may be specially mentioned.																									
LAT. Dalb- CAN. Biti- TEL. Yerd- it e-	<table><tr><th colspan="2">Synonyms.</th><th rowspan="2">Classes corresponding to those in table.</th><th rowspan="2">Localities.</th></tr><tr><th>Botanical.</th><th>Canarese.</th></tr><tr><td>Diospyros melanoxylon, Conocarpus latifolia, Vitex alata, Acacia odoratissima,</td><td>Banlay, Dundugas, Nowladdi, Billawar,</td><td rowspan="3">Over standard of 1st class, 1st class, 2nd class, 3rd class.</td><td>Nugur Kankanully Nugur</td></tr><tr><td>Bamia longifolia,</td><td>Iype,</td><td>Nugur, Coorg, Kan- khanully</td></tr><tr><td>Nuclea cordifolia,</td><td>Yetiaga,</td><td>Coorg, Kankanully and Astagram jun- gies</td></tr><tr><td>Asodarachta indica,</td><td>Bavena,</td><td>4th class, Unclassed, "</td><td>Kankanully and Mai- dan Talooks Nugur Nugur, Kankanully Nugur</td></tr><tr><td>Cedrela toona, Vatica lacifera, Ulmus integrifolia,</td><td>Gundagurghy, Jaloda, Tupissae,</td><td></td><td></td></tr></table>		Synonyms.		Classes corresponding to those in table.	Localities.	Botanical.	Canarese.	Diospyros melanoxylon, Conocarpus latifolia, Vitex alata, Acacia odoratissima,	Banlay, Dundugas, Nowladdi, Billawar,	Over standard of 1st class, 1st class, 2nd class, 3rd class.	Nugur Kankanully Nugur	Bamia longifolia,	Iype,	Nugur, Coorg, Kan- khanully	Nuclea cordifolia,	Yetiaga,	Coorg, Kankanully and Astagram jun- gies	Asodarachta indica,	Bavena,	4th class, Unclassed, "	Kankanully and Mai- dan Talooks Nugur Nugur, Kankanully Nugur	Cedrela toona, Vatica lacifera, Ulmus integrifolia,	Gundagurghy, Jaloda, Tupissae,		
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LAT. Pter- CAN. Hon- TEL. Yeg-	Others such as Mussay, Honnau, and Genseena Murrah, procurable in Nugur, are also well reported on for all work, they have not, however, been identified botanically, or subjected to experiment.																									

Roofs.

Remarks.

ymment of joists, laid transversely over the beams, the weight of the former is here taken ng be used, will be placed at 15 inches from centre to centre, and where the beams are 5 quare ; where 10 feet, $6' \times 4'$. The slope of the roof in this arrangement is obtained mbering them or nailing battens as mentioned in the remarks in the foregoing table. In centre to centre, have been almost exclusively employed for terraced roofs, the interval small joists (burgahs) 3 inches square in section, covered with two courses of tiles, and 4 mental arches, with 4 inches rise, are turned from beam to beam, instead of employing ing being respectively 75 and 91 lbs. per superficial foot, the beams require to be of greater d 2 feet, greater spans would suffice. The precautions regarding the employment of sound sially requisite with this description of roofing, 12 to 15 inches has been allowed here for ample if a wooden plate, or still better a stone slab of the same width, and from 2 to $2\frac{1}{2}$

COMMON TILED ROOFS.

<p>is made 3 e of the</p> <p>Contents in c. feet and decimals.</p>	<p>Remarks.</p>
<p>·92 1·53 1·93 2·58 3·27 3·95 5·06 6·11 7·17 8·20 9·57</p>	<p>By <i>span</i> in this table is meant the clear width between the feet of the rafters. The scantlings are calculated to bear the usual reapers ($2' \times \frac{1}{2}'$) one course of flat tiles and pot or pantiles above, with the weight of the latter increased by saturation from rain. Up to 15 or 16 feet spans the table will be found useful for couples placed at 18 inches from centre to centre, but above this the dimensions can be only usefully employed for rafters unsupported by struts, and as such would only be employed for leans-to. For the dimensions of common and principal rafters for tiled roofs, see Tables Nos. 5 and 7. The length of rafters and hips here given equally, of course, apply to all roofs with a rise equal to one-third of the span.</p>

Distances apart in feet from centre to centre.	Length in feet allowing for seating.	Where the rafter bears the proportion marks. breadth	
		Depth in inches.	Breadth in inches.
3	11	6½	4½
4	11	6½	4½
5	11	7	4½
6	11	7½	5
7	11	7½	5
8	11	7½	5½
9	11	7½	5½
10	11	8	5½

It follows that the purlins will all be of the same length. That ever practicable, the purlin should however be long enough to girth. A square section should also be preferred to rectangular. gth of their bearings from centre to centre of the purlins. In es must be made to the total length of rafter, to allow for the quantity of timber is employed, by placing the purlins at 3 feet latter, is immediately over the junction of the strut, with the ary cases to disregard the slight advantage gained in quantity,

Distances in feet between port, or from inside		13 Feet.		14 Feet.		15 Feet.		16 Feet.	
		D.	B.	D.	B.	D.	B.	D.	B.
6	4½	6½	4½	6½	4½	6½	4½	6½	4½
6½	5	7	5	7½	5½	7½	5½	7½	5½
7	5½	7½	5½	8	6	8½	6½	8½	6½
7½	6	8½	6½	9	7	9½	7½	9½	7½
8	6½	9	7	9½	7½	10	8	10½	8½
8½	7	9½	7½	10	8	10½	8½	11	9
9	7½	10	8	10½	8½	11	9	11½	9½
10	8	11	9	11½	9½	12	10	12½	10½
10½	8½	11½	9½	12	10	12½	10½	13	11
11	9	12	10	12½	10½	13	11	13½	11½
11½	9½	12½	10½	13	11	13½	11½	14	12
12	10	13	11	13½	11½	14	12	14½	12½
12½	10½	14	12	14½	12½	15	13	15½	13½
13	11	14½	12½	15	13	15½	13½	16	14

Roofs.

Remarks.

This table shows the dimensions and contents of trusses, placed 10 feet from centre to centre, and calculated to bear a weight over all of 50 lbs. to the square foot, which gives ample allowance for the weight of purlins, common rafters, reapers, also tiles saturated with n, &c. For dimensions of purlins, &c., see Table, No. 5.

In estimating the length of the *principal rafters*, 12 inches extra has been allowed for raftering in all spans, from 16 to 20 feet; 15 inches in all from 20 to 30; and 18 inches from 30 to 40 feet. For *tie-beams*, 18, 24, and 30 inches are similarly added to the clear span, within same limits. For *king-posts*, 9 inches has been added in all cases.

Should it be desirable to substitute iron for tie-beams and king-posts, the following diameters in inches of round rod iron will answer.

	For all Spans varying from					
	16 to 19 feet.	20 to 24 feet.	25 to 29 feet.	30 to 34 feet.	35 to 39 feet.	40 feet.
e-beams.	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2
king-posts,	$\frac{1}{2}$	$\frac{3}{4}$	1	1	$1\frac{1}{4}$	$1\frac{1}{2}$

as "Bengal terracing" weighs about 45 lbs. per square foot, irrespective of the weight of the burghas, &c., it would be advisable to take out always scantlings for the next larger spans.

A description of terracing lately advocated, which consists of two courses of flat tiles (12" x 12" x 1 1/4" burnt very hard), and plastered over, weighs only 32 lbs. per square foot. Scantlings for the next less spans will be found sufficient for this. The rise of such roofs should not exceed 1/4th of the span.

For corrugated iron or zinc roofs, rafters 6" x 3" spaced 3 feet from centre to centre, and 4 purlins to each sheet, will be found to answer.

No. XXVIII.

MACHINES FOR RAISING WATER.

(2ND ARTICLE.)

Calculation of the labor and cost of raising water by different machines occasionally (but not generally) employed in India. BY SERGEANT J. WEBSTER, Assistant Master, Thomason College.

6. WINDLASS AND BUCKET.

(Worked by one man, with relief.)

Water raised 4 feet.

Content of bucket = 2 cubic feet = 12·5 gallons.

Length of handle = 1 foot.

Diameter of rollers = 15 and $7\frac{1}{2}$ inches.

Velocity of handle per second = 2 feet.

Space passed through by the handle at one turn = 6·28 feet.

Space passed through by the roller at one turn of the handle = 3·9 feet.

Height to which the bucket must be raised = 7·8 feet.

Therefore : Number of turns required to raise the bucket = 2.

Number of turns required to lower the bucket = 2.

Time required for one turn of the handle = $\frac{6\cdot28}{2}$ = 3·14 seconds.

Time required for four turns of the handle = 12·5 seconds.

Time required for filling the bucket = 30 seconds.

Total time between each lift = 42·5 seconds.

Number of lifts per minute = 1·4.

Useful effect = 50 per cent.

Discharge per hour = $1.4 \times 60 \times 2 \times .5 = 84$ cubic feet = 522 gallons.

Estimated weight to be raised at each lift = 112 pounds.

Ratio of power and weight = 1 : 8.2.

Modulus = .7.

Required force to overcome the load = $\frac{112}{.7 \times 8.2} = 50$ pounds.

7. THE DALL.

(Worked by two men, with relief.)

Water raised 5 feet.

Content of dall = 5 cubic feet.

Using a leverage of 1 : $1\frac{1}{2}$, and making one arm of the lever 8 feet, and the other 12 feet, we have—

Velocity of lever = 2 feet per second.

Time required for raising the dall = $3\frac{1}{2}$ seconds.

Time required for lowering the dall = 3 seconds.

Time required for filling the dall = 30 seconds.

Time required for emptying the dall = 5 seconds.

Total time between each lift = 42 seconds.

Number of lifts per minute = $\frac{60}{42} = 1.4$.

Useful effect = 70 per cent., we get—

Discharge per hour = $60 \times 1.4 \times .5 \times .7 = 294$ cubic feet = 1837.5 gallons.

Estimated weight to be raised at each lift = 218 pounds.

Ratio of power and weight is = 1 : 1.5.

Modulus = .9.

Required force to overcome the load = $\frac{218}{.9 \times 1.5} = 161$ pounds.

If two men are at work, each has a load of 80 pounds at every lift to overcome.

8. THE DOUBLE PERSIAN WHEEL.

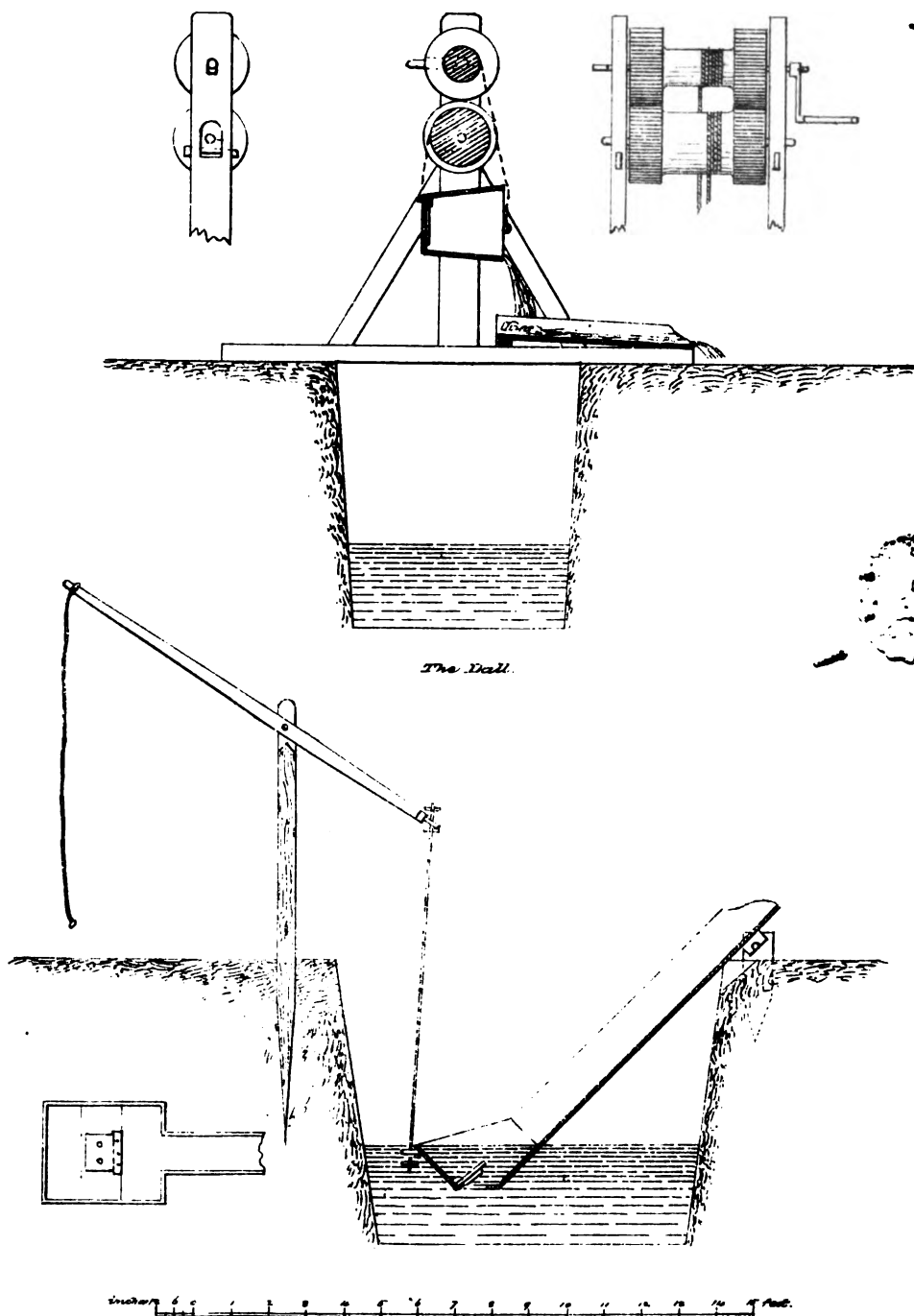
(One man and two bullocks employed.)

Water raised 40 feet.

Proportion of gearing = 2 : 3.

MACHINES FOR RAISING WATER.

Windlass and Bucket

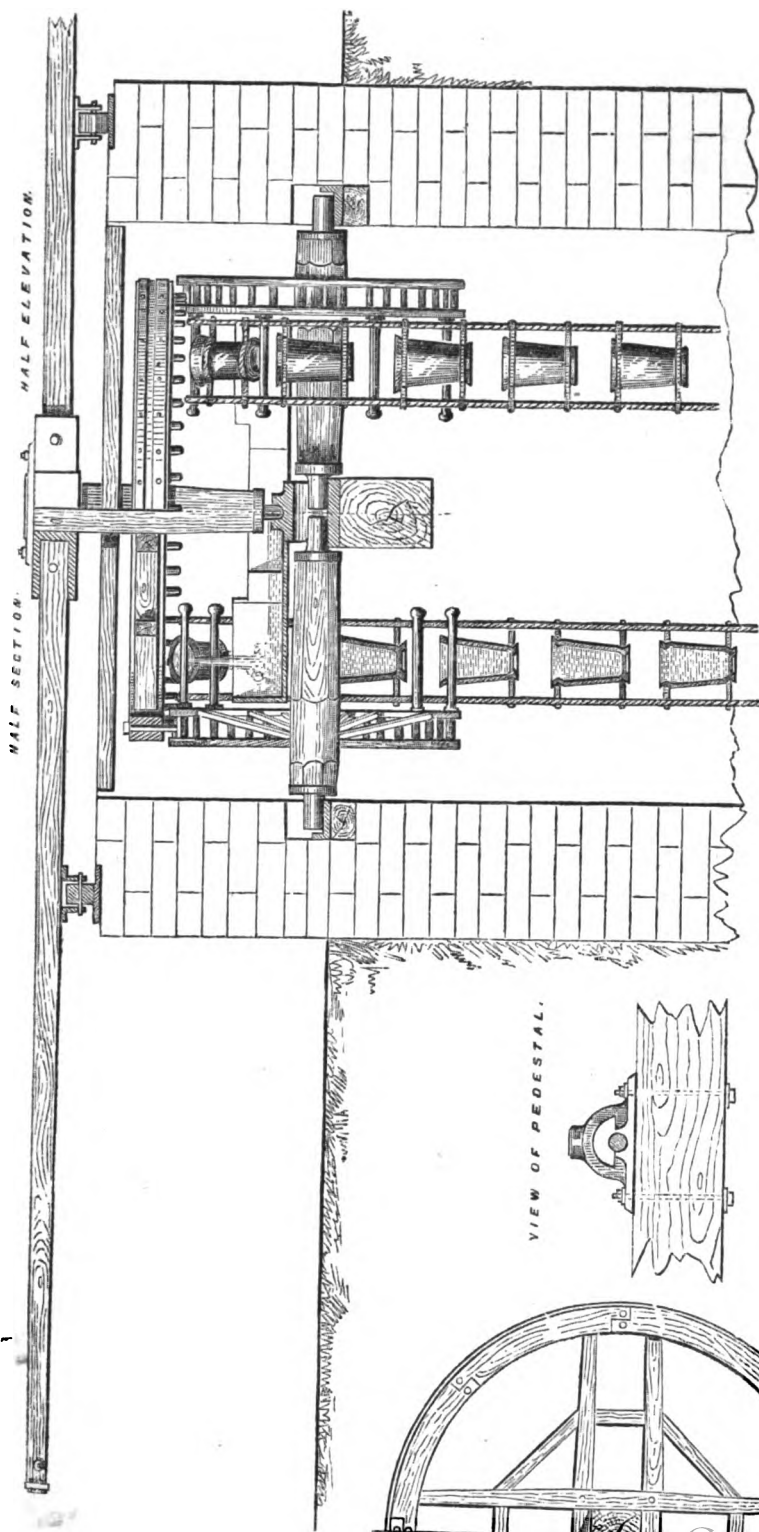


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10

IMPROVED PERSIAN WHEEL.

PLATE XXXIV.



SCALE 1/24TH

WHEELS BEARING THE MARKS.



F



Diameter of driving wheel = 5 feet, pitch = 3.92 inches, cogs = 48.

Diameter of bucket wheel = 3 feet 4 inches, pitch = 3.92 inches
staves = 32.

At each turn of the bucket-wheel 8 buckets are emptied, the 2 wheels empty 24 buckets at each turn of the bullocks.

Content of bucket = $\frac{1}{10}$ cubic foot.

Therefore: Discharge of water at each turn of the bullocks = $\frac{1}{10} = 2.4$ cubic feet = 15 gallons.

If the bullocks work on a lever of 12 feet, the length of the bullock walk is = $24\pi = 75$ feet, and taking their speed at 2 miles an hour, we get—

Speed of bullocks per minute = $\frac{5280 \times 2}{60} = 176$ feet.

Number of turns per minute = $\frac{176}{75} = 2.3$.

Useful effect = 60 per cent.

Discharge per minute = $2.3 \times 2.4 \times .6 = 3.3$ cubic feet = 20.7 gallons.

Discharge per hour = 198 cubic feet = 1242 gallons.

The buckets are 1 foot 3 inches apart, and the well being 40 feet deep, the requisite number of buckets for each wheel will be $\frac{40 \times 3}{1\frac{1}{4}} = 60$, 30 being always full on each wheel, the weight of water on both wheels is = $\frac{1}{10} = 6$ cubic feet = 375 pounds, which is the total weight to be raised, as the weight of the buckets and ropes are not taken into calculation, on account of their balancing each other.

Space passed over by the weight at three revolutions of the bucket wheel = 10π .

Space passed over by the bullocks in two turns in same time = 48.

Therefore: Ratio of power and weight is = 10: 48, or 1: 4.8.

Taking the modulus of the machine at .5, we get—

Required traction = $\frac{375}{.5 \times 4.8} = 156$ pounds.

If two bullocks are employed, each has a traction of 78 pounds to overcome.

9. THE SUCTION PUMP.

(Worked by four men, with relief.)

Water raised 25 feet.

Diameter of piston = 5 inches.

Stroke of piston = 9 inches.

Number of lifts per minute = 40.

Quantity of water raised per lift = $\frac{25\pi}{4} \times 9 = 176.4$ cubic inches.

Useful effect = 50 per cent.

Quantity of water raised per minute = 2 cubic feet = 12.5 gallons.

Discharge per hour = 120 cubic feet = 750 gallons.

The load to be overcome in raising the piston

$$= 62.5 \frac{\pi (\frac{5}{12})^2}{4} \times 25 \times 1.08 = 230 \text{ pounds,}$$

where 1.08 is a co-efficient for the passive resistances, as the friction of the water itself in the pump, the retardation of the water in its passage to the pump by the suction valves, and the weight of these valves.

The pump is worked by a lever, in which the ratio of power and weight is = 1.3, and taking the modulus at .66, we get—

Required force to overcome the load = $\frac{230}{.66 \times 1.3} = 116$ pounds.

If four men are employed, each has a load of 29 pounds to overcome.

10. LIFT AND FORCE PUMP.

(Worked by four men, with relief.)

Water raised 40 feet.

Diameter of piston = 5 inches.

Stroke of piston = 9 inches.

Giving the piston an average velocity of 36 feet per minute, we get—

Number of back and forward strokes, or number of turns of the handle per minute = 24.

Therefore: Quantity of water raised at each turn of handle = $\frac{25\pi}{4} \times 9 \times 2 = 352.8$ cubic inches.

Useful effect = 60 per cent.

Discharge per minute = $352.8 \times 24 \times .60 = 5080.3$ cubic inches = 2.9 cubic feet = 18 gallons.

Discharge per hour = 174 cubic feet = 1080 gallons.

The load to be overcome in raising the piston is

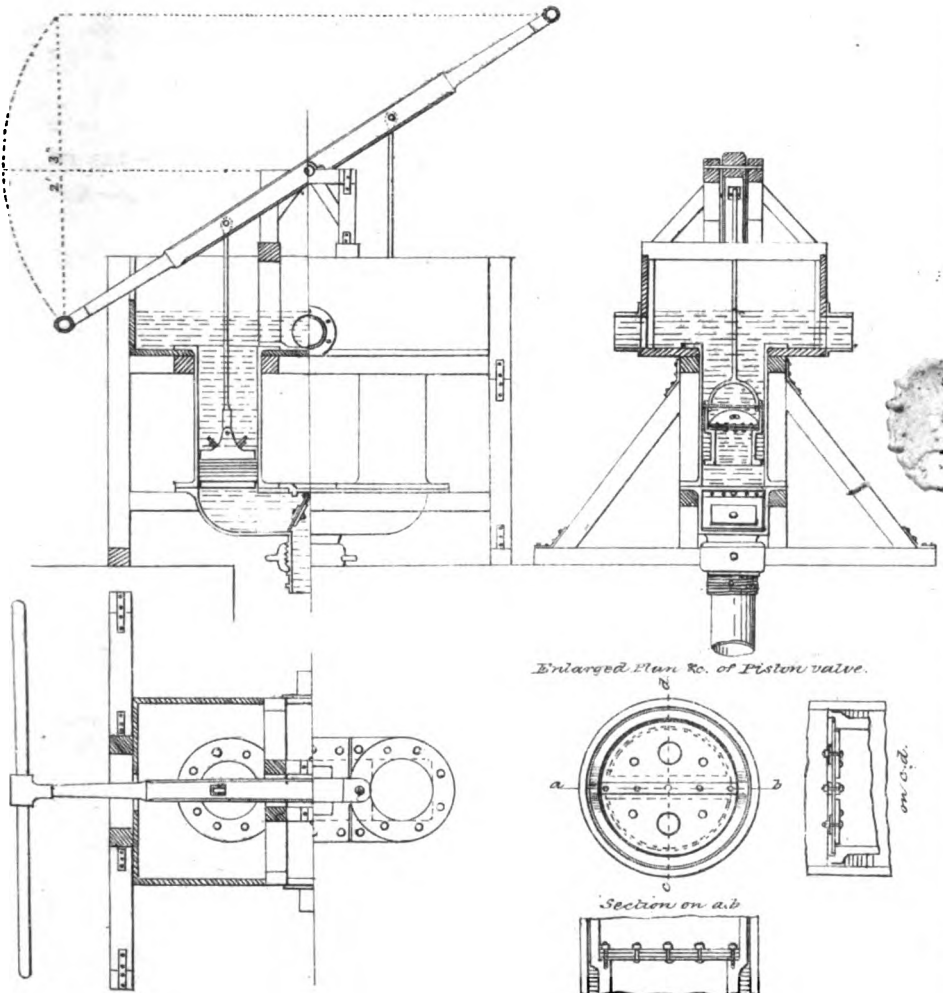
$$= 62.5 \frac{\pi (\frac{5}{12})^2}{4} \times 40 \times 1.08 = 368 \text{ pounds.}$$

The length of handle being 15 inches, the ratio of power and weight

MACHINES FOR RAISING WATER.

5 in.: Suction pump.

9 in.: stroke.

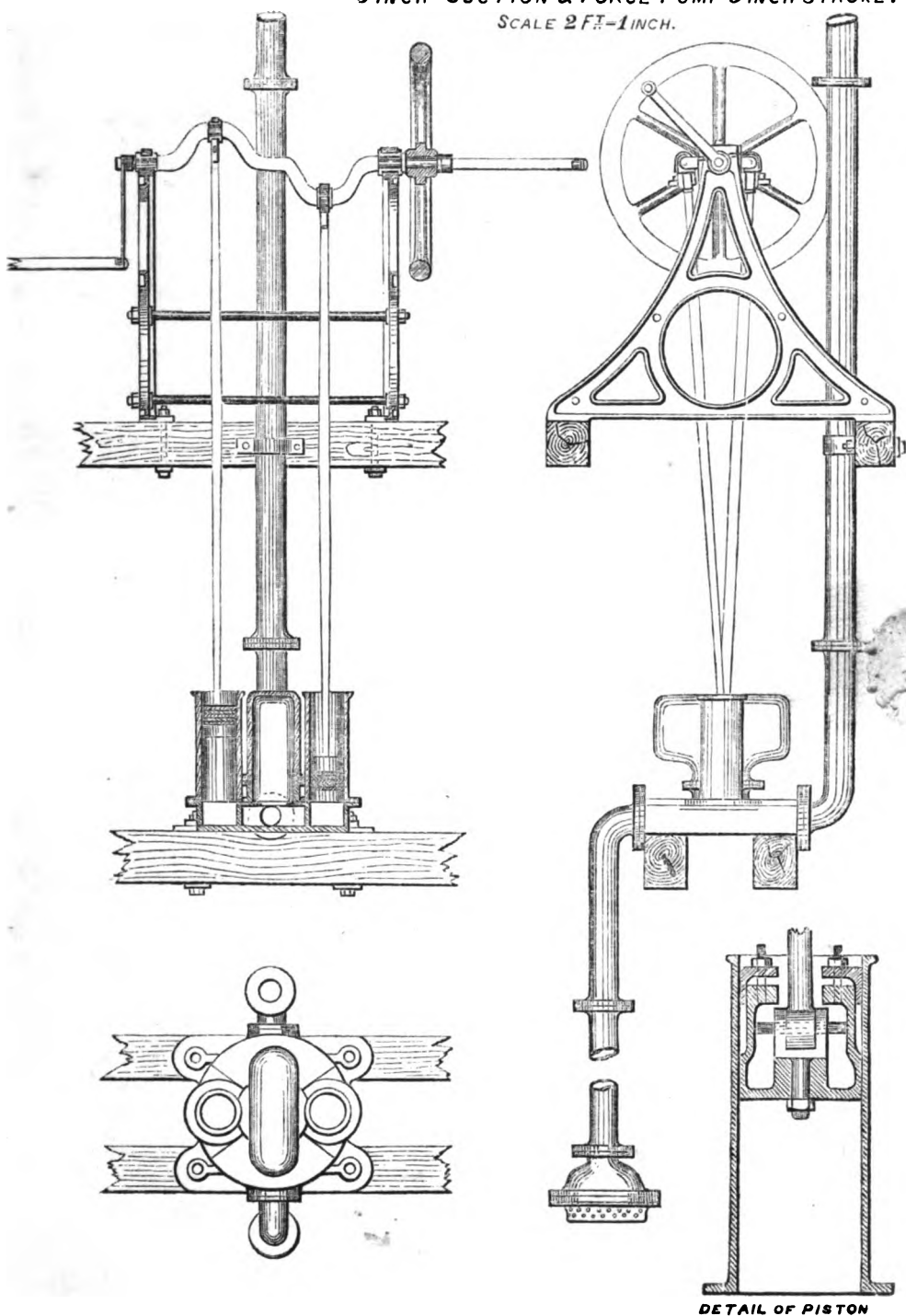


Enlarged Plan No. of Piston valve.

Section on a d.

Scale, $\frac{3}{4}$ in. = 1 foot.

5 INCH SUCTION & FORCE PUMP 9 INCH STROKE.
SCALE 2 FT = 1 INCH.



DETAIL OF PISTON

is = 1 : 5, and if the modulus be .66, we have—

Required force to overcome the load = $\frac{368}{.66 \times 5} = 112$ pounds.

If four men are employed, each has a load of 28 pounds to overcome.

11. STREAM WHEEL.

Water raised $5\frac{1}{2}$ feet.

Length of floats = 6 feet, and depth = 2 feet.

Number of floats = 10.

Number of buckets = 15.

Whole content of buckets = 5.6 cubic feet.

Mean surface velocity of stream = $2\frac{1}{2}$ feet per second.

Revolutions of wheel per minute = 2.45.

Velocity of wheel per second = 1.5 feet = $\frac{1}{4}$ ths of velocity of stream.

Dimensions of box with which the discharge was measured:—

Breadth = 18 inches,	} = content = 4.8 cubic feet.
Length = 22 inches,	
Depth = 21 inches,	

Mean time required to fill the box = 30 seconds.

Discharge per minute = 9.6 cubic feet = 60 gallons.

Discharge per hour = 576 cubic feet = 3,500 gallons.

Useful effect = 70 per cent.

Horse-power of wheel = .68.

The above calculation is from actual measurement.

12. WINDMILL APPLIED TO SUCTION PUMP.

Water raised 20 feet.

Assuming the velocity of the wind at 10 miles an hour, its velocity per minute will be = 879 feet.

The concentrated force of the wind acts at a distance of 4 feet from the top of the sails, or 11 feet from the centre, that is, at the centre of gravity of the triangular sails. Now, the velocity of the sails at this distance, whether unloaded or loaded, so as to produce the maximum effect, should be nearly as great as the velocity of the wind say $\frac{1}{4}$ ths, and we get therefore :

Velocity of sails per minute = $\frac{1}{4} \times 879 = 769$ feet.

Number of turns of wind shaft per minute = $\frac{769}{22\pi} = 11$.

There are two pumps of 10 inches diameter each, and the stroke is made to vary with the strength of the wind from 6 to 8, 10 and 12, inches, and taking 12 inches as the suitable stroke for the abovementioned velocity of the wind, and the useful effect of the pump at 60 per cent., we get:

$$\begin{aligned}\text{Discharge at each turn of shaft} &= \frac{10^3\pi}{4} \times 12 \times 2 \times .60 \\ &= 1180 \text{ cubic inches.}\end{aligned}$$

$$\begin{aligned}\text{Discharge per minute} &= 1180 \times 11 = 12,430 \text{ cubic inches.} \\ &= 8.8 \text{ cubic feet} = 51.8 \text{ gallons.}\end{aligned}$$

$$\text{Discharge per hour} = 498 \text{ cubic feet} = 3,108 \text{ gallons.}$$

Number of arms = 8, and their length = 15 feet each, the sails extend from the tip of the arm 12 feet towards the centre, and their length at the top is = 6 feet 8 inches.

The force of the wind with the abovementioned velocity is = 492 pounds per square foot, and assuming the effective area of the sails at 300 square feet, the total force acting upon the mill will be = 147.6 pounds, if the wind is perpendicular to the surface of the sails.

Space passed through by this force at one revolution = 22π feet.

Space passed through by the piston at one revolution = 2 feet.

Therefore: Ratio of power and weight = 1 : 34.5, and taking the modulus at .5, we get—

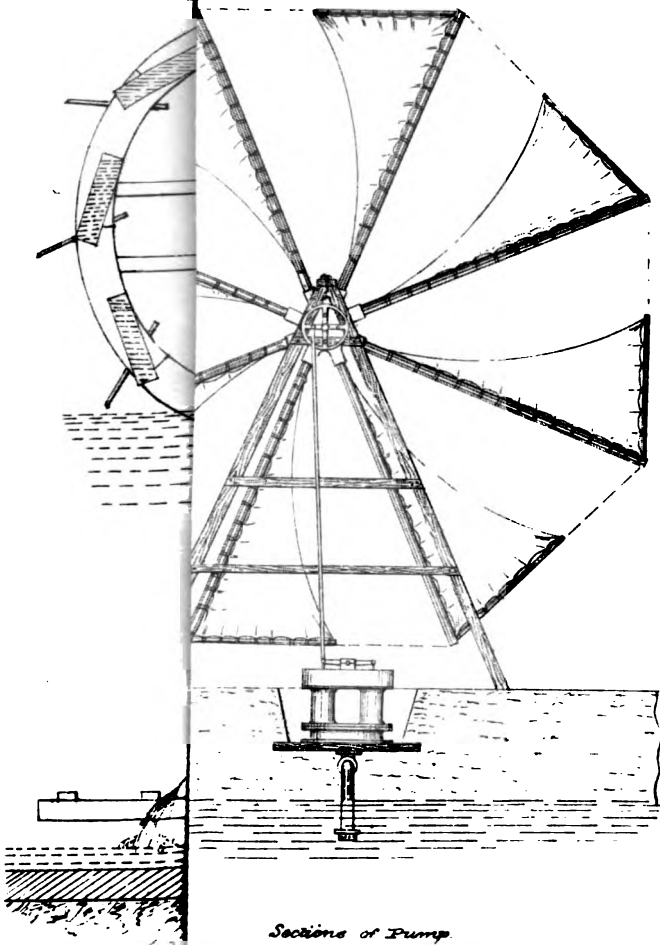
$$\begin{aligned}\text{The load to be overcome in raising the piston} &= \frac{62.5 \times (\frac{\pi}{4})^2 \times 20 \times 1.08}{4 \times .5} \\ &= 1,458 \text{ pounds.}\end{aligned}$$

The required force to overcome this load is only $= \frac{1,458}{34.5} = 42.2$ pounds, which is equivalent to an impulse of .14 pounds per square foot, and is in accordance with a velocity of the wind of about 5 miles per hour, from which it follows that the mill will not begin to turn until the wind reached nearly a velocity of 5 miles per hour. Should it be desirable to let the mill work with a lesser velocity, it is necessary to reduce the stroke of the pump accordingly.

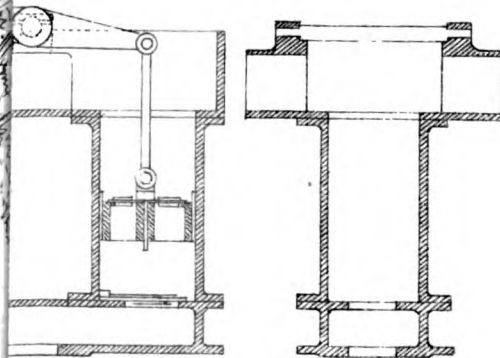
With the velocity of 10 miles per hour, which we assumed in this case, the mill is able to overcome a load of $34.5 \times 147.6 = 5,092$ pounds, or more than three times the requisite one, which is to be accounted for by the fact that the impulse of the wind increases as the square of the velocity.

will applied to 10" suction pump.

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



Sections of Pump



Scale = $\frac{1}{20th}$.

TABLE SHOWING THE COMPARATIVE PERFORMANCE AND COST OF THE ABOVE MACHINES IN RAISING

WATER TO THE SAME HEIGHT (40 FEET.)

The expense of a laborer is put down at 2 annas and of a bullock at 4 annas per diem. Duration of work per diem = 8 hours.

No.	Methods.	Stages.	Useful effect per cent.	Discharge per hour.		Discharge per diem.		Daily employ.		Daily expense in Annas.		Quantity of water raised for one rupee.		Remarks.
				Cubic feet.	Gallons.	Cubic feet.	Gallons.	Men.	Horses.	Annas.	Annas.	Cubic feet.	Gallons.	
6	Windlass and bucket, .	10	50	8.4	52.2	67.2	471.6	2	...	4	268.8	1670.4		{ Discharge increased with decrease of height.
7	Dall,	8	70	73	456	584	1840	4	...	8	1168	3680		Ditto.
8	Double Persian Wheel, .	1	60	198	1242	1704	9936	1	2	10	2534.4	15897.6		{ Discharge the same at any height.
9	Suction Pump, . . .	1.6	50	75	468.7	600	3748	8	...	16	600	3748		{ Discharge the same from 1 to 25 feet height.
10	Lift and Force Pump, .	1	60	174	1080	1392	8640	8	...	16	1392	8640		{ Discharge the same at any height.
11	Stream Wheel, . . .	7.27	70	79.2	496	633.6	3960	2	Water.					
12	Windmill applied to Suction pump, }	2	60	249	1554	1992	12432	8.9	Wind.					

The cost and wear of the machines are not taken into consideration.

No. 1, or the Beam and Bucket, is taken as unit for the ratio of discharge.

J. WEBSTER.

NOTE BY EDITOR.

By a comparison of the Tabular Statements in this and the last No. (II.) and omitting the last two machines of which the motive power is a variable and uncertain quantity, it will be seen that the Double Persian Wheel is the most effective as well as the most economical of any in the list. These wheels may be seen at work at Lahore, and a small working model was exhibited at the Roorkee Agricultural Show; as well as models of the Windlass and Bucket, and the Dall. The latter excited much attention from its extreme simplicity and ought to answer well for short lifts.

The drawings and calculations for the two pumps are merely given for the sake of comparison. By employing horse or bullock gear to either, the power of course will be considerably increased, but it is doubtful whether any form of valve-pump, would be so effective and reliable for *continuous working* as the endless chain of buckets or the Persian Wheel, and up to a depth not exceeding 100 feet. Beyond that depth the gearing is cumbersome and heavy in proportion to the weight lifted.

Full sized specimens of Nos. 11 and 12 were also exhibited at the Roorkee Show and excited much interest. The Stream Wheel is merely the old Chinese wheel raising water from a running stream by its own force; and therefore self acting, costing nothing when once up, and not likely to get out of repair if protected from collision with boats, &c. It can, however, only be effectively employed in a stream running with some velocity and wide enough for the wheel not to interfere with navigation, but its simplicity and economy recommend it where the other conditions are favourable. The wheel exhibited was 10 feet in diameter and cost Rs. 200, but ought to be built entirely of iron at a less price than that.

The Windmill was made at the Roorkee Workshops for the purpose of raising water for filling a swimming bath at Meerut, and seems likely to answer well. Considering the cheapness of the motive power and that the wind blows steadily nearly all the year from one quarter or another in the Upper Provinces, it is curious that so little use is made of it as a prime mover. A few desultory attempts have I believe been made, but not properly persevered with.

If any correspondents will furnish descriptions and calculations similar to the above for any other water-raising machines used in other parts of India, I shall be glad to publish them.

J. G. M.

No. XXIX.

N. W. PROVINCES IRRIGATION REPORT, 1861-62.

*[The following is an Abstract of the Revenue Report, prepared by the
Irrigation Department for 1861-62, but only just printed.]*

The totals of the Canal Revenues for the past year were as follow:—

North Western Provinces	{	Ganges Canal,	Rs. 7,05,800 9 8	
		Eastern Jumna Canal,	" 2,50,581 11 1	
		Doon Canals,	" 16,011 4 8	
		Rohilcund Canals,	" 35,538 6 9	
		Agra Irrigation Works,	" 12,698 9 0	10,20,575 8 9
			<hr/>	
Punjab.	{	Western Jumna Canals,	" 4,06,968 15 6	
		Delhi and Goergaon Irrigation Works,	" 18,790 0 0	4,22,758 15 6
				<hr/>
Grand Total, Rupees,				14,43,334 8 3

The total cost of maintenance and repairs for the same period was—

North Western Provinces.	{	Ganges Canal,	Rs. 4,79,161 2 8	
		Eastern Jumna Canal,	" 1,03,889 6 7	
		Doon Canals,	" 22,543 2 10	
		Rohilcund Canals,	" 25,488 5 2	
		Agra Irrigation Works,	" 11,589 4 0	6,42,171 5 3
			<hr/>	
Punjab.	{	Western Jumna Canals,	" 2,13,577 11 2	
		Delhi and Goorgaon Irrigation Works,	" 1,962 12 2	2,15,540 7 4
		<hr/>		<hr/>
Grand Total, Rupees,				8,57,711 12 7

From the foregoing we find that the balance at credit of Receipts over Expenditure for the works of Irrigation in the North West Provinces, amounted to Rupees 378,711-3-6, and including the Punjab works, to Rupees 585,404-11-8.

GANGES CANAL.

The subjoined details exhibit in a brief form, some useful information, regarding the present state of the Ganges Canal.

Length of main Canal and two terminal divisions,	Miles	520
Length of Futtehghurh branch (in progress),	"	83
Length of Boolundshuhur branch, including right and left branches, (in progress),	"	46
Length of completed rajbuhas to 30th April, 1862,	"	1,921
Number of villages which received the benefits of irrigation, ...	No.	3,982
Area of land irrigated,	square miles,	581
Cost of main Canal, including the two terminal divisions, up to 30th April, 1862,	Ra.	1,60,58,185 9 1
Cost of Futtehghurh, Boolundshuhur, and Koel branches, up to 30th April, 1862,	"	6,86,818 2 3
Cost of rajbuhas up to 30th April, 1862,	"	27,95,270 2 9
Total cost of Ganges Canal up to 30th April, 1862, ..		1,95,39,728 14 1
Value of crops produced by Canal during 1861-62,		1,22,46,875 18 11
Cost of maintenance and repairs,	"	4,79,161 2 8
Amount of revenue,	"	7,05,800 9 3

Deducting the cost of maintenance and repairs from the amount of revenue, it will be observed, that a balance of Rupees 2,26,639 appears, or a surplus nearly equal in amount to that of last year, when for the first time, the Ganges Canal paid its own expenses of establishment and repairs, and yielded a money return to the Government.

It is gratifying then to note that the surplus of the present year is as great as that of its predecessor, and that the Canal revenue, to which an unnatural stimulus was given in 1860-61, still indicates progressive improvement.

In the *Northern Division*, as must always occur, the most work has been done; as here are situated the most important engineering works on the Canal, which require constant and careful supervision and necessitate extensive repairs; these works had to undergo a very severe

trial owing to the heavy rainy season. The bunds which are annually thrown across the Ganges at the close of the rains in order to ensure a full supply to the Canal, are situate in this division, and are works of considerable magnitude; the principal of these bunds was breached on the 17th May, an unusually early date, in consequence of the almost unprecedented early commencement of the rainy season; this led to an immediate fall in the Canal supply, and on the 20th June, the total rupture of the bund took place; owing, however, to the precautions taken in strengthening the bund across the Hurdwar channel, the supply required was maintained without inconvenience.

The boulder bunds or temporary weirs constructed at the head of the Canal to admit of the supply being sent down, were four in number.

- No. 1.—Bund across the Neel-Dharra channel of the Ganges.
- „ 2.—Beemgoda Bund, across the main branch of the Ganges.
- „ 3.—Beemgoda Bund in rear of above.
- „ 4.—Bund across the Hurdwar channel.

The work in these bunds is commenced with triangular cribs or boxes made of young *sál* trees, measuring from 18 to 20 feet in length. These cribs are floated to the site of the bund, loaded with boulders and sunk to the bed of the river; the bund is then formed by filling the boxes with boulders, its face being protected with small stone and gravel, and the whole covered with thick grass mats, to reduce the leakage as much as possible.

The protective works in both the Puttree and Ranipoor Baos, have, notwithstanding the severity of the floods, stood their test well. Mr. Login states that in consequence of the approach of the latter on to the superpassage in an oblique direction, he constructed spurs similar to those at the Puttree, which turned its course perpendicularly to the Canal.

Regarding the effect of the spurs in both of these rivers, Mr. Login observes that the fan of sand which has from year to year extended itself down the Puttree valley, has at last reached the works, and there is now 18 inches of sand on the flooring of the superpassage, while on that of the Ranipoor the sand is 7 feet deep; below the Puttree works, the Canal is in pretty good order, though the bed has considerably deepened.

Mr. Login also remarks that the River Rutmoo has silted up considerably above the Canal, while below it, the retrogression of bed

level is in progress, and as the crib-work at the tail of the Dhunowri dam is becoming decayed, he considers that it should be replaced by boulder masonry.

Mr. Login has lately adopted the plan of never entirely closing the Dhunowri regulating bridge during high floods, but of always keeping up a 3-foot supply in the Canal, which he considers will operate beneficially not only in saving the revetment walls of the Solani aqueduct from unequal and changing pressures, but in restoring the bed of the earthen aqueduct to its proper level by the deposits of silt, held in suspension by the flood waters, and also in keeping up a somewhat uniform supply in the Canal during the rains.

The *Upper Central Division*, commences at Jaoli, and extends from the 51st to the 84th mile of the main Canal. The head of the Futtehghurh branch is likewise situated at Jaoli, and the works on the branch, together with those in the Upper Central Division of the Canal, were superintended to the close of the official year 1861-62, by the same Officer.

The Futtehghurh branch is in course of excavation down to its 83rd mile; the first 40 miles were excavated previous to the mutiny, and the masonry works completed at the same time; another portion, 20 miles in length was also commenced, and work was in progress when it was suspended by the mutiny in 1857; but, it has since been completed. The remaining 23 miles were commenced last year as a famine relief work, and are nearly excavated, so that we may consider the excavation as far as the 83rd mile to be complete.

Two escape channels have been designed for the branch; one at Shajehanpoor and the other at its terminus, near Makhena, at the 83rd mile; the head of the Shajehanpoor escape is nearly complete, and the channel has been excavated, but the Makhena escape has not yet been commenced.

The total increase of revenue in this division is satisfactory and creditable to Mr. Parker; the increase in the khureef is very large indeed, and so would in all probability have been that of the rubbee, had it not been for the constant presence of clouds, and the generally damp season, which led the Zemindars to expect a plentiful fall of rain, and therefore induced them to put off as much as possible the irrigation of their fields.

In the *Lower Central Division* also, the abundant rainy season was unfavorable to the prospects of the Canal; not only was a large kharif crop secured without the use of artificial irrigation, but the ground was left in such a moist state from the plentiful rainfall, that the Zemindars were enabled to plough and sow without further waterings. In spite, however, of circumstances so adverse to Canal interests, it is gratifying to observe that the revenue has shown favorably in comparison with that of the preceding year, which being one of drought and famine, might be supposed to have been exceptionally high. Ensign Willcocks, the Superintendent of this Division, also remarks on the very large and steady increase of the better description of crops, such as sugar-cane and indigo, both of which were almost unknown in this part of the country until the Canal afforded means for their cultivation; he also observes that, "when I first joined the Ganges Canal I certainly took a gloomy view of its prospects; but now I am as sanguine of its prosperity, as those who have had a much longer experience of it than I have had, and I look forward to an early date, when my own division will return, in ordinary seasons, from 3 to 3½ lacs of rupees;" this remark from an Officer of such experience in the Irrigation Department is most valuable.

In order to illustrate the amount of benefit derived by the country from the construction of the Canal, in allowing of the cultivation of the more valuable description of crops, Ensign Willcocks states, that to his knowledge 10 beegahs of sugar-cane were sold in one village for 960 rupees, and he observes that the Meerut district appears peculiarly favorable to this cultivation. Ensign Willcocks also remarks upon the great number of indigo factories, which are being constructed in all directions in the Boolundshuhur and Allyghur districts, and in fact, wherever Canal irrigation gives a fair promise of success.

Cawnpore Division.—The revenue in this division has made a very satisfactory advance in spite of the abundant rainy season, which is the more gratifying as it has been principally made in rajbuhas already in existence, and is not much due to the opening out of new lines.

During the year a syphon has been constructed under the Canal, near the village of Manawa, to provide for the surface drainage of the country. The work was executed under considerable difficulties on account of the depth at which it was necessary to carry the foundation

below the Canal bed, and with a full supply running within a few feet of its site.

The want of a dock at Cawnpore, has for some time past been much felt, as the channel there is very contracted, and the numerous boats which ply up and down the Canal, are laden and unladen along its banks; the work has been commenced this year.

A water-course for the memorial garden at Cawnpore, has also been commenced under the orders of His Honor the Lieutenant Governor, North Western Provinces. This will greatly improve the garden, and by flushing the drains in the city itself, tend much to the comfort and cleanliness of the townspeople.

Mr Anderson brings to notice the large annual expenditure on silt clearance in this division. During 1861-62, the silt taken out from his rajbuhas amounted to no less than 120 lacs of cubic feet, at a cost of 18,500 Rs. The silt is, however, peculiarly valuable for strengthening the banks, where the rajbuhas run, as they do chiefly, through Oosur land, in this division.

Etawah Division.—The increase of irrigation amounting to 50 per cent. in excess of that of the previous year, is very satisfactory, and the more so as it has been almost entirely obtained from old standing lines of irrigation, no new ones having been opened till nearly the end of the year, and then, not in time to afford much aid to the country. This branch as also that of Cawnpore compare very disadvantageously with the remainder of the Canal, as owing to the unfinished state of their rajbuhas, they are unable to utilize the supply to which they are entitled, though at the same time, they require their full supply in order to obtain the necessary level of water surface to admit of free irrigation; the consequence is that the water is necessarily thrown away at points where the Canal contracts in width, and escape channels are situate; this state of things however it is hoped will shortly be remedied, as every endeavour is being made to complete the rajbuha channels, many of them being actually in course of construction, and others, under survey and examination.

The length of this division is 170 miles, in addition to that of completed rajbuhas of 311 miles. Excavation at the tail of this branch has been in progress during the year, but the terminal masonry works have not yet been commenced.

Boolundshukur Branch.—The construction of this line, of which the first 6 miles were excavated before the Ganges Canal was opened, was sanctioned by the Government N. W. Provinces, early in the year 1861, and formed one of the works specially undertaken during the recent famine, for the relief of the starving population of the Provinces.

After a brief but careful survey of the country lying beyond the already completed portion of the branch, employment was given during the month of March, 1861, to the famine stricken people, who were sent from the neighbouring districts in great numbers, by putting them on the prolongation of the original work. Those who were too weak to excavate, were employed on light work, as repairing banks, clearing jungle, &c.; but after a time, these weakly gangs diminished rapidly. The nature of the soil, however, in which the several parties worked was such, that the rates, which were occasionally high, were affected far more by it, than by the physical condition of the people, which was generally good and certainly improved with the progress of the work.

EASTERN JUMNA CANAL.

The total revenue for the year (given in detail below) amounted to Rupees 2,50,531·65, and the total cost of maintenance for the same period to Rupees 1,03,389·41, leaving a balance of income for the year of Rupees 1,47,142·24.

An average of areas of the several kinds of crops irrigated taken from the returns of the past four years may be interesting.

Nature of Crops.	Average, acres.	Per Centage.
Sugar-cane,	26,341·90	12·05
Rice,	38,182·79	17·45
Indian Corn,	8,295·29	3·80
Wheat and Oats,	97,915·98	44·82
Inferior Grains,	33,971·36	15·54
Cotton,	5,750·31	2·63
Indigo,	508·57	0·23
Orchards and Gardens,	4,218·16	1·93
Grasses,	856·48	0·39
Insufficiently Irrigated,	2,542·63	1·16
Totals,	2,18,533·47	100·00

Feeling the desirability of obtaining reliable data for estimating areas irrigable per cubic foot, per second, in each Fussil, Major Brownlow has given the mean discharge of Canal, and areas irrigated in each Fussil, and during the whole year for the last four years, and from the averages obtained, he thinks we are fully justified in assuming 70 acres as the area irrigable during the *khureef*, 130 acres during the *rubbee*, and 200 acres during the whole year, per cubic foot, per second. The mean discharges have been most carefully calculated, and the slight discrepancies observable in the final results arise from the utter impossibility of exactly separating the periods of *khureef* and *rubbee* irrigation.

	Khurreef.	Rubbee.	Whole year.
Mean discharge of Canal,	1,212.50	938.50	1,061.25
Areas irrigated,	86,180.46	1,32,353.01	2,18,533.47
Acres irrigated,	71.05	140.04	205.93

Major Brownlow says—"A comparison of results obtained from the data given above with those furnished by Colonel Rundall, Madras Engineers, in a late letter to Government, will show that the Irrigation Works of the North Western Provinces will bear a comparison with those of Madras. The total cost of construction of this Canal up to commencement of current year, amounted in round numbers to Rs. 14,13,500. The maximum area hitherto irrigated is 2,60,000 acres. The average area of the past four years is 2,18,533 acres; the average water-rate for the same period being Rs. 2,27,835. The average annual cost of establishment is Rs. 52,000; of repairs 44,000. Total, 96,000. From these we deduce the cost of construction as Rs. 5.4 per acre of maximum, and Rs. 6.5 per acre of average area irrigated during the past four years, while the maintenance and establishment amount, to 7 annas per acre of average area. The Madras rates, given by Colonel Rundall, are, respectively, Rs. 6 and 8.3 per acre as cost of construction, and 6.6 annas per acre as cost of maintenance. Colonel Rundall gives the Madras cost of maintenance, repairs, and establishment as 7 per cent. on first cost of construction, ours

amounts to 6·8 per cent. The Madras per centage of maintenance on water-rate is 14, (2,50,000, on a total water-rate of 18,00,000,) ours is 42; but it must be remembered that the Madras water-rate per acre is just treble ours (being Rs. 3, while our average is only 1·04 per acre); and that reduced to our standard of charge, their per centage of maintenance on water-rate would be just equal to ours. Colonel Rundall appears to think that no fair comparison can be instituted between the Irrigation Works of the North Western Provinces and of the Madras Deltas, as the latter not only afford irrigation, but combine therewith a system of river embankments for protection from floods, drainage channels, and navigation Canals. But if these works were absolutely necessary and primarily intended for the completion of the irrigation system, the fact of their sub-serving other purposes does not invalidate the comparison between them and our own, as far as irrigation results are alone concerned; although, of course, it adds largely to the indirect value of the Madras Works."

The floods during the past rainy season have been unusually heavy. The Khara and Fyzabad Heads have been blocked up more than usual with shingle and boulders; at the latter not a trace remains of a large and deep channel, through which the main supply of Canal was drawn. The Khara Head fared somewhat better, and by the aid of spurs afforded the full supply required. The rapid in the main Jumna, just below the mouth of the Khara head channel, has retrograded considerably, and the crest of it will in a few years pass the head, rendering a deepening of its channel necessary.

The Fyzabad dam flooring has been much scored and cut up, but on the whole the work has escaped very well. A couple of gates and some planks were washed away by the floods, and the apparatus was somewhat injured.

The Nyashuhur weir suffered most severely, having been cut through at short intervals along the whole of its length, and the brick-on-edge facing has been torn off by the boulders and trunks of trees that scraped over it during the rains. The section of this weir is very slight considering the heavy and constant floods to which it is exposed, and at some future date it should certainly be strengthened. The apparatus of sluices and regulators suffered considerable injury, and the spur separating the Bhoodee Jumna from the sluice channel, was

entirely carried away during the tremendous floods that came down between the 18th and 20th July, and 8th and 10th of August. The first topped the roadway of the sluices, carrying away the railings fixed along the sides of it, and measured seven feet in depth on the weir sill. The second buried all the masonry works at the place, except the Regulating bridge, under water, for some hours, smashed one of the gates, and was within a very little of forcing its way into the Canal. To prevent the recurrence of such a catastrophe, an estimate for a new regulating bridge was submitted and sanctioned by Government, and the foundations and floorings laid by the end of April, 1862.

Major Brownlow thus explains how the money goes on repairs of torrent works; in three months, he had on nine several occasions, really heavy and dangerous floods raging simultaneously over every dam and weir in the Northern division, none of them discharging less than 10,000 cubic feet per second, and many of the Jumna floods ranging up to treble and quadruple that volume. In the above statement no account is taken of ordinary light floods with discharges of 4,000 and 5,000 cubic feet per second, which quantity of water passes pretty steadily over the Nyashuhur weir during the entire rainy season.

The expenditure incurred in restoring the head works of the Eastern Jumna Canal, enumerated in the foregoing paragraph, and keeping the other masonry works together with the Canal banks and roadway in an efficient state of repair, amounted during the year to no less than Rs. 44,122-6-10.

Lastly, operations have been carried on in the Sultanpore swamp. Drainage cuts were steadily pushed on through the heart of the old swamp for an aggregate length of six and a-half miles, while lateral cuts were excavated from the main channel tapping the worst parts of it, and leaving but a very small portion unculturable.

These drainage operations I am happy to say have been eminently successful. At the close of the last rainy season, luxuriant rice was growing in places where four feet of water used to stand all the year round, and land that formerly would not even produce rice was being broken up for wheat.

The financial state of this Canal is fast approaching to a most satisfactory one. At the close of last year the balance of the charges over the income amounted to Rs 1,28,740-6-1, and this sum has been re-

duced during the present year to 52,278-4-4, the expenditure being for the current year 1,08,889-6-7 including all charges; against a revenue of 2,50,531-11-1, shewing a rate of profit for the year upon the capital, viz., of 14,20,720 of 10·3 per cent. Next year it is hoped that the balance of charges over the income will be very small, and that at the close of the following year the balance of the income will exceed that of the charges, i. e., the Canal will have paid up the whole cost of maintenance and repairs, plus five per cent. interest on the capital into the Government Treasury, and leave a balance in hand at the credit of Government.

DOON CANALS.

The peculiar circumstances attending the Doon Canals, inasmuch as they are meant to supply water not only for irrigation but for drinking purposes, when it could not be obtained by any other means, have been dwelt on before, and Mr. Forrest remarks thus on their peculiarity of construction—"There are also peculiarities in their construction which it may be needful to point out as bearing on their heavy original cost and heavy charges for repairs afterwards, and the fluctuations in the revenue from them. With a small section and carrying but a small quantity of water, they have heavy and dangerous works on them, arising from the nature of the country in which they are constructed. They have to wind round hill sides, pass over wide and deep ravines, and cross rapid mountain torrents. The Beejapoor water-course runs for a long distance along the face of a perpendicular cliff, the channel being partially let into the living rock. The Kutta Putthur Canal is exposed for half a mile to the direct attacks of the Jumna river, immediately on its rush forth from the Himalayas, has then to cross a dangerous hill drainage line; its masonry channel runs for three miles along the edge of an almost perpendicular bank, exposed in many parts to the attacks of water below, and it crosses deep and wide ravines, by means of three arches of 50 feet span each, two of 80 feet span, and long embankments. Towards its tail it has an embanked channel, in some places 20 feet high, more than 1,000 feet in length, in which are four aqueducts, one of which has two openings of 50 feet span each. The Kallunga Canal has on a very short space of its length three aqueducts of 30 feet span each, and one of 50 feet span.

The water crossing the latter, runs 80 feet above the bed of the stream below." Colonel Morton, in his Report for 1858-59, described these works as "of gigantic size, compared with the capacity of the channel. The masonry channel of the Jakhun Canal winds four miles round a hill side, and in many places seems to hang in the air 500 feet above the bed of the river below. All these works are subject to the attacks of the mountain torrents running down slopes of 8 feet or 4 feet per 100 feet, and swollen by showers of rain, which throw down 5 or 6 inches in as many hours. By all the points of attack being gradually discovered and guarded against, and works of bad construction being removed, the works are in time rendered perfectly safe, though constant vigilance and instant repairs are always necessary. There has not been a day's interruption in the supply of the Beejapoor Canal for the past five years. And in time, all the Canals will come to that, but in the meanwhile they have to bear heavy expenses and the Revenue meets with unexpected checks."

THE FOLLOWING IS THE ABSTRACT OF INCOME AND EXPENDITURE FOR THE YEAR.

	Expenditure.	Income.	Profit.	Loss.
Beejapoor,	8,846 1 9	7,056 5 1	3,210 3 4	..
Rajpooor,	5,107 0 10	6,712 15 11	1,605 15 1	..
Kutta Putthur, ..	8,389 8 8	1,503 3 5	..	6,886 5 3
Kallunga,	5,200 7 7	788 12 3	..	4,461 11 4
Total, ..	22,543 2 10	16,011 4 8	4,816 2 5	11,848 0 7
Net Loss, ..	..	..	..	6,581 14 2

Two water-courses are therefore unproductive, and their unproductiveness eats up the productiveness of the others. But the Kallunga Canal is only just beginning to irrigate, and the Kutta Putthur Canal, after a long period of unproductiveness, is rapidly and steadily increasing its revenue, doubling it each year, for some three or four years back, so that there is every reason to hope that it will not be long ere this excess of expenditure over income will be caught up, and the balance be in favor of the latter. As both the Kutta Putthur

Canal and the Kallunga Canal, discharge more water than the Beeja-poor Canal, the revenue from them ought at least to equal that from the latter, and that being the case the total revenue would amount to nearly 80,000 rupees, and the balance of income over expenditure be a large one. The above then, the works constructed being taken as stock in hand, equal to the capital sunk, is the charge of the Doon Canals to the Government. The indirect advantages of these Canals to the people and to the Government have been sufficiently dwelt on before.

Mr. Forrest notices a striking instance of the indirect advantage to the Government from these works of irrigation on the Jakhun Canal; he says, "the masonry channels having now reached to the edge of the forest lands, numerous applications have been sent in for the purchase of the latter. Looking at the map of these lands, it will be observed how often is marked, 'site of village,' such site being only now distinguished by a group of mangoes trees and grass grown tanks. The former settlers could not provide drinking water for themselves, or their cattle, and gave up the ineffectual struggle to redeem the wilderness."

In my Report for last year, I mentioned the large increase that had taken place in the irrigation and revenue owing to the failure of rain during the famine year. The return for the rubbee of 1860-61 was nearly $2\frac{1}{2}$ times more on the Boejapore Canal, twice as much on the Rajpore Canal, and $4\frac{1}{2}$ times as much on the Kutta Putthur Canal, as in the corresponding season of 1859-60. It is interesting to remark that though the famine year has passed away, the revenue it called forth has not fallen back. It ever seems to be the case on these occasions, that the people being forced into taking water by the pressure of the season, find its benefits and continue to take it. The following table shews at once that a permanent impetus was given in 1860-61 to the Canal revenue.

1859-60,	..	..	..	..	Rs. 12,808 0 8
1860-61,	..	..	..	..	„ 14,923 4 7
1861-62,	..	..	..	..	„ 16,011 4 8

The above facts point to the increasing prosperity of the Doon Settlement.

ROHILKUND CANALS.

The irrigation works in Rohilkund, under the direct control of this Department, are confined to four rivers, viz., the Kylas, East Bygool, Kitcha and Dhora, and Paha, from which the Rohilkund canals or water-courses derive their names.

Kylas Canal.—This canal is only in course of construction, and is not yet available for irrigation; its head is situated near the village of Byranee, about six miles above the junction of the Deoha with the Kylas, where a masonry dam having 15 openings of 9 feet each, has been constructed across the latter river; this dam is built on the ordinary plan, having piers eight feet in height, the openings between them being fitted with gates and planks; the foundations have been sunk to a depth of 18 feet, and its flooring is on a level with the river's bed. On the right flank the canal is taken off by a masonry head of two openings 8 feet each, the floor being raised 2 feet above that of the dam.

The Kylas canal has a bottom width of 15 feet, and is calculated to carry 150 cubic feet per second; it is nine miles in length, along the whole course of which excavation has been commenced and about one half completed. For the first seven miles the digging is very deep, varying from 12 to 20 feet in depth, and as the spring level of water is found at an average depth of 6 feet, considerable difficulty exists in carrying on the work.

At the village of Dhoondree, the main line divides into two, called the east and west branches; the former will be 15 miles in length, of which 11 have been excavated, with a bottom width of 8 feet; it runs along the watershed between the Upserria Nuddee and the Deoha, and is intended to irrigate the tract lying between these streams. The west branch is to be of the same width as the east, but reduced to 10 miles in length, and of this about 1 mile only has been excavated; it will cross the Upserria Nuddee, close to the village of Dhoondree by a masonry aqueduct, and run along the watershed between that stream and the Pungheelee Nuddee.

East Bygool Canal.—The construction of the east and west Gerem Branches, and the prolongation of those issuing from the Oogunpoor Partiteur, from the only new works on the East Bygool, and these

were undertaken to afford employment to the starving poor in Rohilkund.

The Gerem Branches are taken off from either flank of the Gerem dam, and have each a bottom width of 10 feet at their heads, gradually decreasing to 6 feet, with a discharge of 40 cubic feet per second. The east branch will be $8\frac{1}{2}$ miles in length, of which about three-fourths are out of hand, and the west 10 miles, which are quite complete. The upper 5 miles of the west, and about $1\frac{1}{2}$ mile of the east branches, have however only been in operation during the past rubbee season.

The total area irrigated was 5,61,160 local Beeghas, or 1,40,290 standard Beeghas = 137 square miles. The total water-rate charged upon the above was Rupees 33,032-8-0, giving an average charge of 8 annas and nine pies per standard Beegah.

The income for the year 1861-62, was as follows:—

Water-rent,	Rs.	33,032	8	0
Sale of produce, sundry collections, &c., ..	,,	2,500	14	9
<hr/>				
Total Rupees,	,,	35,538	6	9

The working expenses amounted to Rupees 25,483-5-2, shewing a balance in favor of the income of Rupees 10,045-1-7, and giving a rate of profit for the year upon entire capital of 4·7 per cent.

[*A notice of the Agra Irrigation Works will appear in a future number.*]

NOTE BY EDITOR.

SEEMING that much uneasiness has been lately felt as to the state and prospects of the Ganges Canal, and that many have been even in a hurry to pronounce it a "failure," the data of the above report (the last one issued), cannot but be considered as very satisfactory. The returns for the past year, which are now being made up, are, I understand, still more favorable, shewing a return from water-rent of nearly 10 lakhs of rupees on this one Canal.

The fact is, (paradoxical as it may appear,) that it is the *complete success* of the work which has been the great difficulty of the Irrigation Officers. So rapidly and completely has the Canal become bound up with the agricultural prosperity of the Doab, that a few weeks' closure for the purpose of executing repairs, causes a loud outcry, and a serious loss both to Government and the people. Like most other great works, defects have been discovered in the original construction, which did not shew themselves at first when they could have easily been remedied, and the state of

some of the masonry works below Roorkee has become dangerous, not from error of design but from faulty construction. If the Canal could be closed for six months this could be easily remedied, but as that is to be avoided if possible, the work of repair has to be done bit by bit as it best can, and under circumstances which naturally cause much anxiety to all concerned.

It is difficult to avoid some reference to the controversy which, has now to a great extent, at least been made public, between Sir Arthur Cotton and Sir Proby Cautley, on the defects alleged by the former to exist in the original design of the Canal ; while the great weight justly attached to any opinion of General Cotton's on such a subject, and the difficulty of understanding the points at issue without maps and plans and elaborate explanations, makes it impossible to do full justice to either side of the argument in a short note. In a future number the whole controversy may perhaps be placed before the reader. It may suffice here to offer a few remarks on the two main points at issue :—1, The excessive slope of the bed. 2, The position of the head of the Canal.

As regards the 1st, it is called a minor objection by Sir Arthur Cotton, but is admitted by Sir Proby Cautley himself, to be the one great mistake he made. That the slope is too great for such a depth of water, and in such a soil, no engineer will now deny, but as the reduction of it would have necessitated double the present number of falls and locks, it would have amounted to a practical stoppage to Navigation, which General Cotton evidently considers to be as important as Irrigation.

As to the 2nd point, it is allowed on all sides, that no choice remained between that of the present site for the head, and that of a weir or series of weirs across the sandy bed of the Ganges lower down. That no objection exists on the part of the Canal Engineers to the employment of weirs, will appear from the fact that a project for a masonry weir across the Ganges at the present head (Hurdwar), was sent up more than two years ago, and is still before Government. But the bed of the river there is shingle, not sand, and weirs across sandy beds have no doubt been strongly objected to by engineers in Upper India, as works which however well adapted to a Delta are inapplicable to a Doab. A Delta is a tract of low alluvial country below the bifurcation of a river, whose bed is raised above the level of the surrounding ground from the deposits of silt thrown down. A dam of very small height across such a river, with cuttings through the lip of the channel on both sides, will evidently give great facilities for irrigation.

A Doab is a tract of high table land (the *Bangur*), between two rivers, which run in narrow beds (the *Khadir*), considerably depressed below the high land, from which indeed they are generally separated by a steep bank from 80 to 150 feet high. A weir across such a river must extend across the whole valley from 3 to 8 miles wide, and must either be of such a height as to flood the whole country above, and be altogether impracticable in construction ; or, if of a moderate height, the water can only reach the high land by long and *deep* cuttings, through a sandy subsoil and below the level of the springs, along the whole course of which surface irrigation would be impossible.

One other point may be noticed ; there is no system of irrigation extant in India, so far as I am aware, whether the Canal systems of the N. W. Provinces and the Punjab ; the Ancient system of Madras ; or, the Tank system of Central India, which is not simply an improvement on the old native system in use almost from time immemorial.

Doubtless, the improvement has been great, but the leading idea had been first seized upon by our native predecessors. If this be so, and as there are no remains of weirs across any of these rivers, it is, I think, strong presumptive evidence against their applicability to this part of the country. It is easy to say that the experiment should be made, but the experiment would prove nothing unless carried out on a grand scale, and at a vast expense, and if unsuccessful, the experimenter would be placed in a very unenviable position.—J. G. M.

No. XXX.

IRON SUSPENSION BRIDGE OVER THE BEOSI
RIVER, NEAR SAUGUR.

(Reprinted from the Journal of the Asiatic Society for 1833.)

WE take peculiar pleasure in bringing to the notice of our readers the completion of this work of art, because it has been constructed entirely out of the resources of the country, and being the first attempt at such an adaptation of native material and native workmanship, more than ordinary credit is due to the skilful Engineer who planned and executed it; and who, moreover, from his long residence in India, could have acquired only a theoretical acquaintance with the system of suspension bridges introduced within these few years, and now so rapidly spreading in Europe.

The bridge was erected at the suggestion of T. H. Maddock, Esq., agent to the Governor General in the Sagar and Nerbuda territories, upon the plans and under the sole superintendence of Major Duncan Presgrave, mint and assay-master at Sagar.

Engineers in Europe, accustomed to find everything provided to their wants, can have little idea of the personal labor which devolves upon their brethren of the craft in this country, where to the duties of architect and draughtsman are not only added those of builder and overseer, but the whole of the subordinate trades of the brick-maker, mason, carpenter, and iron-manufacturer; in a climate too where a trifling exertion produces exhaustion; and incautious exposure, fever or death; and where the tools must be made and the hands that employ them instructed *ab initio*. We will not say that the native mistrees and

laborers are not capable of learning or of working well, especially in Upper Hindustan ; the bridge before us is a sufficient refutation of that common and indolent remark : but all will agree that a peculiar talent is requisite to manage, instruct, and drill them ; and this faculty is possessed by Major Presgrave in an extraordinary degree. The secret of his influence may be easily traced—he is a workman himself : he wields the hammer ; makes and works the lathe ; surveys the ground ; searches the mines ; smelts the ore ; and has all the skill of contriving with the simplest means,* for which the people of this country are themselves so conspicuous.

The Sagar bridge may indeed be called an experiment to try the resources of the country—to see whether the iron could be manufactured into bars of a quality fit for bridges ;—and whether these bridges could be made by native workmen who had never wrought or even seen iron of the dimensions required. The question has been satisfactorily answered ; and even in point of economy, notwithstanding the numberless extra expenses incident to a first undertaking, and the distance, eleven miles, of the work from the yard at Sagar, the bridge has been pronounced cheaper than those in Calcutta made with English materials ; while of its design and execution no higher encomium can be given than the assurance of the visiting Engineer Major Irvine, that he had seen nothing superior to it in Europe. The Governor General is stated to have expressed equal satisfaction after inspection, and only to have regretted that so noble a bridge should be wasted upon so remote a locality !

We have with permission taken a reduced copy of the elevation and plan, lithographed by M. Tassin, to accompany a private Memoir of the Beosi bridge. The latter authentic source supplies us with the following particulars of the works.

The foundation was laid in April, 1828, and the roadway opened to the public in June, 1830.

The iron of which it is composed is entirely the produce of the Sagar district. When the bridge was projected, it was still in the state of ore in the mines, whence it was extracted, smelted, and made into irregular small lumps, in the common native fashion. The working of these

* As an illustration of this remark, we refer to the description of the rollers on which the chains rest.

crude impure masses into good bars of the requisite dimensions was a matter of very great labour and difficulty.

The bridge is 200 feet in span between the points of suspension.

The piers, resting on the solid rock, 6 feet under the low level of the river, are 42 feet high to the roadway; being elevated two feet above the ordinary surface of the country; they have a base of 32 feet by $22\frac{1}{2}$, decreasing upwards in front one in five, and on the sides one in eight feet, which gives on the road a superficies of 21 by 14 feet for each pier. On the sides are wing walls or abutments, running back into the bank 26 feet.

The pillars, or rather arches, of suspension, have a base of 21 by 12 feet, admitting a roadway of 9 feet broad. The arches are 15 feet high, and are faced with accurately wrought stone. The points of suspension are elevated 22 feet $4\frac{1}{2}$ inches from the road; the pillars have a total height of 33 feet, and the whole masonry from the rock, 68 feet. The piers and abutments contain 82,488 cubic feet of masonry; the arched standards and bridge parapets, 8,900; in all 91,388 cubic feet.

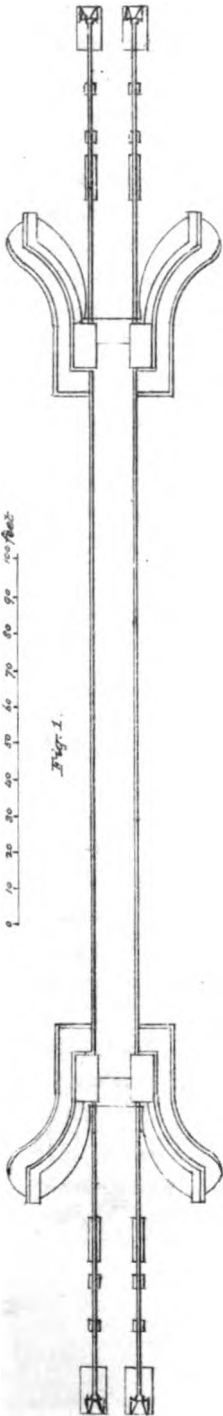
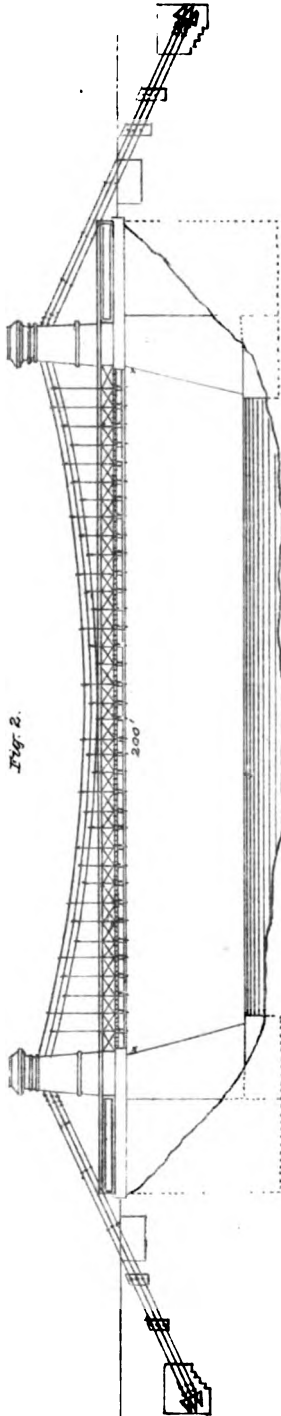
The platform measures 200 feet in length by 12 feet broad, and is calculated to weigh, with the chains, $52\frac{1}{2}$ tons. Supposing the bridge crowded with men, at 69lbs. per superficial foot all over the platform, the whole weight would be 120 tons, whence it is calculated that the tension to be sustained at each point of suspension would be 85·632 tons.

The suspending chains are 12 in number, arranged in pairs, three pairs on either side, 2 feet above one another. They pass over rollers one foot in diameter, and are securely moored in masonry 16 feet below the surface of the road. The back chains are 101 feet long, rising at an angle of 27 degrees. The angle of the catenarian at the roller is 16° with the horizon, the versed sine at the centre of the curve is 14 feet 3 inches.

The 12 main chains are of round bar iron, $1\frac{1}{2}$ inch diameter, bolted together in pairs. They are from 15 to 15·5 feet long, and so arranged that the vertical rods may fall from the joints of each chain alternately in parallel lines 5 feet apart. The descending chains are square bars measuring $1\frac{1}{2}$ inch on the side; their lower ends pass through 24 conically wrought stones, below which they are capped and keyed. (*Figs. 1 and 2.*)

SUSPENSION BRIDGE AT SAUGOR.

Over the Beas River.



The connecting links of the chains, and indeed all the bolt holes in the bars, and the drops, are bored out of the solid iron, and broached to fit the bolts accurately. (Figs. 5, 6.) None were punched at the forge. The bolts are $1\frac{1}{2}$ inch in diameter, and are secured by rings, or washers and keys. Two adjusting links with iron wedges are fitted to each chain, close to the masonry landward, to regulate its curve and dip. (Figs. 7 and 9.)

The method of constructing the rollers is thus described in the memoir :—

“The iron rollers 12 in number weigh about one cwt. each. They are not solid, but are composed each of about 28 separate pieces of wrought iron, viz., a centre tube or box for the axle over which thick rings are driven; and an exterior drum between which and the inner ringed tube, flattened bars, as spokes, are driven. The centres were broached out clean and true, and cylindrical axles 3.1 inch in diameter were turned to fit; the ends of these axles rest on broad thick iron bearings mounted on very strong and solid frames of timber well bolted, clamped, and blocked together, covered with pitch cement and secured in the masonry of the pillars.” (Figs. 7, 8.)

The platform was made in a different mode from those of our Calcutta bridges, as will be understood by the following explanation :—

“From the short links set between the centre plates of the shackles, (of the main chains) are suspended alternately from each tier, 74 vertical round rods 1-inch in diameter, connected to a short link (Fig. 6) by a 1-inch round bolt passing through it and the socket at the upper end of the bar; at their lower ends the rods have eyes, through which doubled loops of iron pass (3, 4) for sustaining the flat bars or girders, set on their edges and proceeding from one end to the other on both sides of the bridge.

“The flat bars, four inches broad by $\frac{3}{4}$ inch thick and in lengths of 15 feet, are joined together at their ends by nicely turned bolts passing through bored holes 2 inches in diameter; they are adjusted in their height by double wedges, resting on holders that connect the sides of the loops together. The girders are also adjustable in their lengths, the bars that enter the masonry have their ends made broader than the rest of the bars, in which are long openings 2 inches broad to receive wedges. (Figs. 10, 11.)

“Eight timbers in an upright position are set in the masonry of the pillars, having upright grooves or spaces cut through them, and faced with thick plates of iron; through two of these beams each end bar passes, and may be wedged on either side of the timber towards the land as occasion may require; thus is the whole length of girder drawn more or less to either end of the bridge, and also rendered exceedingly tight and steady. The grooves in the timbers towards the river, being about four inches longer than the breadth of the bars, permit them to adapt themselves to their proper directions when drawn lengthwise by the wedges acting against the landward beams; by these means the bars have sufficient play to adapt themselves to the motion of the platform, and all jerks at the pillars are obviated.

"Thirty-seven double joists 12 feet long are (having their ends notched below for the purpose) laid on the girders: their centres 5 feet apart correspond exactly with the vertical rods that pass through them; the joists are composed each of two cheeks a foot in depth and 8 inches thick, separated at intervals by four blocks of wood of the same height and thickness; all firmly put together with bolts, screws, and nuts: two cleats are nailed to each end of the joists on their under sides, whose ends fit flat against the girder and keep all steady.

"Planks 16 feet in length running longitudinally, each plank stretching over three spaces, and regularly disposed as to their joints, are spiked down on the joists; in a direction across these and upon them other planks are spiked down, their lengths being the same as the breadth of the platform. The planks are all imbedded in a composition of resin boiled in linseed oil, which in laying on is mixed with ashes. The lower planks are 3 and the upper ones $2\frac{1}{2}$ inches thick: they are only 6 inches broad to prevent warping, and have two strong square-headed spikes passing through them near their edges, at every crossing of the upper over the lower planks; their points are clinched below the platform, to accomplish which 16,370 spikes, weighing a ton and a half, were used; thus the platform has been rendered extremely strong and firm.

"The better to secure the sides of the platform and the ends of the timbers from the weather, a cornice or moulding of wood is nailed along the outside.

"The hand-rail is trussed, and consists of iron pillars or stanchions; diagonal braces of iron; and a stout wooden rail running from end to end of the platform; the whole put together with screws and nuts, and adjusting screws for setting up or tightening the diagonal braces whenever required. (Fig. 10.)

"The rise in the platform is (as before stated, 9 inches, but the curve of the hand-rail is only 3 inches, to effect which the stanchions that support the rail are of varying lengths. The rail being 4 feet 6 inches above the platform at its connection with the masonry, but only 4 feet in the centre of the bridge."

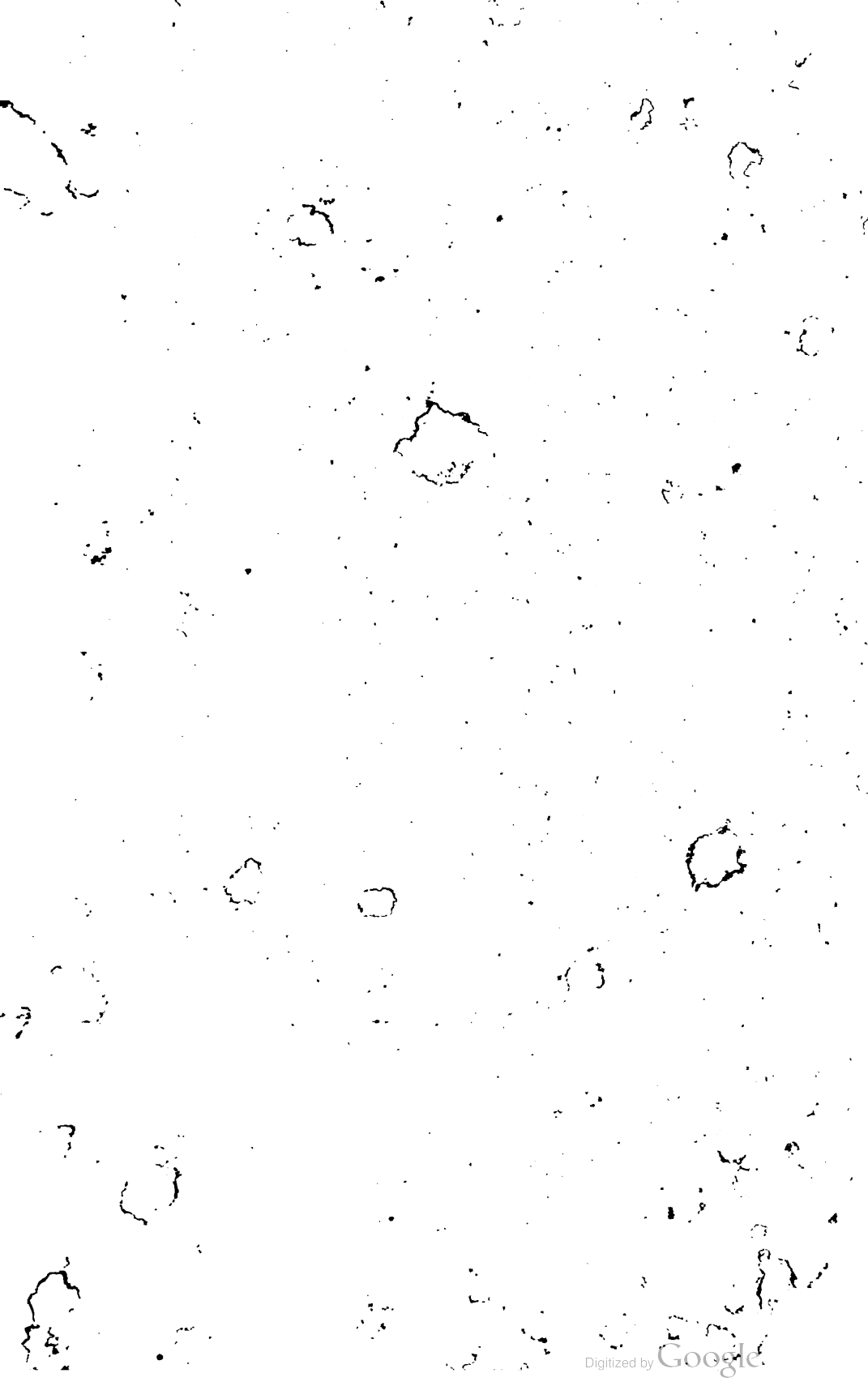
The following are the weights of the chains, rods, and materials of the platform:—

	<i>Iron. Tons.</i>	<i>Wood. Tons.</i>	<i>Tons.</i>
6 double main chains, joints and bolts, . . .	8.5		
74 vertical rods, with joints, bolts, &c., . . .	1.385		
Flat bars and bolts,	1.726		
37 double joists, blocks, cleats, &c.,		6.190	
Bolts, nuts, screws, stanchion plates, flat rings, &c., from beams,	0.883		
Planking 1,124 cubic feet, s&l wood,		27.000	
Iron spikes, 16,370, for planking,	1.467		
Iron railing trussed, screws, nuts, &c.,	1.814		
Wood for the hand-rail, 52 cubic feet,		1.479	
376 feet of cornice to the platform,		1.581	
	14.775	36.200	50.976
Composition of resin and oil,			1.745
Total weight hung between the pillars,			52.720



Gawnpore Memorial Church.

EAST ELEVATION.



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THE FINANCE OF ENGINEERING.

By the Finance of Engineering is simply meant that branch of the science which relates to the *Cost and Returns* of Public Works. If not so interesting as the strictly professional view of the subject it is quite as important, though unfortunately Engineers are apt to look upon it as something beneath their notice, or at least quite apart from their proper avocations. Hence have arisen insufficient estimates—ill-considered schemes—unremunerative works—Railways paying two per cent—and Engineering triumphs like the Thames Tunnel or “the Great Eastern.”

It is indeed curious how little attention has been paid to this subject. Lardner's book on Railway Economy was the first scientific investigation of the question of Transit financially considered, and Sir A. Cotton's pamphlet on Indian Public Works, though put forth to advocate the writer's own special ideas, was the first systematic attempt to show the true bearing of Public Works on the general prosperity of the State, and startled the public like the announcement of some new discovery in Science.

It may, therefore, be worth our while to bestow a little attention on the subject, if only to show what data we have and what are wanting for a proper enquiry into the laws of Engineering Finance, at least as far as India is concerned.

Like any other question of Finance, the subject resolves itself into the two branches of Expenditure and Receipts. By a proper system of accounts we can apportion and classify the expenditure, but of the receipts in return for, or as a direct consequence of, that expenditure, our data are of the very vaguest. Yet it is only from

a just idea of the proportion between the two that the higher problems of the question can be solved, such as, what portion of its Revenue a Government is justified in expending on Public Works, or whether it may fairly raise Capital to construct them.

As regards the question of Expenditure, the present system in use in India, comprises—1st, The preparation of an Annual Budget, in which the sums to be expended by the several Local Governments, under various classified headings, are annually allotted after a due consideration of actual and probable requirements, and of the total amount that can be spared to meet them. Works are classed under the three great headings of Military, Civil Administration, and Public Improvement—the first two comprehending works required for Government purposes, such as Military and Civil Buildings, &c., the last those for the good of the community, such as Municipal Buildings, Roads, Canals, and the like.

2nd. A system of Accounts by which the actual work done, and its cost are shown, the results being summed up in the Annual Progress Report, which is a corollary to the Budget, and shews the performance of the year as compared with the promise. Much difficulty has been practically experienced, and many changes made from time to time in perfecting a system of accounts, which should be satisfactory to Government without being burdensome to the Engineer. That a man may be a very good Engineer, and yet a very bad Accountant, is quite certain. Yet it is impossible to divest the man who spends money, from being answerable for the way in which it has been spent. But that responsibility may yet exist, without compelling the disburser to give an account of it himself, which for a long time was done, until an Engineer found that while one-fourth of his time went in doing work, the remaining three-fourths were occupied in writing about it. No system can relieve an Engineer of being answerable for the cheapness or dearness of his work, but by giving him an Accountant, who will be responsible, not to him, but to Government, for the details of expenditure, as he will be for the return for that expenditure, the Engineer will be relieved of the most irksome part of his duty, without being freed from his proper

responsibility. This system is, I believe now being introduced, and will no doubt work well.

One much discussed question may just be noticed before quitting this branch of the subject—the question of Establishments, as bearing on the total cost of a work. That their amount should bear some proportion to the work done, appears almost an axiom; yet it is not certain that it is even true. As a forcible way of putting the case, it has been asked whether (for instance) it is right that it should cost *eight annas* to spend a rupee? But there is another way of putting it; whether if it only cost *four annas* you would not spend *two* rupees? The late Secretary to Government, in dealing with this question, rightly acknowledged the difficulty of drawing the line between the two items of Establishment and Labor, and it is indeed difficult to understand how the two can fairly be separated, or why Establishment is not considered an integral portion of the total cost of a work. It is true that to set down the cost of any Establishment as out of proportion to the expenditure incurred, *may* induce a reduction of establishment, but it may also produce an increase of expenditure as an equally effectual mode of diminishing the proportion, and looking at the ultimate aspect of the question, the result to be arrived at is the *total* cost of a work, and not the cost of its several items, whether labor, materials, or establishment. The effect of the employment of an efficient, and therefore, an expensive establishment, is, or ought to be, a reduction of other expenditure, and provided there is a reduction on the sum total, the details of that sum ought to be a matter of comparative indifference.

Having said thus much on the question of Expenditure, let us turn to the other side of the account and enquire into the Receipts.

Public Works may *pay* in two ways—1st, They may pay the promoters in the shape of a *direct* return, such as in the case of Tolls on a Road, Water-rent from a Canal, or Traffic receipts on a Railway.

Of the above, as regards India, Government has made the Roads, and, anxious to remove all hindrances to free traffic, has given up all Tolls, trusting to receive back its money indirectly, in the shape

of customs' dues or otherwise through the general prosperity of the community. Where Roads are made by private individuals, which may yet come to pass in India, the principle on which tolls should be levied is sufficiently obvious without further explanation.

Railways are yet in their infancy, and Government has but a part-ownership in them. From the latest returns available, it appears that the traffic receipts on all open Indian lines, of more than 100 miles in length, average in round numbers 10,000 rupees per annum per mile of opened line. If we estimate the working expenses at 50* per cent. of the gross receipts, we shall not be far wrong; and the average estimated cost may be taken at 1,35,000 rupees per mile, shewing a clear return of less than 4 per cent. per annum on the capital expended. This is not very encouraging in a financial point of view, but it must be remembered that the traffic is still only partially developed, and that until the great lines are opened throughout, no fair average of results can be struck. After that time, and especially as roads and branch railways are made to feed the main lines, a considerable extension of traffic may be looked for, but it is after all by the indirect returns that the value of railways to India must for a long time be judged.

As to the direct returns from Canals and other works of Irrigation, it appears that on the only large canals in Upper India, where irrigation has as yet been fully developed (the E. and W. Jumna Canals), the net annual profit is rather more than 10 per cent. on the total cost. But it is not probable that this per centage of profit will be realized by the *new* Canals for many years to come. The strict financial reckoning now exacted by Government, in which the interest of the capital is reckoned from the commencement of a work, shews that in the case of the Eastern Jumna Canal, that work has already defrayed the whole cost of its maintenance and repairs, *plus* 5 per cent. interest on the capital, leaving a balance in hand at credit of Government. Major Brownlow, the late Superintendent of this canal, has reckoned the cost of its construction at 6.5 Rs. per acre of average area irrigated, and the

* It is over this at present, I believe, but will probably be reduced below this per centage before long.

maintenance and establishment at 7 annas per acre. Colonel Rundall, R.E., gives Madras rates as 8.3 Rs. for construction, and 6.6 annas for maintenance, per acre.

Madras works are, however, believed to be generally more profitable than in this presidency. In a late minute on Irrigation by H. E. Sir W. Denison, the annual *cost* of the water to Government is reckoned at 1 rupee for 4,200 cubic yards, the supply being spread over a period of about three months; while the *value* of this water is reckoned at 1 rupee per 1000 cubic yards. Capitalizing the above cost at 5 per cent., the returns show a profit of more than 20 per cent. on the outlay.

2nd, Public Works may pay *indirectly*.

The returns in this case are more difficult to determine, and the data are indeed most imperfect, but it will be useful to show what we have, and what are wanting.

Roads operate indirectly—1st, By diminishing the cost of transport; 2nd, By setting free a large amount of labor, which may be employed otherwise.

The Post-Master-General, N. W. Provinces, in 1850, calculated that the actual haulage of a ton of goods by the Bullock Train cost Government *one anna* per ton per mile on a metalled, and *three annas* on an unmetalled, road, exclusive of prime cost and wear and tear of animals and vehicles.* I have no returns of traffic on any roads, but if the above calculations be accepted, (and they were made from very fair data,) and taking the cost of a metalled and bridged road at an average of 7,500 rupees per mile, the cost of repairing it at 800 rupees annually, and interest of money at 5 per cent., it would appear that on any line on which there is traffic to the amount of 5,400 tons yearly, it would *pay* to construct a metalled road.

* Sir A. Cotton gives the following as the actual cost of various kinds of transit in India, per ton, per mile:—

Sea navigation,	-	-	-	-	-	-	5 to 8 pie (½d. to 1d.)
River do.	-	-	-	-	-	-	4 pie, or ½d.
Completed roads,	-	-	-	-	-	-	1 anna, or 1½d.
Imperfect do.	-	-	-	-	-	-	2 annas, or 8d.
Unimproved tracks,	-	-	-	-	-	-	3 annas, or 4½d.

He also gives the actual traffic on the first 125 miles of the Great Western Road from Madras as 100,000 tons yearly.

As to the increase to the wealth of a district through which a road runs, or the extent to which Government, as the road-constructor, benefits by that wealth, I have no means of ascertaining it, but I believe such data might be collected in certain districts, and would be very valuable.

If the cost of carriage is diminished by a metalled road, it is needless to point out how much more this is the case in respect to a Railway.* In the back settlements of America this fact alone has created railways, not as with us as luxuries, but as the first necessities of the settler and the first step towards civilization. Rude as they are, often consisting of flat iron bars spiked down to rough logs of timber, laid without ballast on the natural surface of the ground, they answer their purpose and pay indirectly by giving the makers facilities of transport for their produce, and by enhancing the value of their land.

Though the same facilities of construction (in the abundance of timber) do not exist in India, yet we have a counterbalancing advantage in the comparative cheapness and abundance of labor, and at least as strong inducements to open up communication between remote districts. We have indeed a further inducement, which it is astonishing we have until lately been so slow to recognize—I mean the facility of transport for Troops, Artillery and Stores, which, to a Government in our position, is an absolutely incalculable advantage. The strongest Military Government that the world has ever seen, (the Roman,) were not slow to perceive the importance of this—their first step on the acquisition of a new country being to drive a broad Military Road into the heart of it from the nearest Cantonment, made by the soldiers themselves.

And this leads me to remark (though it has often been the subject of remark before), on the feasibility of employing a considerable portion of our Army, English and Native, in the construction of Public Works; pressing it, as I would, as an important step in Financial Economy, towards remedying the two greatest acknowledged drawbacks to improvement in India—the (necessarily)

* Dr. Lardner gives the actual cost of transit of goods per ton per mile on English Railways at 1.11d. The rates charged on Indian lines vary from 7 pie ($\frac{1}{4}$ d.) to 5 annas (7½d). What the actual cost is I do not know.

excessive Military expenditure, and the want of means of internal communication; for, as the increase of roads would lessen the cost of Military transport, so the employment of soldiers would increase the roads. In round numbers we have 70,000 English and 180,000 Native soldiers in India, whereof I would urge that one-half might be employed for 6 months out of the 12, in other than Regimental work, not only without any sacrifice of efficiency, but with a positive increase to it,* as few can doubt that the men who were well and constantly employed all the year round, off as well as on, parade, who could use the spade and pickaxe, the saw and hammer, would be the best men for the real hard work of a campaign. I am fully aware of the difficulties in the way, of the requirements of parade and rifle drill, &c., but making every allowance for that, I think that the proportion above estimated (only *one-fourth* the strength of the Army annually), might be employed as suggested. Now, the money value of this unemployed labor, cannot at the lowest estimate be put down at less than 25 lakhs of rupees, or a quarter of a million sterling, whereof one-half should go into the pockets of the soldiers as working pay, and the rest should be clear profit to Government. This half sum represents 170 miles of first class road annually.

Closely allied to this subject, are the indirect returns which may be said to arise from good Barracks, and such like expenditure which is commonly set down as unremunerative. For the value† of this we must go to Sanitary statistics, but, as I have hinted above, the question is so mixed up with other things affecting the health of the

* The great cause of sickness and mortality in the Anglo-Indian Army is—*not* drunkenness (that is an effect only of other causes)—*not* bad barracks or unsuitable food—*not* exposure to the sun (for the classes of men most exposed to the sun in India are generally the healthiest)—but *want of occupation*. I am aware of the claims of Regimental Workshops on much of this unoccupied time, and if they could be put on a proper footing, would be the first to advocate them. If the whole of the accoutrements, barrack furniture and fittings, &c., could be made by the men, sharing the profits with Government, no one can doubt the advantage to both. But I hold that any system of *amateur* workshops is simple illusory—it is *playing at work*. It is well known that the French Army in Algeria is largely employed as above suggested.

† The cost of housing the European troops in the Punjab Cantonments was certainly not less than 800 Rs. per man.

soldier, that it is impossible to say how much saving of life (*i. e.*, of money) is due to good barracks in lieu of bad ones. There are some of our older stations, however, whose statistics, if available, would doubtless throw some light on this head, and allow us to estimate to a very fair approximation, the capital which might be employed in providing good dwellings, whose interest would be the improvement of health in the dwellers. As a practical question, however, it may be said to be unnecessary now, Government being fully alive to the duty, as well as economy, of not sparing money in this direction, as has been shewn in all the Cantonments lately built.

As to the indirect returns of Works of Irrigation, we have some statistics which will serve to shew their immense value and importance. These indirect returns, which can be measured or estimated, consist in the increased land revenue obtainable by Government from the districts benefited, either by waste land being brought under cultivation, or by the difference in value between *wet* and *dry* cultivation,* as it is technically termed.

From a comparison of data on five first class canals in Upper India, constructed, in hand, or estimated, it appears that the average prime cost of a cubic foot of water per second of discharge at the heads is 4,000 rupees; that the average annual value of a cubic foot (including the increase to land revenue), is 750 rupees; and the average annual expenditure per cubic foot is 120 rupees. So that the clear return to Government is 630 rupees, or nearly 16 per cent. annually on the capital invested, besides the general benefit to the community.

The returns from Madras Canals are more favorable than this, being estimated by Col. Baird Smith, in one district, at 20, and in another at 23 per cent., annually, on the capital invested, and by Sir A. Cotton, and others, at very much more than this.

There are also other indirect returns which cannot be reduced to figures, such as the saving in remissions of revenue, which are often

* Sir A. Cotton reckons this difference in the case of rice at 9 Rs. per acre, computed on the gross value of the crop. Colonel Baird Smith estimated it on the Western Jumna Canal at 364 Rs. per square mile for land revenue only, making a total profit (including water-rent) of 36 per cent.

forced on Government during years of drought, in districts where there is no artificial irrigation;* besides, as before remarked, the general prosperity of the community, a prosperity in which Government necessarily shares, if only by the increased consumption of taxable commodities.

In the above remarks I have only made a passing allusion to the general question of the execution of Public Works by Government. It is indeed too important a question to be disposed of in an off-hand manner, yet people often think that as soon as they have proved Public Works to be remunerative, it follows as a matter of course that it is the duty of Government to construct them; and that if it has not got the money, it ought to borrow it for the express purpose. Without entering too far into such a large question it may be sufficient here to remark—1st, That though it may be the right or interest of the Government to undertake such works, it does not follow it is part of its duty, and that Government has already enough of its own proper functions to perform; 2nd, That it is a pretty generally admitted maxim that the construction of Public Works is much better left to private enterprise, and that even in the exceptional case of India, the *onus* of proof at least lies with those who would contend for a different principle; 3rd, In answer to those who ask for Public Work Loans on the ground that it is unfair to tax the present generation alone for benefits equally shared by a future one, it may be answered that it is at least as unfair to plunge a future generation into debt on account of speculations, in which they cannot possibly have a voice. Government has in effect been compelled to try the experiment and the result of it, in the Railway Guarantee system, is not encouraging nor is it likely to be repeated. With the progress of education the people's eyes will be opened to working together for their own benefit; the influx of capital into the country within the last seven years has been enormous, and it is to be hoped we may soon see Railways, Roads, and Canals constructed

* The value of the crops produced by the Ganges Canal alone during 1861-62, was one and a quarter million sterling. The water-rent paid to Government was £70,000.

under the auspices of intelligent and respectable bodies of native proprietors.

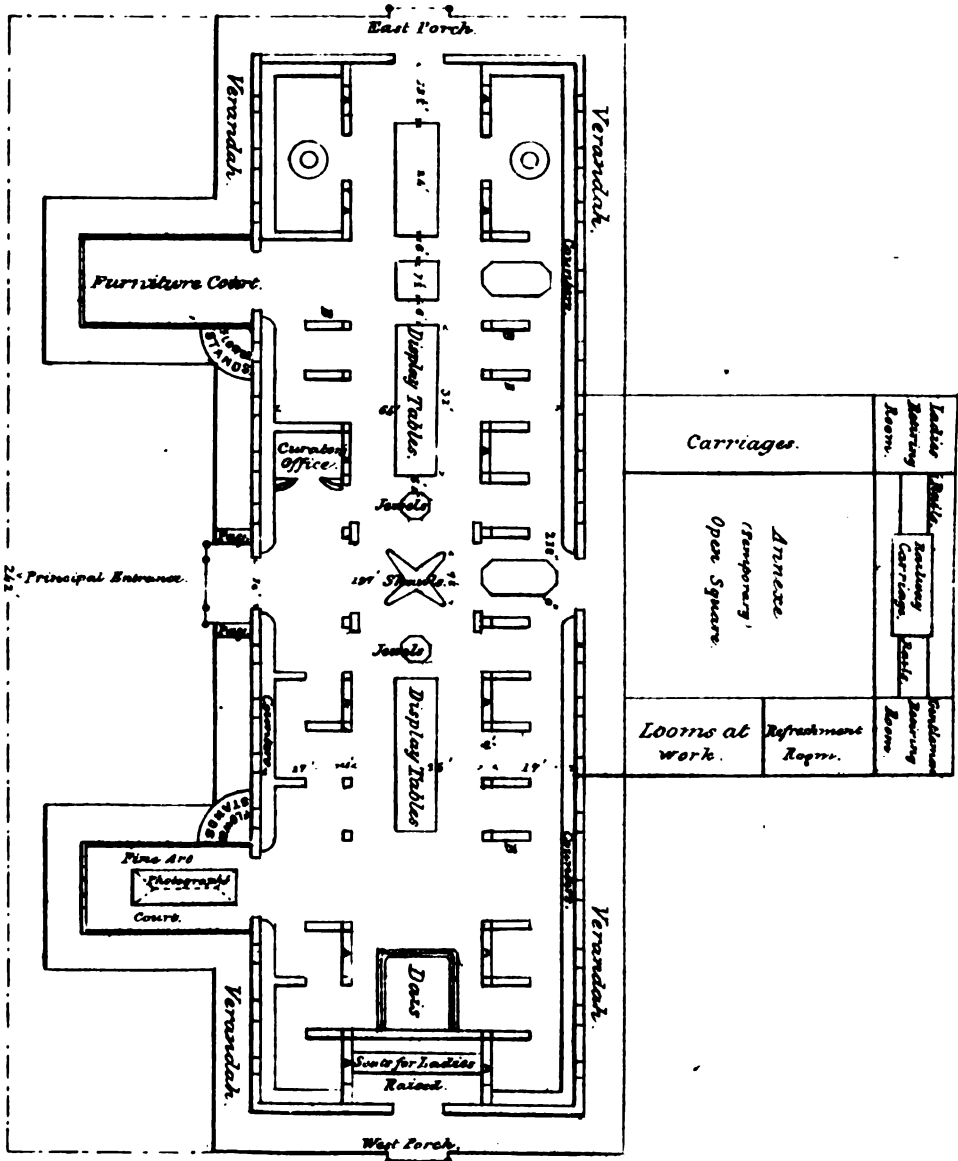
Here for the present we must stop. I am quite aware of the imperfect manner in which such an important subject has been treated, but shall be content if these few remarks may induce others to collect data and compare results, which may be useful in elucidating the laws on which the Finance of Indian Engineering should be based.

J. G. M.

PUNJAB EXHIBITION BUILDING.

Ground Plan.

Scale 40 feet to one inch



A. A. A. Glass Cases between Arches.

B. B. B. Tables.

No. XXXI.

PUNJAB EXHIBITION BUILDING.

Designed and erected under the Superintendence of EDWIN E. BAINES,
Esq., District Engineer, Punjab Railway.

COMMENCED 5th June, 1863; handed over to the Committee 7th December, 1863; opened the 20th January, 1864, by His Honor the Lieutenant Governor; cost, Rs. 60,000:

The above speedy result of completion was principally owing to the energy of Captain Hall, the Deputy Commissioner (Officiating) in procuring workmen from Lahore and the adjacent towns of Umritsur, Ferozepore, Jullundur, &c., &c., and the liberality of the Punjab Railway Company, in allowing a portion of an organised establishment to be brought immediately to bear on the preparation of the carpenters' and joiners' work.

Average number of men employed, 1000 per diem.

The style chosen by the Engineer was that of Belgian Gothic, on account of its grouping in a picturesque manner with the surrounding buildings, and being a style that would allow of freedom of treatment.

The building was executed in Lahore bricks; arches, string courses, plinths, &c., in English sized bricks.

Roof tiled, with tiles 1 foot square and $\frac{3}{4}$ inch thick, layed on $\frac{3}{4}$ inch boarding, with tarred cloth between that and the tiles. Valleys, gutters &c., lined with zinc.

Flooring, boarded with $1\frac{1}{4}$ inch planks, with spaces of $\frac{1}{8}$ th inch between, to get rid of the dust.

Tables covered with green cloth. Dais and Ladies' seats with red velvet, and former with gold fringe dressings.

E. B.

No. XXXII.

MEMORIAL CHURCH—CAWNPORE.

Designed by WALTER GRANVILLE, ESQUIRE, C. E., *Consulting Architect to Government of India.*

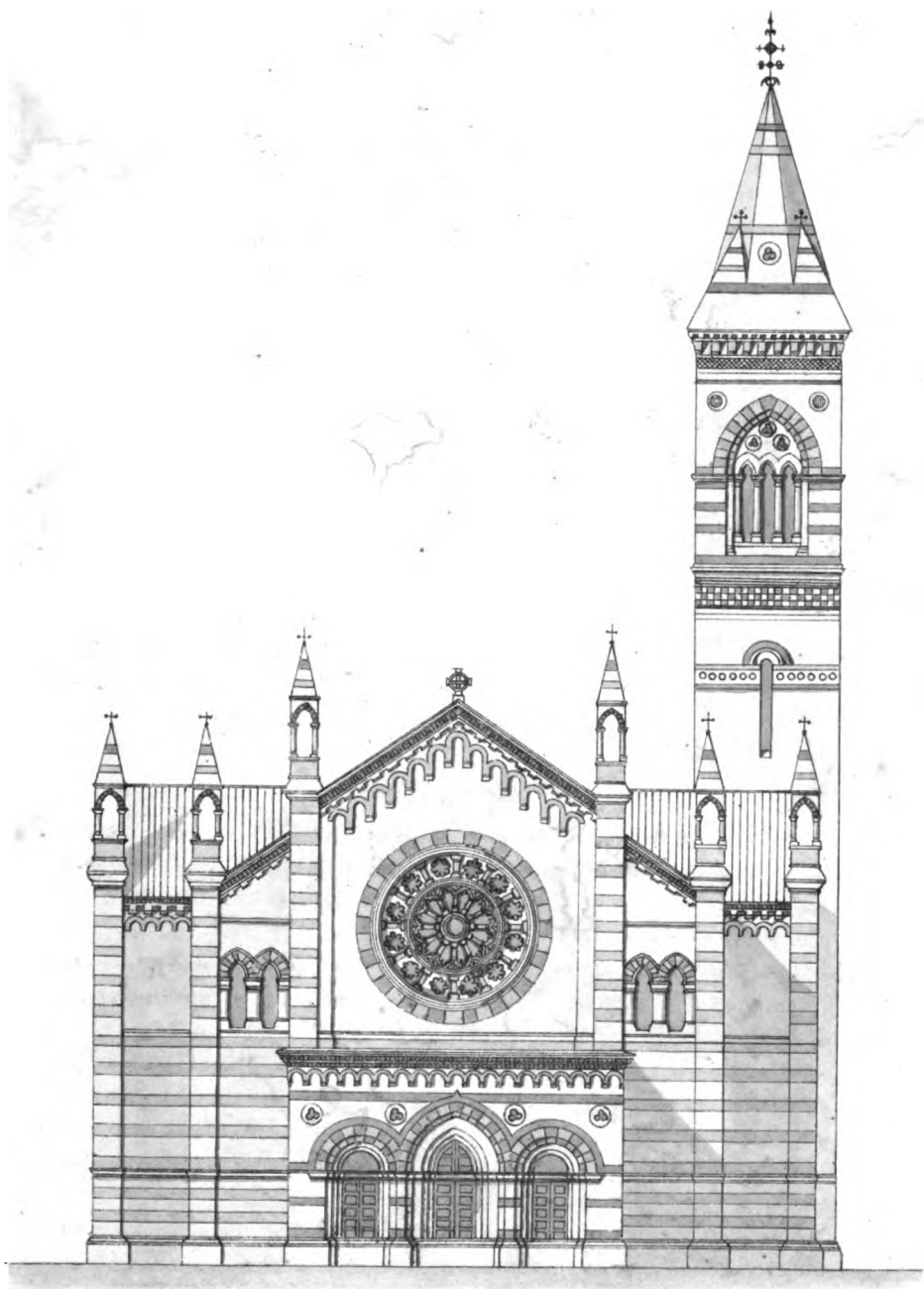
[Competitive designs for the Cawnpore Memorial Church, were called for in 1861, the estimated cost of the building being limited to 1,20,000 rupees, when Mr. Granville's design was selected.]

DESCRIPTIVE REMARKS.

THIS design is founded on the round-arched Lombard and Romanesque styles of Architecture, with introductions from the later Italian pointed style, and is thus in accordance with the suggestion of the Government of the North-Western Provinces of India. It is a study of the leading elements which permeated Ecclesiastical Architecture in Italy during no less than five centuries, from the reign of Charlemagne, A. D. 768, to that of Rudolph of Hapsburg, A. D. 1278.

Like other styles of Architecture, the Lombard and Romanesque styles were slowly progressive and transitional, and it was not till the latter end of the twelfth century that they fairly reached their climax: from this time forward, owing to the continued influx of Germans, they began to assume greater Transalpine features.

Stone intersecting vaults of a pointed form were introduced so early as the eleventh century at Piacenza and Novara, and the first pointed pier arch was introduced about 1219-1222 by an English Architect, named Brigwithe, in the Church of St. Andrea, at Vercelli. Lancet doors and



Gwynne Memorial Church.

WEST ELEVATION

windows naturally soon followed. Grey or red bands were introduced at the Cathedral of Pisa in 1163, and were copied at Sienna in 1243. The rose window is a genuine Germano-Lombard and Romanesque feature, first seen about the middle of the eleventh century. The campanile is of Cisalpine origin, and the rich arcade, with its slender colonnettes is a general characteristic of the Lombard style.

I have thought fit to draw attention to these facts in the history of the Italian Gothic styles, to show that I have a precedent for each of the main features of my design; and whilst I have amalgamated in my own way the characters of the round and pointed styles, I lay claim to have attempted to do only what the Italians, after a lapse of several centuries, themselves seemed anxious to accomplish.

It must, however, be admitted, that they were seldom very successful in grafting the true principles of Gothic pointed Ecclesiastical Architecture on the round-arched styles, probably because they never thoroughly understood them; or, may be, they did not sufficiently appreciate the Architecture of the more Northern Nations. If I have been at all successful, it is because those principles are now more widely diffused than they ever were in Italy, and they are better understood.

It is proposed to build the walls of the Church of red pressed bricks, faced in part *outside* with Chunar stone in dark grey bands; *inside*, the walls are to be faced solely with stone. The roof is groined in stone in the simplest manner. The cornices, arches, and columns are to be also of Chunar stone. The flooring is also of stone, with a pattern of grey Chinese marble. It is not intended to have any plastering either externally or internally, as, after the lapse of a few years, it requires to be constantly repaired, and the tendency of plaster Architecture is constantly to extravagance in detail and bad taste. Moreover, it is urged that this Church especially should be a Memorial Church, *ære perennius*, and as such, typical of our enduring supremacy.

The dimensions of the Church are as follows:—

	<i>Feet.</i>	<i>Inches.</i>
Extreme length inside,	141	0
Extreme width inside,	50	6
Height of Church,	46	0
Width of Nave,	25	6
Depth of Chancel,	42	0

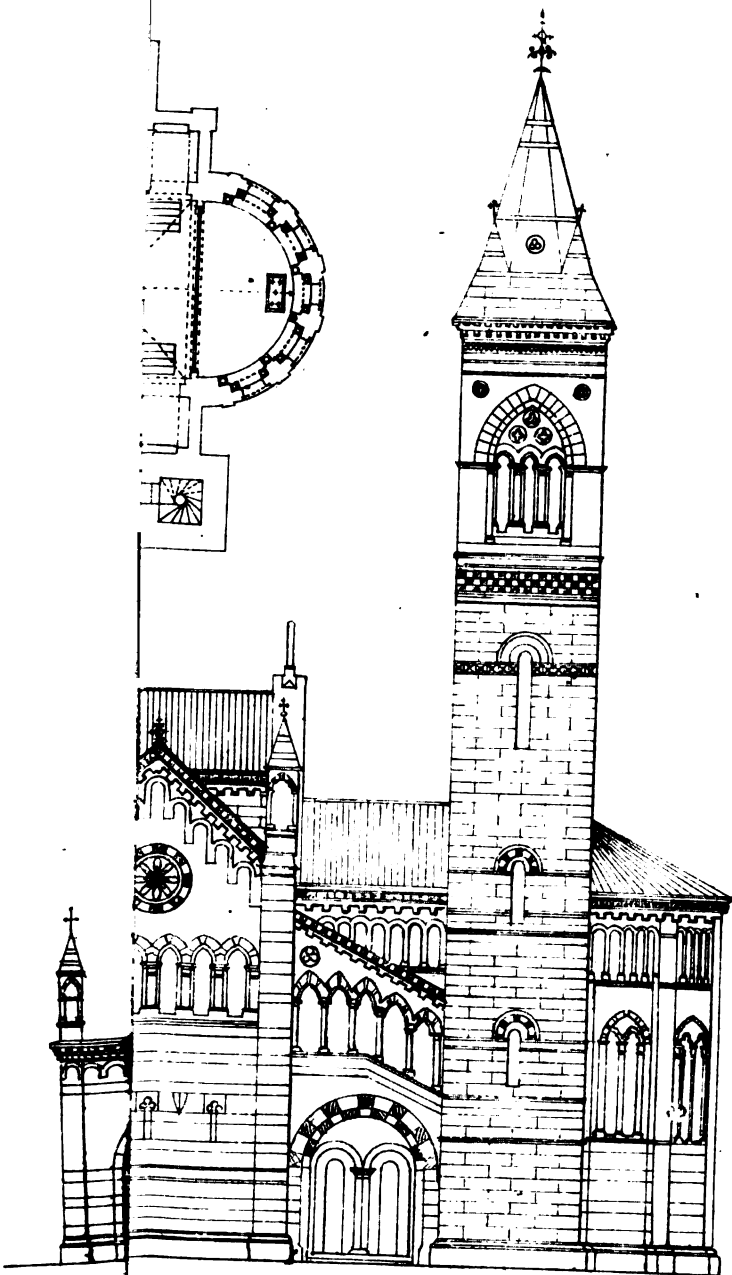
The Church is capable of affording sittings for 500 persons on the

ground floor. In the gallery at the west end, over the vestibule, 100 more persons can be seated. The organ is placed in the gallery of the south transept, and there is a corresponding gallery in the north transept: these will seat, if required, 100 more persons—thus giving accommodation in all for 700 persons.

The method by which the Church is lighted and ventilated and secured against the intensity of glare, forms one of the chief objects of the design. In this bright climate light should be admitted with caution, and there is this advantage that it produces a shadowy effect or "dim religious light," which is highly favorable to Architectural grandeur. The principal light is obtained from a considerable elevation immediately above the lower passages or aisles. It is admitted, *firstly*, through a series of small pointed arches pierced in the outer walls of an upper arcade built over the passages below; *secondly*, through a series of similar arches left in the inner walls of the Church. This double arrangement for admitting light will tone down the rays of the sun and obviate any inconvenient glare, while it effectually prevents the rays from falling directly on the people occupying the seats on the floor of the Church. By leaving all these openings free from glass, a free current of air is afforded for the ventilation of the Church, whilst in the extreme hot weather, when the Church should be closely shut up, kuskus tatties can be fixed with advantage against the outer openings, and kept constantly wetted by coolies during the service, without at all interfering with the congregation. The necessity of using large hanging punkahs, so unsightly in Churches, will thus probably be obviated. The rain which beats through the outer arches only, will fall on the floor of the arcade, and be carried away through the down pipes. Small openings to act as ventilators have been placed in the passages of the ground floor, and light is also admitted through the deeply recessed windows at the east and west ends, and in the transepts.

The Lombard style of Architecture is peculiarly adapted to the above arrangements for admitting light and affording ventilation in the most efficacious and natural way that can be devised for a climate like India, on account of the continuous arcade being one of the most pleasing characteristics of the style. Mr. James Fergusson, in his *Illustrated Handbook of Architecture*, when speaking of these Lombard arcades, remarks, "There is nothing in the style of which we are now speaking either so common or so beautiful as these galleries. These arcades have all the

arch.



shadow which a cornice gives without its inconvenient projection, and the little shafts with the elegant capitals and light archivolts have a sparkle and brilliancy which no cornice ever possessed. Indeed, so beautiful are they, that we are not surprised to find them so universally adopted; and their discontinuance when the pointed style was introduced was one of the greatest losses sustained by architectural art in those days."

One word in conclusion before giving the estimates as to the suitability of the design. It has been already stated that the method of lighting and ventilation is peculiarly adapted for a hot climate—so far the design differs from any known Church; but whilst I have departed from the usual plan of Northern Churches in this particular, on account of the climate, I have adhered to the orthodox plan of a Church appointed for celebrating the rites and ceremonies of the United Church of England and Ireland. I have moreover endeavored to give to the exterior and interior at least an Oriental stamp, by the introduction of colored bands, which, so far as I remember, had their origin in the East amongst the Tartar tribes, and were introduced by them into every country they occupied.

ESTIMATE.

The prices have been based on the rates of work prevailing at Cawnpore, which were furnished to me by the Executive Engineer of the Cawnpore Division of Public Works, by direction of the Secretary to Government, N. W. Provinces, P. W. Department.

Full allowance has been made in addition to those rates where there was more than ordinary labor attached to the work, and 10 per cent. has been added to the Estimate to cover unforeseen contingencies.

c. f.		R.	A.	P.
6,500	Rough dry ballast, at Rs. 6 per 100,	390	0	0
24,225	Brick-work in foundations, at Rs. 18 per 100,	4,360	8	0
97,250	Ditto above, including extra labor in connection with stone facing, &c., at Rs. 20 per 100,	19,450	0	0
750	Ditto, moulded in small arches of outside cornice, at Rs. 30 per 100,	225	0	0
19,850	Chunar ashlar stone in plain faces, 6" thick, including beds and joints, at Rs. 1-8 per foot,	59,775	0	0
6,220	Ditto in arches, at Rs. 2 per foot,	12,440	0	0
1,329	Ditto in plain moulding, at Rs. 2-4 per foot.	2,990	4	0
	Carried forward,	98,630	12	0

ESTIMATE.—(Continued.)

		R.	A.	P.
	Brought forward, . . .	98,630	12	0
389	Chunar ashlar stone in moulded plinth, at Rs. 2-8 per foot,	972	8	0
1,748	Ditto in columns, at Rs. 3 per foot, . . .	5,244	0	0
675	Ditto in moulded bases, at Rs. per 3-4 per foot, . . .	2,198	12	0
1,350	Ditto in large and small carved caps, at Rs. 4-8 per foot, . . .	5,625	0	0
460	Ditto in moulded blocks, at Rs. 2-4 per foot, . . .	1,085	0	0
<i>a. f.</i>				
1,320	Khoa floor, at Rs. 18 per 100, . . .	237	9	7
3,800	2½-inch Chunar stone paving, at Rs. 28 per 100, . . .	1,064	0	0
2,000	1-inch China marble ditto, at Rs. 50 per 100, . . .	1,000	0	0
1,475	1-inch Tile gutter, at Rs. 15 per 100, . . .	221	4	0
<i>c. f.</i>				
741	Sál timber in roof, at Rs. 4 per foot, . . .	2,964	0	0
385	2½-inch plain Sissoo-wood doors, complete, at Rs. 1-8 per foot, . . .	577	8	0
45	1½-inch ditto ditto ditto, at Rs. 1-8 per foot, . . .	67	8	0
<i>a. f.</i>				
9,450	Corrugated Iron, at Rs. 45 per 100, . . .	4,252	8	0
<i>c. q.</i>				
15 8	Milled lead, laid in ridge, at Rs. 28 per cwt., . . .	441	0	0
3 1	Wrought iron, at Rs. 28 per cwt., . . .	91	0	0
<i>a. f.</i>				
420	16 ounces sheet glass, at Rs. 0-12 per foot, . . .	315	0	0
	Communion Table of Sissoo-wood, . . .	50	0	0
	Stone Altar Rail, . . .	150	0	0
	Ditto Reading Desk, . . .	250	0	0
	Ditto Pulpit, . . .	500	0	0
	Ditto Font, . . .	400	0	0
	Seats for 600 persons of Sissoo-wood, . . .	3,600	0	0
		Rupees,	1,00,882	5 7
Low enclosure wall with gateways, gates, and roads of approach, . . .			6,117	10 5
Total Rupees, . . .			1,07,000	0 0
Add 10 per cent., for contingencies, . . .			10,700	0 0
Grant Total Rupees, . . .			1,17,700	0 0

CALCUTTA, }
August, 1961.

W. GRANVILLE.

[NOTE.—Subsequent experience showed that the estimate was insufficient and it was afterwards raised to 1,51,181 Rs. This sum was sanctioned by Government, and the building is now in progress.—ED.]

No. XXXIII.

LOCAL ATTRACTION.

On the Local Deviation of the Plumb-line from the True Vertical, as affecting the accuracy of a Trigonometrical Survey. BY LIEUT. HERSHEY, R. E., *First Assistant, G. T. S.*

It is not easy at this period of our knowledge of the constitution of the earth's crust, to do more than speculate on the importance which this subject may one day attain; but no one who has even a slight acquaintance only with the way in which gravity manifests itself, as 'local attraction,' will hesitate to acknowledge, that even in our present state of ignorance regarding it, attention will not be drawn to it in vain.

It is not intended in this paper to enter into any minute details, so much as to point out in general terms the way in which local attraction manifests itself, and the difficulties which must always be met with in endeavouring to determine its force, and the origin of that force. I may perhaps, too, venture to speculate on the probable results of a more intimate knowledge of its general laws, or hazard an opinion on the direction which any attempt to collect data should take, so as best to discover those laws.

Before attempting anything of the kind, however, let us understand exactly what is meant by the term 'local attraction.' Many people who use the word frequently, without having had the good fortune to come across a late article in the "*Cornhill Magazine*," (to which I shall have occasion to refer again presently,) or on whom a different view of the matter has not been forced by some equally startling facts, would say, the words referred to the deflection of the plumb-line, due to the lateral attraction of some mountain mass; and that this is the more natural view is not to be denied,

for mountains are palpable things, and we naturally expect them to attract a plummet more or less, and so deflect it from the perpendicular; and though a moderate exercise of our reason would lead us to argue that variable density of subterranean strata would produce the same effect, still the fact remains that that variable density is little more than an hypothetical one. In short we might reasonably look for deflection in a certain direction near a mountain, but we should hardly do so in a plain. *Local attraction* is in common parlance almost synonymous with *Mountain attraction*. I prefer, however, in the present instance to be understood to mean "a force, due to local constitution or configuration of the materials forming the earth's crust, which causes deflection of a plumb-line from the direction of the normal," i. e., from the direction which the plumb-line would have but for local inequalities of surface or density. (I just now made use of the expression 'deflection from the perpendicular.' According to ordinary ideas 'the perpendicular' is the direction of gravity, i. e., of the plumb-line when in a state of rest, but no sooner do we come to talk of 'local attraction,' than we are compelled to distinguish between 'the perpendicular,' i. e., the direction of the normal, and the direction of gravity).

Let the reader conceive a plumb line suspended from the ceiling, with the point of the plummet just grazing the surface of a sheet of paper on the table before him, on which are drawn lines defining the four cardinal points, and let him adjust the paper so that the point of the plummet shall coincide with the intersection of the cross lines, and let him conceive this state of things to represent the absence of all local attraction. Now let a magnet be laid on the table any where, (the plummet being of iron); the latter will move and take up a position, differing more or less from its former one according to the distance and power of the magnet, &c., and permanent so long as the magnet continues undisturbed. This is an exact parallel to the state of things when local attraction exists. The only difference is to be found in the nature of the attractive force, which is here magnetic instead of molecular, and in one other very important respect, which constitutes in fact the whole difficulty, and I may add, interest, of the subject, viz., that whereas in this experimental illustration, it would be easy to measure the amount and direction of the disturbance directly and absolutely, in the case illustrated we can do neither. In other words we should have a more exact parallel, were a clean sheet of paper substituted for

that on which the cross lines were drawn and were we asked to point out the spot where the plummet would rest were the magnet removed. We could not do it *directly and absolutely*, neither can we, or have we, or shall we ever be able to assign the absolute amount and direction of local attraction at any place. But we may *guess* any number of times, and our guesses being rightly biased, we may approximate very closely to the truth. Nay, more than this, though judicious guessing will help us more quickly perhaps to a conclusion, we may arrive at the same conclusion in time without such questionable help.

Dispensing for a time with the assistance of the magnet, conceive the plummet deflected by the force of local attraction alone. In the absence of any positive knowledge of the amount and direction, or even of the very existence of such deflection, let us assume that there is none, and that a dot on the paper immediately below the point of the plummet represents the position due to no attraction, at that point of the earth's surface where the plumb-line has been suspended. Now, let the reader conceive himself, his table, paper and plumb-line, transported to a place, say twenty miles off; and let him, for the present, take it for granted that it would be possible so to deposit him and his apparatus, that the dot he made at the first station should be in the exact position which the plummet would indicate were the local attraction at the two stations identical, (i. e., on the assumption that there was none at the first, were there none at the second also), and that his paper should maintain the same position with regard to the north and south points. Being so deposited, he observes that the plummet indicates a different point altogether, and he is driven to the conclusion that there is local attraction at the second station and that its amount and direction are measurable. Having marked this new point he is transported to a third, and so on, at each new station making a dot to indicate the position which the plummet occupied. When a large number of stations have been thus visited, the paper will present a group of dots, more or less evenly scattered, or clustered according to the nature of the local attraction in the several districts visited.* Now since each individual dot occupies a position relatively to No. 1, it follows that each occupies a position relatively to any one of them, or to any arbitrarily assigned imaginary point among them. Let the centre of gravity of the whole be

* The reader is cautioned against confounding this experimental chart of points indicated by the plummet, with a chart of the corresponding stations. There is no connection between them as far as appearance is concerned.

such an imaginary point, then it is clear that this is the point which the plummet would have indicated at some station where the local attraction partook equally of the character of the attraction at all the stations visited, quite independently of our original assumption of absence of attraction at No. 1. That assumption would be justified or not, according to the proximity of dot No. 1, to the centre of gravity, but whether true or not matters little now, for we have obtained a *mean direction of the plumb line*, and by reference to it, can assign a numerical value of the absolute deflection at any one of the stations visited, (No. 1 included). When I use the word *absolute* in this place, however, I am assuming that the *mean* direction is the *true* one, which I am perhaps hardly justified in doing without some caution. Means never do more than approximate to the truth, and that only in the absence of any bias, constant for the whole or great part of the quantities whose mean is taken. Thus, for instance, were the above experiments confined to a portion of the surface of the earth in the vicinity of a lofty mountain range, we might fairly say that the *mean* direction of the plumb line would very erroneously represent the *true* direction of the normal. To ensure the absence of any such bias, the stations visited must be very numerous and scattered over the entire globe, either at random, or according to some law quite independent of the configuration of the earth's surface. We might indeed confine the observations to a small portion of the globe, as England for instance, or the Indian peninsula, but it would be on the distinct understanding that the result would be erroneous by a quantity, small perhaps, but on no account to be ignored, which would have to be called "mean English (or Indian) deflection, amount unknown," and this is all that we can at present hope to do, even if we can do so much.

The reader will remember that he was called upon to take for granted, that it was possible so to deposit him and his table and paper at two places that, were there no local attraction at either (or the same at both), the point of his plummet should indicate the same spot on his paper at both, so that his paper should hold the same position with regard to the north and south points. The object in view in so placing the paper was to show at a glance the amount and direction of the deflection at the second station, relatively to that at the first. It is unnecessary to go into detail to show how this could be done. It will be sufficient to show that the results thus intended to be illustrated, can be obtained. To do this I must first re-

mark that the position of a point on a spheroid of revolution of known excentricity, is known, as soon as its latitude and longitude (measured from some assumed fixed point) are known. Now the latitude of a point is defined as the angle which the normal makes with the plane of the equator, a quantity clearly indeterminate except on the assumption that the direction of the normal itself is known. This definition must therefore be modified, and we must acknowledge two latitudes, a *local* or apparent, and a *true* or astronomic latitude, of every place. The difference is the resolved portion of the deflection, in a north and south direction, arising from local attraction. *Assuming absence of attraction at A*, we can determine its position on the spheroid, and thence by geodetic triangulation lay down the position, and determine the *quasi* astronomic latitude of B. We can also, by direct observation, determine the *local* latitude of B, and comparing the two, we have the resolved portion of the deflection at B, in the direction of the meridian. Again by direct observation at A, and the help of the intermediate triangulation, we can lay down the *quasi* astronomic meridian at B, comparison of which with the result of direct observation at B, determines the resolved portion of the deflection at B, in the direction of the prime vertical.* Combining these two, the reader will allow that we may obtain the amount and direction of deflection at B, always on the assumption of *no attraction at A*, the truth of which assumption, as I said before, is after all immaterial.

It will have been noticed that the possibility or impossibility of doing as above, depends on our power of triangulating between all the points visited. It is, therefore, evident that we are to all intents and purposes restricted to comparatively small and isolated portions of the earth's surface. Thus we might, were there no other difficulties in our way, obtain a mean direction of the plumb-line for England, for France, for Prussia, for Russia, nay, as things now stand, perhaps for the greater part of Europe as one portion; for North America as another; for India as a third; and so

* Some explanation is perhaps needed of the reason why deflection in a direction perpendicular to the meridian is measured by determining the angular deviation of the local from the true meridian, rather than the actual difference between local, and true longitude. The fact is that at present we have no means of determining local longitude with any degree of accuracy at all comparable with that to which we can attain in latitude. But inasmuch as longitude is merely another word for 'position of meridian' we come to the same result by ascertaining the latter. This we do by measuring the horizontal deviation of the point, where a local (i. e., deflected) vertical circle passing through the pole meets the horizon from the point where a true vertical circle would meet it. This angular deviation is to the resolved portion of the deflection in a direction perpendicular to the meridian, as the tangent of the latitude is to unity. Hence deflection perpendicular to the meridian (or in longitude) = horizontal deviation of meridian $\times$ cotan. latitude.

on for the chief portions of the earth's dry surface; but beyond this we can not go until these several portions shall have been connected by actual triangulation, a tolerably remote prospect. And even then we shall have covered but a third of the globe with connected points. How the remainder is ever to contribute its due share of data of the required kind is to me a problem so incapable of solution that I think, I was justified in saying that "we never shall be able to assign the absolute amount and direction of local attraction at any place."* It may indeed be said in reply that we never can obtain perfect accuracy in any thing in this world. Granted; we can at any rate aim at local accuracy; and we shall soon see that the attainment of even this, is hardly better than a wild speculation as yet.

To enable us the better to estimate our powers, I will now draw attention to the magnitude of the quantities which we have to measure, and the degree of accuracy attained or attainable in the means of measurement.

At page 664, of the "Account of the Principal Triangulation of the Ordnance Survey of Great Britain and Ireland," there is a table showing the results of direct computation of the deflection at 16 points, independently of any considerations other than those founded on the configuration of the neighbouring surface, and the assumed mean density of the materials forming them. Their range is about $\pm 5''$ in the direction of the meridian. Valuable as these computations are, they show rather what the deflection *should be* according to certain assumed laws than what it is *found to be* according to certain laws which we desire to know more about. I therefore pass on to the more reliable results of actual observation.

In the "Cornhill Magazine" for October, 1862, appeared a notice of the amount of local attraction detected near Moscow, within a circle of 21 miles across, by comparison of actual observation with the results of inter-triangulation. It has a range of $\pm 8''$. Even allowing the existence of large errors of observation, the mere inspection of the data is sufficient to lead to the conclusion of relative deflection amounting to $\pm 10''$ within

* I have perhaps hardly laid sufficient stress on the necessity of even distribution of the stations of observation over the whole globe, in order to approximate as nearly as possible to the only conditions under which a perfectly true result could be attainable, viz., when every point on the earth's surface is one of an infinite number of stations of observation. The attraction of the sea being negative, (or rather, less than what would exist were the sea land,) it is clear that the negative influence of an Eastern sea will produce a constant bias unless counteracted by a corresponding bias caused by a Western sea also. The Indian peninsula presents a case in point; but although Eastern and Western bias may here be fairly assumed as counteracting one another, there still remains a Southern negative influence due to the absence of a counteracting Northern sea. Pursuing this train of thought, we come to the conclusion that so long as we are restricted to land surveys and stations we shall fall of eliminating bias, owing to the known preponderance of sea in the Southern, and land in the Northern hemisphere.

a direct distance of 12 miles on an appreciably level country.* It is not easy to restrain speculation in presence of such facts as these.

Here in India we are ready to accept 30" to 40" of deflection as reasonable, within short distances of the Himalayan range. But we rarely trust anything above 10" or 15" elsewhere—not that we have any reason to doubt the *possibility* of such large quantities, but simply that such cases as that at Moscow, have not yet been substantiated sufficiently to remove old prejudices.

The accuracy of any measure of local deflection depends—1st, On that of the trigonometrical deduction from origin; and 2nd, On that of direct observation of the local latitude and meridian. The latter is tolerably uniform, 1" to 2" representing the limit of probable error, beyond which it would appear unwise to attempt any deductions. The former, on the other hand varies greatly; so greatly indeed that nothing but the most careful consideration of all the varying circumstances which enhance or detract from its value, such as instrumental appliances, system of triangulation, of observation, and of reduction, character of country traversed, &c., &c., would justify even a guess at the degree of accuracy to be expected; at the close of any triangulation of given length, *ceteris paribus*, however, it would probably be as the square of its length. Assuming that an error of an inch per mile may fairly be expected in the length of the closing side of a series of triangles of 500 miles in length, (which be it understood is the very least that can as yet be looked for in the best triangulation,) and we have at once an error of half that amount for every mile of the whole length or an error of 20 feet in direct length. But this gives a very inadequate idea of the probable error of position of the end of the triangulation, for not only would error in linear unit and error of observation, producing erroneous *direction*, very considerably increase this uncertainty, but we have an element of uncertainty arising from the very nature of the question we are dealing with, which it would seem impossible to guard wholly against. Let me explain. In illustrating just now the process by which the absolute amount of deflection might be determined (by the help of perfect triangulation over the entire globe) by reference to a mean direction of the plumb-line I assumed *no attraction at the origin*, and afterwards asserted that the result was independent of such an assumption. That

* I speak from recollection of a chart of the district, accompanying a report on the subject, alluded to in the "Cornhill Magazine."

assertion was only true when the distance from A to B was supposed short. It was quite true that, however false the assumption of no attraction *in the direction of the meridian* might be at A, such assumption would in no respect vitiate the result at B relatively to A, whatever the distance; but the case is very different as regards *error of direction of meridian* (i. e., deflection in a direction *perpendicular* to the meridian) at A. The position of B, trigonometrically deduced from A, is entirely dependent on the truth of the assumption in this respect, when the distance is great, and therefore also the deflection obtained by comparing such position with that assigned by direct observation. To illustrate more clearly my meaning, and to show the great importance of starting at some place, where we have reason to believe that the assumption of no attraction *perpendicular to the meridian* is a true one, let us suppose the station A to be on the sea coast at Bombay, and B on the sea coast at or near Vizagapatam, on the opposite side of the peninsula, the two stations being connected by perfect triangulation. Let the meridian have been determined by direct observation at Bombay. There is a strong probability amounting almost to certainty, that the plumb-line is then drawn considerably to the eastward owing to the preponderant attraction of the land, and defective attraction of the sea, and the consequence of such deflection would be that the local meridian would fall to the eastward of the true meridian. Let us for the sake of example assume the horizontal deviation so caused to be $10''$. With azimuths founded on this local meridian let the triangulation have been computed and plotted. It is evident that every point in it, B among others, will have a position assigned to it slightly to the north of its true position. The error will be represented in feet by $5280 \times \sin. 10'' \times$ distance from A in miles; or, taking the breadth of the peninsula here at 700 miles, B will be assigned a position 180 feet south of its true position, corresponding to an error in latitude due to deflected azimuth at the origin, of nearly $2''$. By exactly this amount would our determination of relative deflection *in the direction of the meridian* at the two points A and B be erroneous from this cause alone. This might in practice be considerably increased from the several causes of error before alluded to. And be it observed that the deviation here assumed, viz., $10''$ is by no means an improbable one.

I think this is sufficient to show the importance of seeking a locus of no attraction for observations for initial azimuth.

We have now arrived at the following conclusions—1st. That the amount and direction of local attraction at any place are unassignable *à priori*.

2nd. That the *relative* amount between two points not very far apart may be determined with tolerable accuracy, but that at distances exceeding (say) 200 miles, none but triangulation of the best description can be expected to give reliable results.

3rd. That great accuracy cannot be looked for even over small areas owing to the labor and expense of astronomical observations of the requisite value.

Lastly, that until the whole habitable (and inhabitable) globe, or, to confine ourselves within reasonable limits, until the whole of India, and more especially the Southern portion, shall have been covered with first class triangulation such as the North and West alone can as yet boast of, here and there, and with numerous astronomical stations (whose present number may be counted on the fingers) it is vain to do more than speculate on "Local Attraction."

In one word, we know little on this subject but our own ignorance, the necessity of knowing more, and the difficulties in the way of the attainment of such knowledge. Reliable data we have absolutely none that I care to call such—and with this confession of ignorance I leave the subject for the present.

J. HERSCHEL.

No. XXXIV.

TURBINE AND CENTRIFUGAL PUMP,
AT ASUFNUGGUR, ON THE GANGES CANAL.

Constructed at the Roorkee Workshops.

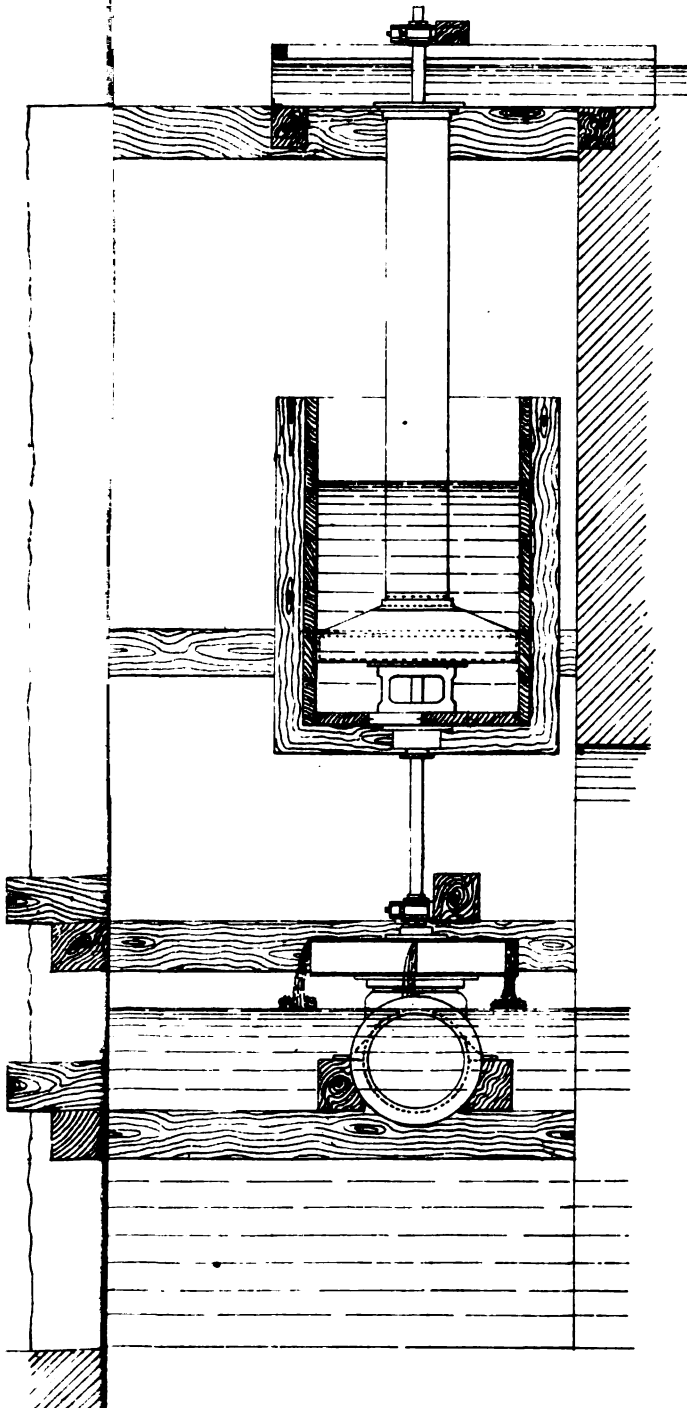
THE Centrifugal Pump at Asufnuggur was ordered by Col. Turnbull, Superintendent General of Irrigation, N. W. Provinces, during the famine year 1860-61, as an experiment to test the practical value of irrigating the high land at these Falls, which, owing to the great distance from the Puttree Falls (the ones immediately above those at Asufnuggur), and the difficult nature of the ground, rendered the bringing of a rajbuha remuneratively, impossible; this will readily be seen when it is stated that the Puttree Falls are more than 12 miles from Asufnuggur, and the valley of the Solani intervenes between them.

The machinery is placed at the side of the lock, in the mill channel, a wooden box or trough conducting the water from the upper mill channel to the supply pipe of the Turbine, and also to the Centrifugal Pump. The description of Turbine used, is the ordinary re-action one of Messrs White-law and Stuart; the Centrifugal Pump is also the ordinary one, with four curved vanes. The Turbine and Pump are fixed on the same shaft, and make the same number of revolutions per minute.

The action of the machine is as follows:—When the valve at the bottom of the wooden box is raised, the water descends through the pipe, and issues from the four orifices of the turbine; the re-action of this water issuing causes the turbine to revolve: at the same time the pump draws the

JMP

Section on a b.



LITH. T. C.



water into the centre of its disc and throws it out at the circumference, from which it rises by the vertical pipe to the channel above. The arrows show the direction the water takes.

The pump being placed in the water there is no necessity for fanging it; the valve only requires to be raised, when the water immediately commences to flow, and continues to do so night and day, without trouble and with very little attention.

Appended is a memo. from Lieut. Forbes, R.E., Superintendent Northern Division, Ganges Canal, giving the quantity of land irrigated, and the revenue derived from it; from this it is evident that the pump has been a success. There is a further saving from the pump, which is not shewn in Lieut. Forbes' statement. This is the irrigation of the mangoe garden at the Falls: previous to the pump being erected, this garden was irrigated by bullocks at a cost of 18 rupees per month, during the months that irrigation was necessary. If the gain on this head had been included, the result of what is only to be considered as an experiment, would have been more favorable.

ANGUS CAMPBELL,
Officiating Superintendent Workshops.

Memo. on the Asufnuggur Pump, by LIEUT. FORBES, R.E. (referred to above.)

The following table shews area irrigated and revenue derived, from the machine since it was first erected:—

	Beegahs.	Sis.	R.	A.	P.
Rubbee, 1861-62, . . .	44	2	36	1	6
Khureef, 1862, . . .	41	10	59	7	2
Rubbee, 1862-63, . . .	0	0	0	0	0
Khureef, 1863, . . .	21	10	28	2	8
Rubbee, 1863-64, . . .	129	14	107	15	10

This latter amount of 129-14, is I fancy, below the mark. I only received the revenue papers a few days ago, and think the true measurements will be somewhere about 200 beegahs.

The pump is capable of affording irrigation to about 230 beegahs, and the revenue that could be derived from it should be about Rs. 300 per annum, viz. (Rubbee, Rs. 160, and Khureef, Rs. 140). The cost of the pump was Rs. 1,176, so the income derived from it should be 25 per cent. on the original cost.

J. G. FORBES.

No. XXXV.

NOTES ON RETAINING WALLS.

By "DHARWAR."

WATER PRESSURE.

PRACTICALLY the maximum pressure against walls is that produced by water, the formula for which is, $P = 31.25 h^2$, which multiplied by its leverage $\frac{h}{3}$ is equated with the moment of stability of the wall which is $W_1 h \frac{b^2}{2}$, and therefore

$$\text{Breadth of base} = b = \sqrt{\frac{4.56 h}{W_1}} \quad \dots \quad \dots \quad \dots \quad (1)$$

where, P = horizontal pressure of material retained, in foot pounds, per unit of length of wall.

h = height to top of wall, which is always supposed level with upper surface of mass retained.

b = breadth of vertical rectangular wall, at base.

W_1 = weight of masonry per unit;

all units being in feet pounds, and the walls to resist being supposed to be a vertical rectangular wall of rubble in mortar, which can only over-set by turning round the outer angle of its base.

Where specific gravity of masonry is given, the above formula becomes

$$b = .58 h \sqrt{\frac{1}{S_1}} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (1a)$$

S_1 being the specific gravity of the wall.

In the above equations, W_1 and S_1 being the only variables, it will be easy to obtain average values for b , and such when obtained I purpose to equate with walls of other sections, which are more valuable in

practice; and to make diagrams of these, so that the relative dimensions of various sectioned walls may be seen at a glance.

If we assume stone masonry to vary between 120 and 150 lbs per cubic foot then, b will be equal, as

$$\text{a Maximum } .58 h \sqrt{\frac{1}{1.9}} \text{ and as}$$

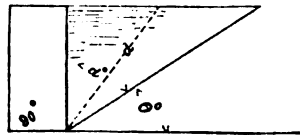
a Minimum $.58 h \sqrt{\frac{1}{2.4}}$, or, .42 and .36 times h , and averaging .39 h ; this gives a wall of about 15 feet base for a height of 40 feet, for diagram of which see *Fig. 1*, in sheet.

For a brick wall $W_1 = 100 \therefore b = .46 h$.

EARTH PRESSURE.

A wall being properly drained at back, will, when it retains earth, have to sustain, as a maximum, the pressure of *loose* earth.

I. The ordinary case of this is that of a bank whose top is on a level with the top of the wall and is horizontal, the pressure is usually calculated by the formula



$$P = \frac{W h^2}{2} \tan^2 \frac{1}{2} \alpha \dots \dots \dots (2)$$

and multiplying by $\frac{h}{3}$ we have its moment: which, equated with $\frac{W_1 h b^2}{2}$ (the moment of a vertical rectangular wall,) gives

$$b = .58 h \tan \frac{1}{2} \alpha \sqrt{\frac{W}{W_1}} \dots \dots \dots (3)$$

where $\alpha = (90^\circ - \theta)$

θ = angle of repose or natural slope, and its tangent equals the coefficient of friction of earth

W = weight of loose earth per unit, and the other symbols, as before.

In Weale's Engineer and Contractors' Pocket Book, for 1862, is published Mr. Neville's deductions on retaining walls, and he has there given a Table, the use of which facilitates the calculation of strength of walls for every case; using his tabular coefficient = Cf we have for any bank, whether horizontal, or not,

$$P = Cf W h^2 \dots \dots \dots (2a)$$

and in case, as equation (3) $b = \sqrt{\frac{2 P}{3 W_1}} = .82 h \sqrt{Cf \frac{W}{W_1}} \dots (3a)$

In equations (3), (3a), the variables are, for any given height, $\frac{W}{W_1}$, and $\tan \frac{1}{2} \alpha$, or $\left\{ \begin{array}{l} C f; \frac{W}{W_1} = \frac{S}{S_1} = \text{specific gravity of earth} \\ \text{of wall.} \end{array} \right\}$

for earth, S will range from 1.5 to 1.9, and for rubble, S_1 from 1.9 to 2.5.

$\tan \frac{1}{2} \alpha$ or its value $\left(\frac{90 - \theta}{2} \right)$ will vary with θ , which ranges from 30° to 46° , and $\therefore$ the $\tan \frac{1}{2} \alpha$ from .58 to .40.

The possible combinations of these variables is infinite from,

$$\text{as a Maximum, } b = .58 \times .58 \sqrt{\frac{1.9}{1.9}} = .33 h$$

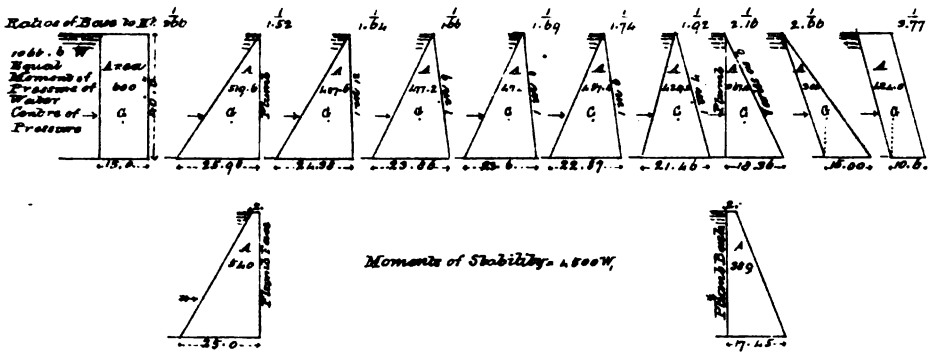
to a Minimum, $b = .58 \times .40 \sqrt{\frac{1.5}{2.5}} = .18 h$ and the mean of these coefficients, or .25 is probably near the truth for all usual cases. It is evident by the following tabular arrangement, of several values of the variables with the deduced bases in terms of the height that, excepting the extreme cases, the above average coefficient is suitable for most cases; also it is evident that the variation of the value of the co-efficient due to the ratio $\frac{W}{W_1}$, is of more consequence than that of the $\tan \frac{1}{2} \alpha$, hence that the difficulty of determining b , from direct experiment, is not very great if we assume an approximate angle of repose, because $\frac{W}{W_1}$ can be obtained by any person having command of a set of scales and weights.

TABLE I.

No.	DATA.			CALCULATIONS.				REMARKS.
	$\angle$ of repose.	Weight of e. f. of bank.	Weight of e. f. of wall.	$\tan \frac{90 - \theta}{2}$	Square root of ratio of wall to bank.	Constant multiplier.	Breadth of base.	
	θ	W	W_1	$\tan \frac{1}{2} \alpha$	$\sqrt{\frac{W}{W_1}}$		b	
1	17°	135	140	.74	.98	.58	.42 h	Wet-clay, basalt rubble, } Basaltine.
2	45°	120	180	.41	.96		.23 h	Damp clay, limestone do., }
3	29°	90	120	.59	.87		.25 h	Mixed sand and earth, dry, }
4	$43^\circ 10'$	97	125	.43	.88		.22 h	Dry earth and rubble, }
5	54°	106	143	.32	.86		.16 h	Moist do. basalt do., } Mahan.
6	54°	97	106	.32	.95		.18 h	An average case with brick or light } (stone.
7	34°	112	130	.53	.93		.28 h	Earth. Neville. }
8	43°	55	120	.43	.67		.17 h	Moist black soil, slate } Bharwar
9	40	82	120	.46	.82		.22 h	rubble, do. } by soil.
10	34	100	100	.53	1.00		.31 h	Red soil, loose, do. }
11	37°	94	120	.50	.88		.25 h	Earth and brick wall.
12	37°	94	130	.50	.85		.24 h	Average cases.
13	34°	100	110	.53	.95		.29 h	do. do.

DIAGRAMS OF RETAINING WALLS OF EQUAL STRENGTH.

FOR WATER PRESSURE



FOR EARTH PRESSURE.

