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Numbers 8 and 9, give the results of some experiments I have made in this country on the values of $\frac{W}{W_1}$ and θ, but I am convinced that each case must be determined by its own experiments, and that unless such be done and the data be well assured, it will never be safe to design a vertical faced rectangular retaining wall, with a base less than $\frac{1}{2}$ the height; even a shower of rain may alter the value of θ and W, or carelessness on the part of an overseer, in neglecting the precautions of back drainage and "weeping holes" at base, may upset the value of the most accurate investigation. I have therefore assumed a base of $\frac{1}{2}$ for the wall, for earth pressure, in the diagrams.

Law, in Weale's Series on Rudiments of Engineering, framed a table, which I give, adding a column shewing the base which I deduce from his constant multiplier (k) equal W tan $\frac{2a}{2}$, in equation (2); or Cf, in equation (2a.)

In calculating, I assume $W_1 = 140$, which although a high value, is obtained as follows:—

W_s = weight of stone 150 lbs.
W_m = weight of mortar 106 lbs. } mixed in the proportion

of $\frac{4}{5}$ mortar to $\frac{1}{5}$ stone, which is a fair proportion for good rubble.

Hence $W_1 = \frac{4}{5} W_s + \frac{1}{5} W_m = \frac{(4 \times 150) + 106}{5} = 140$ lbs., nearly.

Equation (2) with these values becomes

$$b = \cdot 82\, h \sqrt{\frac{h}{40}}$$ from which equation the last column of Table II is calculated.

TABLE II.

No.	Nature of Bank.	Weight in lbs. per c. f.	Angle of repose.	Constant multiplier = k.	Breadth of base in terms of height.
1	Fine dry sand, .	94° to 119°	30° to 40°	15·66, to 12·938	·22 to ·246 h
2	Loose dry shingle, .	106° to 94°	34° to 43° 10′	12·06 to 8·81	·24 to ·17 h
3	Common earth (dry),	106	54°	5·595	·156 h
4	Do. do. (moist,)	125	55°	6·213	·16 h

Having by any of the equations, or tables, got the proportions of a vertical faced rectangular wall, it will always be desirable to know what other walls may be substituted for them; practically, there is a great waste of material in rectangular walls, and, of all wall sections

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those that are, or approximate to, triangles will be the most economical as in those the mass of masonry will be, at every point, proportional to the pressure.

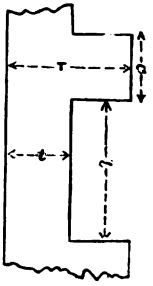
To obtain walls of equal strength we may equate their moments with that of our standard wall, which is $W_1 \frac{h b^2}{2}$ for the unit of length; or area of section × leverage, the weight of unit being neglected as common to both; therefore

$$A \frac{b}{2} = A' y \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

where A = area of standard wall
A′ = area of required wall
y = leverage, round outer angle.

II. For a counterforted vertical rectangular wall, this equation becomes $\frac{h b^2}{2} = \left(\frac{h l t^2}{2} + \frac{h C T^2}{2}\right)\left(\frac{1}{l + C}\right) = \frac{h}{2}\left(\frac{l t^2 + C T^2}{l + C}\right)$, and $b^2 = \frac{l t^2 + C T^2}{l + C}$, from whence any of the dimensions can be obtained, the others being assumed

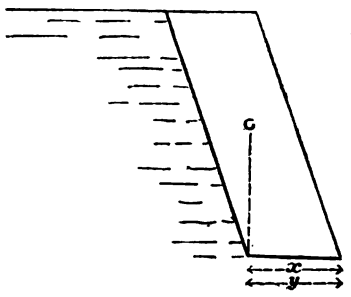
where l = length of wall between counterforts
t = breadth of ,,
C = length of counterfort
T = breadth of ,,



If l be assumed = $3t$, C = t and T = $2t$ then

$$t = \sqrt{\frac{4}{7} b^2} = \cdot 75\, b.$$

III. For a rhomboidal wall, the maximum stability is where the wall reclines, that is, when the vertical through the centre of gravity cuts the interior angle of the base.



in equation (4) $A = h\, b$
$A' = h\, x$
$y = x$

$$\therefore \frac{h b^2}{2} = h x^2 \text{ and } x = \sqrt{\frac{b^2}{2}} = \cdot 707\, b^*$$

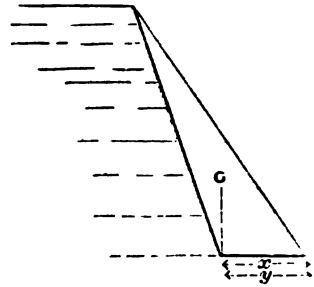
IV. Also in a reclining triangular wall the maximum stability to

* In this, and the following, I neglect the changes in value produced by the slope of the back of wall, and assume the plane to be vertical.

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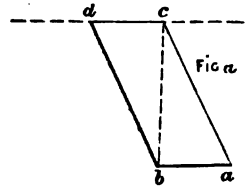
resist forward oversetting will be when $y = x$, in equation (4), and as

$$A' = \frac{h\,x}{2} \therefore \frac{h\,b^2}{2} = \frac{h\,x^2}{2}$$

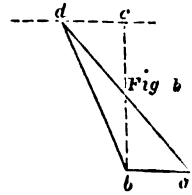


and $\therefore x = b$.

The sections of these walls are constructed as follows :—For rhomboidal wall, *Fig. a*, set off $a\ b = x$, at b erect a perpendicular $b\ c = h$; join $a\ c$ and draw $b\ d$ parallel to $a\ c$, then $a\ b\ c\ d =$ required wall.



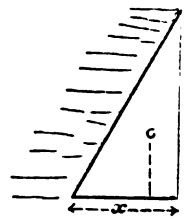
For triangle, *Fig. b*, proceed as above, and the face of the wall is a line from (*a*) passing through bisection of $c\ b$. Join $d\ b$, for back of wall then $a\ b\ c\ d$ is the required wall.



V. A triangular wall with plumb face, $A' = \frac{h\,x}{2}$ and $y = \frac{1}{3}\,x$,

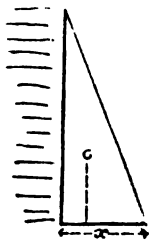
therefore equation (4) becomes $\frac{h\,b^2}{2} = \frac{h\,x^2}{2\times 3} \therefore x =$

$$\sqrt{3\,b^2} = 1{\cdot}73\ b.$$



VI. Or with a plumb back, A' as above, and $y = \frac{2}{3}\,x$,

whence (4), $\frac{h\,b^2}{2} = \frac{2\,h\,x^2}{3\times 2} \therefore x = \sqrt{\frac{3}{2}\,b^2} = 1{\cdot}23\ b.$



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VII. Any triangle such as in *Fig.* 2, whose face batter r, in terms of the height, is given, has,

$A' = \frac{h\,x}{2}$, and $y = \frac{x}{3} + \frac{r\,h}{3}$ because,

$$H\,G + H\,t = y$$

but $H\,G : \frac{2}{3}\,h :: \frac{1}{3}\,x : h$

$$\therefore H\,G = \frac{x}{3}$$

and $H\,t = \frac{r\,h}{3}$

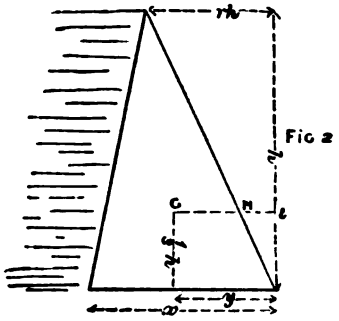


Fig 2

In equation (4), with the above values of $A'y$, we have

$\frac{h\,b^2}{2} = \frac{h\,x}{2}\left(\frac{x}{3} + \frac{r\,h}{3}\right)$; and $x^2 + r\,h\,x = 3\,b^2$, a quadratic whence

$$x = \sqrt{3\,b^2 + \left(\frac{r\,h}{2}\right)^2} - \frac{r\,h}{2} \quad \ldots\ \ldots\ \ldots\ \ldots\ (5)$$

where

x = breadth of base of any triangular wall with a given face batter, b and h as before, and

r = the fraction representing batter of wall face, in terms of the height.

The equation for the moment of stability of this wall = M^1

$$= W_1\left(\frac{h\,x^2 + h^2\,x\,r}{6}\right) \quad \ldots\ \ldots\ \ldots\ \ldots\ \ldots\ (6)$$

VIII. A trapezoidal wall, such as *Fig.* 3; by equating moments we get—

$$\frac{W_1\,h\,b^2}{2} = \frac{W_1\,h\,z^2}{3} + W_1\,h\,z\,t + \frac{W_1\,h\,t^2}{2}$$

$$\therefore b^2 = \tfrac{1}{3}\,z^2 + 2\,z\,t + t^2$$

Where z = portion of the base due to batter,

t = thickness of top,

x = breadth of base, $= z + t$.

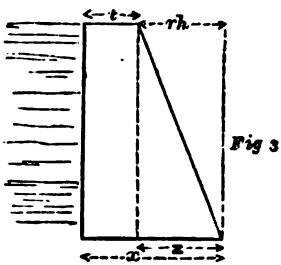


Fig 3

If the batter of face be given, $z = r\,h$, the breadth of top is then required, and is, $t = \sqrt{b^2 + \frac{z^2}{3}} - z$, and $z = \sqrt{\frac{3}{2}\,b^2 + \frac{3}{4}\,t^2} - \frac{3}{2}\,t$, when the breadth at top is fixed.

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IX. Also in one, as in *Fig.* 4, where the back batters and the face is plumb, $t = \sqrt{b^2 - \frac{z^2}{12}} - \frac{z}{2}$, and

$$z_1 = \sqrt{3\,b^2 - \frac{3}{4}t^2} - \frac{3}{2}t.$$

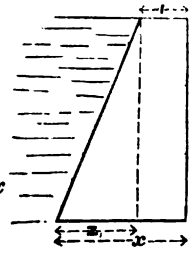


Fig 4

In these two cases, if $t = o$, z and z_1 become $= x$ in cases *Figs.* 4 and 5 ∴

X. In one such as shewn in *Fig.* 5, let z_1 = part of base due to batter at back, $z = r\,h$

Then equating stabilities we have $\frac{h\,b^2}{2}$

$= \frac{h\,z^2}{3} + h\,t\left(\frac{t}{2} + z\right) + \frac{h\,z'}{2}\left(\frac{z'}{3} + t + z\right)$

and t and z being given

$z_1 = \sqrt{3\,b^2 + \cdot 25z^2 - (\cdot 75\,t^2 + 1\cdot 5\,t\,z)} - 1\cdot 5\,(t + z)$; and $x = z + t + z_1$.

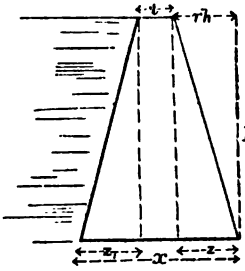


Fig 5

This last section will not be found of much value, and a section as in *Fig.* 6, will be superior.

The above equations I recapitulate in the following tabular form, giving also the equations by which, x may be got from the data direct, instead of through the medium of the standard wall.

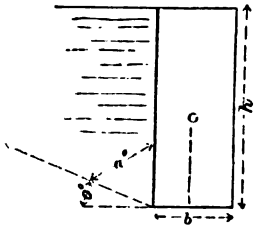
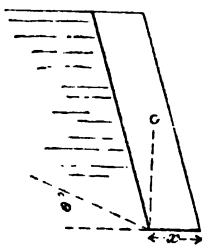
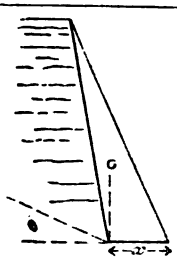
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TABLE III.

(Giving values of x.)

P = Horizontal pressure against wall, obtained either by Neville's tables, or by formula, and is independent of shape of mass retained.
h = Height of wall, taken vertically.
b = Breadth of wall, when vertical and rectangular.

$\frac{W}{W_1} = \frac{\text{Weight of mass retained}}{\text{Weight of masonry}} = \frac{8°}{S_1}$ and $\sqrt{\frac{1}{S_1}} = 8\sqrt{\frac{1}{W_1}}$
$\theta = \angle$ of natural slope. $\alpha = 90° - \theta$
r = Fraction of height representing batter of wall as $\frac{1}{2}h = rh$.
x = Breadth of base of any wall.

Figures of Walls.	Values of x the breadth of base of walls, as in Column 1.			
	When compared with standard.	Generally for any ascertained horizontal pressure.	For water.	For earth with top horizontal.
1	2	3	4	5
	b	$\cdot 8\sqrt{\frac{P}{W_1}}$	$4{\cdot}5\,h\sqrt{\frac{1}{W_1}}$	$\cdot 58\,h \tan \frac{1}{2}\alpha \sqrt{\frac{W}{W_1}}$
	$\cdot 7\,b$	$\cdot 58\sqrt{\frac{P}{W_1}}$	$3{\cdot}2\,h\sqrt{\frac{1}{W_1}}$	$\cdot 41\,h \tan \frac{1}{2}\alpha \sqrt{\frac{W}{W_1}}$
	b	as in	case	No. 1.

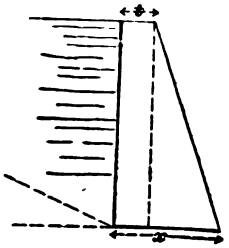
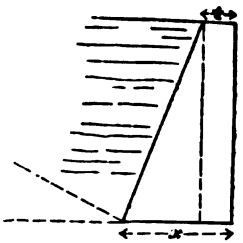
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TABLE III—*(Continued.)*

Figures of Walls. 1	Values of x the breadth of base of walls, as in Column 1.			
	When compared with standard. 2	Generally for any ascertained horizontal pressure. 3	For water. 4	For earth with top horizontal. 5
	$1{\cdot}7\ b$	$1{\cdot}4\sqrt{\frac{P}{W_1}}$	$8\ h\sqrt{\frac{1}{W_1}}$	$h\tan\frac{1}{2}a\sqrt{\frac{W}{W_1}}$
	$1{\cdot}2\ b$	$\sqrt{\frac{P}{W_1}}$	$5{\cdot}6\ h\sqrt{\frac{1}{W_1}}$	$\cdot71\ h\ \tan\frac{1}{2}a\sqrt{\frac{W}{W_1}}$
	$\sqrt{3\ b^2+\left(\frac{r\,h}{2}\right)^2}-\frac{r\,h}{2}$	$\sqrt{\frac{2P}{W_1}+\left(\frac{r\,h}{2}\right)^2}-\frac{r\,h}{2}$	$\sqrt{\frac{62\frac{1}{2}\,h^2}{W}+\left(\frac{r\,h}{2}\right)^2}-\frac{r\,h}{2}$	$\sqrt{\frac{W}{W_1}\,h^2\tan^2\frac{1}{2}a+\left(\frac{r\,h}{2}\right)^2}-\frac{r\,h}{2}$

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TABLE III—*(Continued.)*

Figures of Walls.	Values of x the breadth of base of walls, as in Column 1.			
	When compared with standard.	Generally for any ascertained horizontal pressure.	For water.	For earth with top horizontal.
1	2	3	4	5
	$\sqrt{1{\cdot}5\,h^2 + {\cdot}75\,t^2} - \frac{t}{2}$	$\sqrt{\frac{P}{W_1} + {\cdot}75\,t^2} - \frac{t}{2}$	$\sqrt{\frac{31\frac{1}{4}h^2}{W_1} + \frac{3}{4}t^2} - \frac{t}{2}$	$\sqrt{\frac{h^2\,W}{2\,W_1}\tan^2\frac{1}{2}a + {\cdot}75\,t^2} - \frac{t}{2}$
	$\sqrt{3\,h^2 - {\cdot}75\,t^2} - \frac{t}{2}$	$\sqrt{2\,\frac{P}{W_1} - {\cdot}75\,\frac{t^2}{2}} - \frac{t}{2}$	$\sqrt{\frac{62{\cdot}5\,h^2}{W_1} - \frac{3}{4}t^2} - \frac{t}{2}$	$\sqrt{\frac{h^2\,W}{W_1}\tan^2\frac{a}{2} - \frac{3}{4}t^2} - \frac{t}{2}$

It appears from deductions in pp. 327-328, that the proper thickness of an average retaining wall with vertical faces will be, for water = ·36 h, and for earth—loose earth = ·25 h. These breadths are not far from the rules of practice; and I think may be taken as safe guides: doubtlessly we see weaker walls stand, but we often hear of failures; and although by special consolidation, and by placing the earth in counter-sloping layers, we may much reduce the values of θ; and, by-the-bye, increase those of W, yet the possibility of water getting behind the work, and saturating the stuff, should I think be looked to as a possible contingency, and that no walls should, except

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under special circumstances, be designed less than I have assigned to those in the attached diagram.

The triangular sections in this diagram diminish at the top to a point, but in practice walls would be designed of a practical breadth, which would give an additional stability, and they should also batter at the back in steps, as shewn in *Fig.* 6, as there is a very considerable vertical element of the pressure, which tends to the stability of the wall. It appears that this vertical force bears a large proportion to the horizontal pressure, hence retaining walls should have greater spread given to their foundations than the mere weight of the walls themselves would demand.


Fig 6

Return walls and wing walls of bridges, usually have not the full triangle of earth pressing on them, hence a less section of wall should suffice, their breadth if no water is allowed behind them need seldom exceed, for a vertical rectangular section, the proportion of $\frac{h}{5}$.

Although it is argued above that ·25 h will be the average breadth of a vertical rectangular retaining wall, to resist the horizontal pressure of a bank of loose earth, whose top surface is level with the top of the wall, the friction between the earth and back of wall being neglected; yet this can only be taken as a rough practical guide when no exact data exist. Should, however, the variables in the formula $b = ·578\ h \tan. \frac{90 - \theta}{2} \sqrt{\frac{W}{W_1}}$ be obtainable by actual observation, the following table will be found to facilitate the calculation of the proper breadth of wall.

K, K, K, &c., of the table represent ·578 tan. $\frac{90 - \theta}{2} \sqrt{\frac{W}{W_1}}$ and are coefficients of h in the general formula, whence $b = h$ K, for vertical rectangular walls.

When $\theta = 0$, K is the coefficient for water pressure.

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TABLE OF COEFFICIENTS OF h, FOR FINDING BREADTH OF STANDARD WALLS; $b = h$ K.

Top of Bank Horizontal.

Ratios of $W \div W_1$	Fracts.	$\frac{1}{1}$	$\frac{1}{1\cdot1}$	$\frac{1}{1\cdot2}$	$\frac{1}{1\cdot3}$	$\frac{1}{1\cdot4}$	$\frac{1}{1\cdot5}$	$\frac{1}{1\cdot6}$	$\frac{1}{1\cdot7}$	$\frac{1}{1\cdot8}$	$\frac{1}{1\cdot9}$	$\frac{1}{2\cdot0}$	$\frac{1}{2\cdot1}$	$\frac{1}{2\cdot2}$	$\frac{1}{2\cdot3}$	$\frac{1}{2\cdot4}$	$\frac{1}{2\cdot5}$
	Decs.	1	·909	·833	·769	·714	·667	·625	·588	·555	·526	·5	·476	·455	·435	·416	·4
Angles of Repose. θ °		K															
0°		·577	·55	·527	·506	·488	·472	·456	·448	·43	·419	·408	·399	·389	·381	·373	·365
30°		·334	·317	·304	·292	·282	·272	·263	·256	·248	·242	·235	·230	·224	·220	·215	·211
31°		·327	·311	·298	·286	·276	·267	·258	·251	·243	·237	·231	·225	·22	·216	·211	·207
32°		·320	·305	·292	·281	·270	·261	·253	·245	·238	·232	·226	·221	·216	·211	·206	·202
33°		·314	·299	·286	·275	·265	·256	·248	·240	·234	·228	·222	·217	·212	·207	·203	·198
34°		·307	·293	·280	·269	·260	·251	·243	·236	·229	·223	·217	·212	·207	·203	·198	·194
35°		·3	·286	·274	·263	·254	·245	·237	·230	·224	·218	·212	·207	·202	·198	·194	·19
36°		·295	·28	·268	·258	·248	·240	·232	·225	·219	·213	·208	·203	·198	·194	·19	·186
37°	M	·288	·274	·262	·252	·243	·235	·227	·221	·214	·209	·203	·199	·194	·190	·186	·182
38°		·282	·268	·257	·246	·238	·230	·222	·216	·209	·204	·199	·194	·189	·185	·182	·178
39°		·276	·262	·251	·241	·232	·225	·217	·211	·205	·199	·194	·19	·185	·181	·177	·174
40°		·269	·256	·245	·235	·227	·219	·212	·206	·2	·195	·190	·185	·180	·177	·173	·170
41°		·263	·250	·240	·23	·222	·215	·207	·202	·196	·192	·186	·181	·177	·173	·170	·166
42°		·257	·244	·234	·225	·216	·21	·202	·197	·191	·186	·181	·177	·173	·169	·165	·162
43°		·251	·239	·229	·220	·212	·205	·198	·192	·187	·182	·177	·173	·169	·165	·162	·158
44°		·245	·233	·223	·214	·206	·2	·193	·188	·184	·177	·172	·169	·164	·161	·158	·154
45°		·239	·227	·218	·209	·202	·195	·188	·183	·178	·173	·168	·165	·161	·157	·154	·151

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Example.—The height of a loose earthen bank with horizontal top is 20 feet; its angle of repose is 34°; the weight of a cubic foot is 112 lbs., what will be the breadth (b) of a vertical faced rectangular rubble wall, whose weight per cubic foot is 150 lbs., to retain the bank?

$$\theta° = 34°, \quad \frac{W}{W_1} = \frac{112}{150} = \frac{1}{1{\cdot}34}$$

In left vertical column we find angle of repose 34°, and in top column of ratios $\frac{W}{W_1}$ $\frac{1}{1{\cdot}3}$, and at intersection $K = {\cdot}269$; therefore breadth,

$$b = h\,K = h\,{\cdot}269 = 5{\cdot}38 \text{ feet.}$$

More minute accuracy may be obtained by interpolation of coefficients the mean of coefficients for angles 30° and 31°, giving that for 30½°, and ratios of $\frac{1}{1{\cdot}1}$ and $\frac{1}{1{\cdot}2}$ giving that for $\frac{1}{1{\cdot}15}$.

In the case above the ratio $\frac{1}{1{\cdot}35}$ would be closer to the actual ratio $\frac{1}{1{\cdot}34}$ than $\frac{1}{1{\cdot}3}$; we have therefore by interpolation the coefficient for the former $= \frac{{\cdot}269 + {\cdot}260}{2} = {\cdot}264$, hence the breadth of the wall would have been now exactly 5·28 feet.

This is the breadth for mere equilibrium, and it remains to decide what margin is to be allowed to the wall for stability.

I shall only remark here that in making this allowance the following points are to be noted—

That the stability is decreased by any saturation of the earth retained.

That the stability of the wall is increased by the friction of the earth against its back.

That it is increased by the tenacity of the mortar, joining the wall to its foundation courses.

That it is increased by precautions for thorough drainage at the back, by filling in with chips and shivers of the stone used in building, and by the arrangement of the earth in punned layers.

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No. XXXVI.

CHENAB SAW-MILLS.

Design for erecting SAW-MILLS *on the river Chenab, in the Punjab. By* J. D. SMITHE, ESQUIRE, C. E., *Executive Engineer, Baree Doab Canal Workshops.*

Position of Proposed Site.—THE site selected for the erection of Saw-mills is on an island on the right bank of the river Chenab, close to the boundary of British and Jummoo territory, and where the boundary line runs North-west, along the right bank of the Meeran Khor.

The Meeran Khor.—The Meeran Khor is a stream which, taking out of the Chenab right bank, joins the main river about 12 miles lower down; the island thus formed is much cut up by several other streams into smaller islands.

The Bhag.—The Bhag takes out of the Chenab below the Meeran Khor, but the land between the Chenab and Bhag is covered in floods, and unsuited for building on.

Nature of Site.—This large island, lying between the Meeran Khor and the Chenab, is well above the river, it has several villages upon it towards the lower part, but near the proposed site of Saw-mills there is only one small village called Keree, composed of a few wretched huts. This village will probably not interfere with the contemplated works. There are a few small patches of cultivation about here, but nothing worth taking into consideration, also a large quantity of land below the village not cultivated.

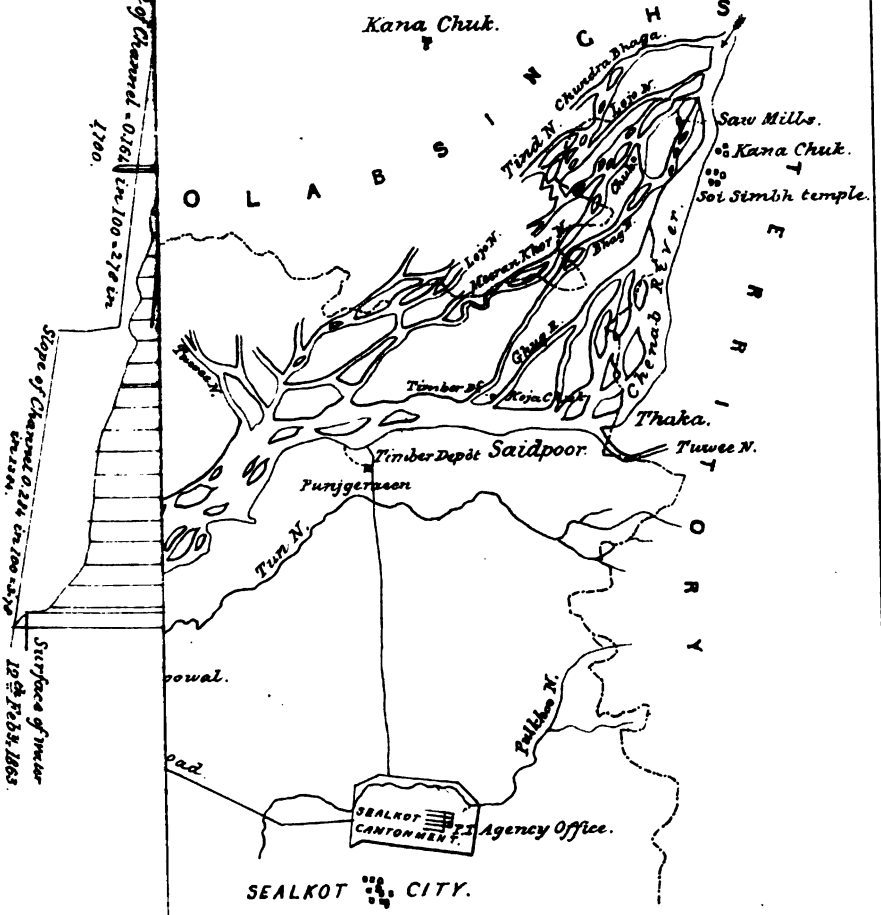
Reasons for Selection of Site.—The country bordering the Chenab was well examined before fixing on the proposed site. The Maharajah of

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No 2.

Survey of Chenab River and Channels Adjacent.

Showing Position of Mills with regard to Sealkot & adjoining Country.



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Jummoo's boundary crossed the Chenab rather low down, and rendered it unadvisable that any place should be selected beyond it. It would have been advantageous on the other hand to keep as low down the river as possible, and near the large roads leading to Sealkote and Wuzeerabad, for facilities of catching and transport, but this could not be done without interfering with villages and cultivated land, and giving a very large mill channel, as well as a secondary channel from the river to look after and control. The slope of the country and river lessens rapidly as we get lower down, and the shingle disappearing gives place to sand, which in the river and secondary channels become quick-sands; we recede also from our building material. These matters being kept in view the proposed place was selected. The field work subsequently showed it possessed natural advantages, and taking all matters into consideration, meets most of our requirements of a site for the erection of Saw-mills.

Levels of Island.—The sheet of sections forwarded will show the nature of the levels; it will be seen that the difference of level of surface of water at head of island, Z, and head of inlet to mill, E, is 11·90 feet, affording ample opportunity of securing a certain depth of water at the inlet, the difference between E and natural surface of land at narrowest part of the island is 2·71, thus showing that the fall is into the river and not from it.

Fall available for a Water-wheel.—The levels of beds of the streams, Meeran Khor, at E, and Ghug, near T, being the proposed inlet and outlet, show that the site of the inlet bridge is 12·59 above outlet. This fall is ample for all our wants and would give much more power than is needed for the mill.

Supply of Water.—A sufficiency of water can always be ensured for the mill, and the nature of the point of island, and its position with regard to the right bank of the Chenab, afford great facilities for controlling the supply, should there be naturally either too little or too much.

Controlling the River.—Should the river show any tendency to leave the front of the island near A, a small spur thrown out diagonally up-stream would give ample water. The bed is all shingle, and medium sized boulders afford material on the spot for the spur. This probably will require to be done eventually. On the contrary should the river come over to the right bank too much, or show signs of going down the Meeran Khor or the Jago above it, small shingle spurs pushed out on the right bank

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would protect them from the force of the river, but instead of enlarging these channels I believe the natural tendency of the river is to cut across the salient angle on the left bank of the Chenab, there being numerous large channels across it now with very low land between them.

Advantages of site for Catching and Landing timber.—The proposed site possesses great advantages in having secondary channels easily controlled on either side, so that it is not so exposed to the eroding action of the streams, as it would be if subject to the full force of the main stream of the Chenab; it gives us a length of water frontage on two sides of nearly 12,000 feet, for floating down large quantities of timber and landing it easily, and this is an immense advantage over a site bounded by main stream of river. A large body of water running at a high velocity, such as that of the Chenab opposite this place, would sweep much of our timber past before it could be secured and landed.

Storing and Despatching.—As will be seen on reference to plan of the island, &c., the piece of ground is of some extent, and gives us ample space for landing and stacking a large quantity of timber, both in logs above the mill, and in scantling below the mill. The Bhag below the tail race is better suited for making up rafts in, than the main stream; as it meets the Chenab lower down, it provides water carriage for the rafts of sawn wood to any place on the Chenab below this.

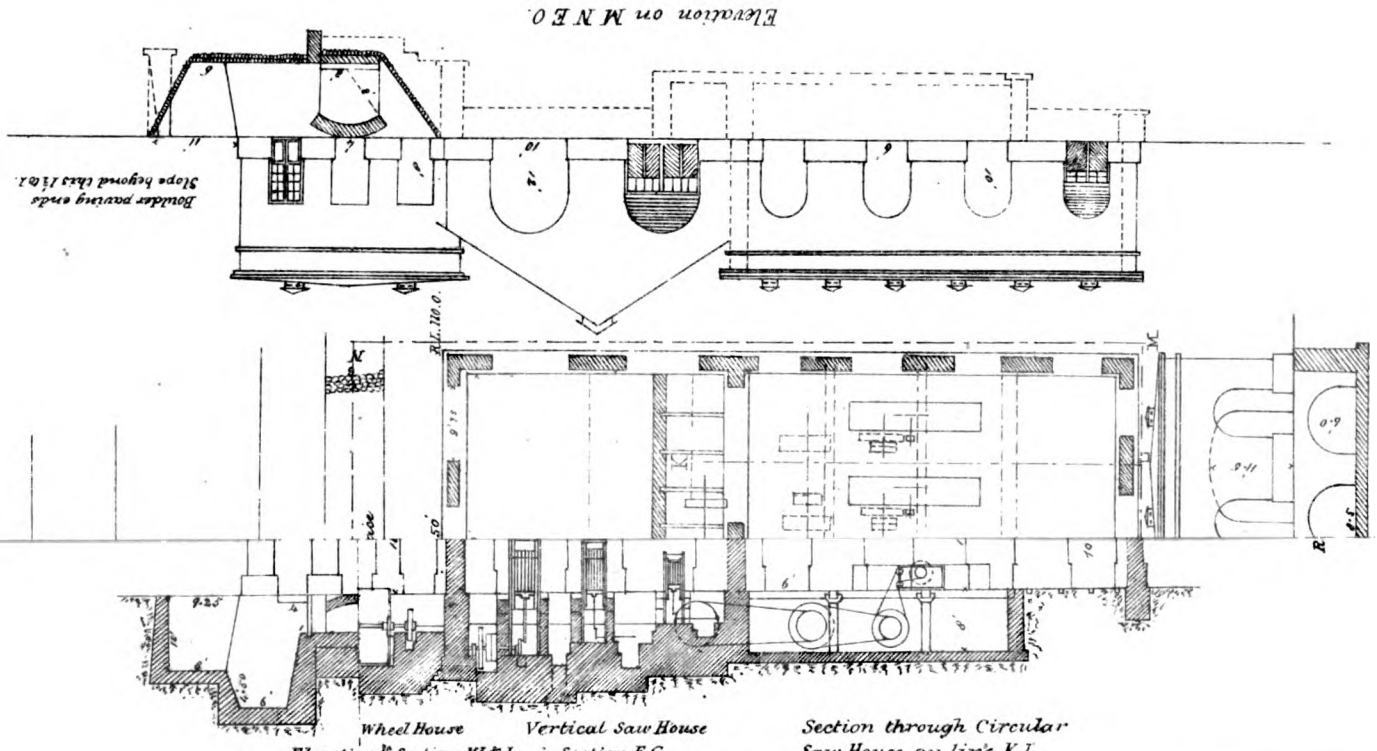
Catching places with regard to site of Mill.—The position for the mill, with regard to length of river and catching depôts is well situated. Of 30,000 logs caught in one season, 25,000 were secured above this island at Aknoor and Reasi. With mills at work it would of course be advantageous to catch as much as possible above them and send it down afterwards when the river is moderate in height and the timber controllable. With this in view no doubt nine-tenths of the timber could be sawn up by the mills, (and which if carried past by floods would not be available for the mills,) and could be disposed of in logs as at present.

Building Material.—With regard to materials for building, they are close at hand; boulders close under the surface, and in beds of streams and river; lime-stone collected and burnt, one-fourth of a mile from site. The upper soil is shingle and earth but this is of no thickness.

Description of Wheel.—The motive power is Water, which will work an Under-shot Wheel. The principle of the Wheel is that known as Poncelet's, the chief feature of which is the curved floats for the water to exert

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PLATE XLIV.



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itself upon; this is considered a great improvement over the ordinary radiating floats of under-shot wheels; it will give 75 per cent. of the effective power of water usually, and more than double the power for the same amount of water, which an ordinary radial under-shot wheel requires.

Size of Wheel.—The wheel is to be 10 feet diameter; width 8 feet; area of sluice, $8{\cdot}0 \times 0{\cdot}6 = 4{\cdot}80$; with head of water for working, 5·80.

Calculation of Power.—The following will show particulars connected with the wheel:—

$$h = 5{\cdot}80 - \frac{0{\cdot}6}{2} = 5{\cdot}5 \quad V = {\cdot}95\sqrt{2gh}$$

$$= {\cdot}95\sqrt{64{\cdot}4 \times 5{\cdot}5}$$

$= 17{\cdot}878$—velocity of water in channel.

$$v = \frac{V}{2} = 8{\cdot}939\text{—velocity of run of wheel.}$$

$$R = \frac{v}{3{\cdot}1416 \times d} \times 60$$

$$= \frac{8{\cdot}939}{3{\cdot}1416 \times 10} \times 60$$

$= 17{\cdot}04$ revolutions of wheel per minute.

$$D = SV = 17{\cdot}878 \times 4{\cdot}80$$

$= 85{\cdot}81$—discharge of water per second in cubic feet

$$P = \frac{D \times 62{\cdot}5 \times H}{550} = 53{\cdot}6 \text{ nominal horse power.}$$

75 per cent., of which = 40·2 effective horse power.

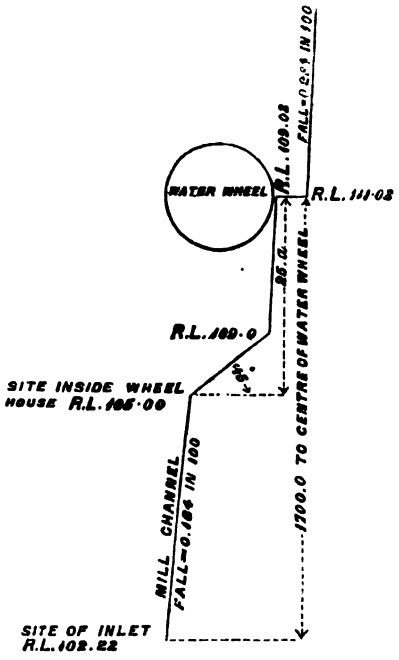
Distribution of Power.—The power of the wheel will be thus disposed of—

11	horse	power	for No. 1 frame.
10	„	„	for No. 2 „
8	„	„	for No. 3 „
8	„	„	for two circular saws.
Total, 37			

But the three frames and two circular saws can under no circumstances be all kept working together. Stoppages to regulate saws, adjusting timber, removing it and bringing up new wood to saws, will keep one standing whilst the others are working, and as there is no occasion for more power than is required, there being no probability of any other machinery ever being attached to the wheel, I consider 40 horse power as sufficient. If needed, however, more power can be obtained by increasing the head of water and the opening of sluice without altering any part of the machinery; these points have been kept in view and provided for.

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Mill Channel.—The slope of mill channel being 0·164 in 100, the quantity of water required will give a depth of about 2·5 in the channel. There is a point in the channel worth noting. Instead of excavating it at a uniform slope from site of bridge to lower point of outlet at wheel, the bed has been kept up, and a sudden slope given into the cistern at the wheel. This reduces the slope in the channel very much, and enables it to be made in natural soil without any boulder paving, it keeps the width of channel uniform and prevents the ground being cut up by a very wide channel, which otherwise becomes necessary when side slopes are kept uniform and the depth of excavation increases towards the wheel. A wide mill channel is objectionable through land required for stocking large quantities of timber near the mill. The plan proposed also saves excavation.



Side Channel for Escape.—An escape channel has been provided for use when the water-wheel is standing. The water in the Punjab rivers for many months in the year is so highly charged with silt that it becomes a nuisance and source of expense when allowed to settle, as it does in a mill channel when a head of water is required; the water being held up and only escaping in a small body at one part, silt falls rapidly, and nothing but digging it out will remove it. The side channel will be opened whenever the water-wheel is not at work, and grooves have been provided for planking at the inlet under the end wall of wheel-house.

Regulating.—The escape channel under ordinary circumstances will be planked up to a height of 6 feet above the bed, and forms an overfall or (weir) for any sudden accession of water; the weir can be regulated by the removal of planks, and the water thus kept at a constant height in the

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wheel cistern. The gate at the inlet to mill channel shuts off the communication with the river when desirable.

Machinery.—Simple and Strong.—In the design of the water-wheel and gearing, simplicity combined with effectiveness have been kept in view; each part is amply strong and no special repairs are likely to be needed. As it is not probable anything beyond the first conversion of timber into scantlings will ever be required here, no provision for future extensions have been taken into consideration.

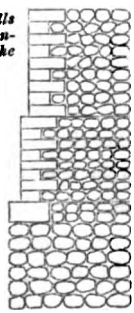
Specification.

There are three buildings for the Saw-mills, viz., Wheel-house, Vertical Sawing-room, and Circular Sawing-room.

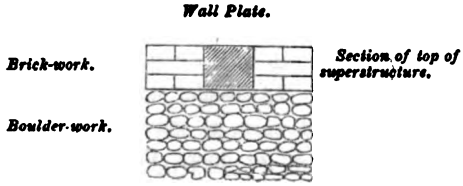
Masonry in Foundation.—The foundations of all the buildings are of boulder masonry in mortar, they vary in depth according to position, the only portion below the ground line faced or built fair on one side, is the following:—The inside of wheel-house above wheel seat; from lower floor to ground level; revetment walls at escape, including mill and crest wall; also the diverging walls.

Superstructure.—The whole of the superstructure is to be faced boulder work in mortar, except arches and other exceptions, hereinafter noted; all right angles being brought up true with half bricks, and all off-sets with half brick-on-edge; walls to have a fair face of split boulders, and built true.

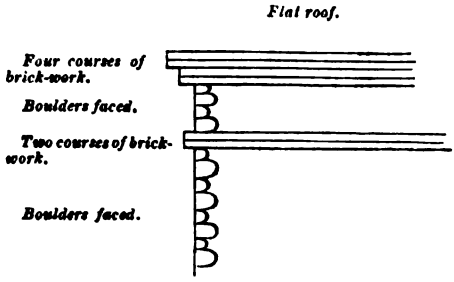
Section of walls showing the brick angles worked into the boulders.



Tops of all walls of buildings to have a few courses of brick-work under and about wall plates, ends of kurries, beams and trusses of framed roof.

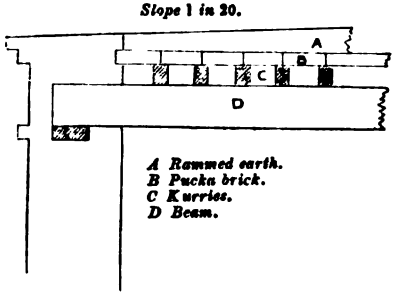


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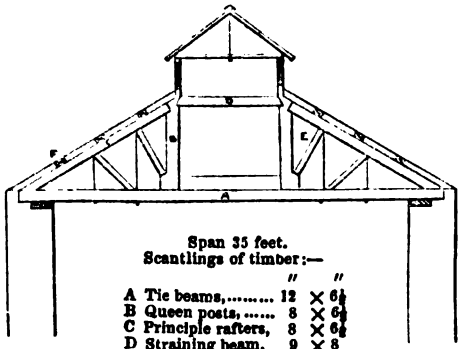


All arches to be built of good pucka bricks in mortar; a cornice and string course to run round buildings with flat roofs, as per sketch in margin.

Roofs Flat.—The roofs of Wheel-house and Circular saw-house to be of beams and kurries, with pucka brick laid flat, in mortar, and covered with well beaten earth, mixed with *bhoosa* (chopped straw), finished to a slope of 1 in 20, all roofing beams to be cut with a camber of 0·1 in 20 feet; small ventilators to be built at intervals on the flat roof.



Roof Trussed and Slated.—For the Vertical saw-room the roof is framed, with ventilators along the ridge. Over the purlins, planking 0·10 inches thick is nailed, and on this is laid the slates 20 × 10 inches, with two-thirds lap, dimensions of scantling, as shown in the margin. The ventilators to be slated similar to the roof, sides sheet iron, open, with a sheet iron ridge cap.



Boarding between Wall Pillars.—The east side of the vertical saw-house as far as the wheel-house, and west side of the circular saw-house to be masonry, pillars filled in between with wood-work, as shown in drawing. The timber to be framed so as to form *chokuts* for doors, the upper part and sides to be filled in with boards 0·10′ thick, nailed on to the framing;

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the upper board overlapping, the lower ones 0·10′; this extends up to the roof, and saves arching and masonry over the doorways.

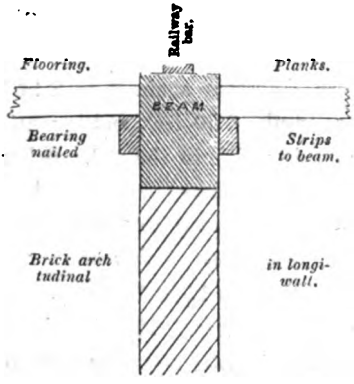
Doors Glazed.—The upper portion of large end doorways to be similarly finished to save framing a circular headed door. All doors are square headed, with glass in the upper part, to admit light; all the doors are double boarded and framed for panel.

Floorings.—The whole of the three buildings are to be floored with 0·25′ planks, laid in narrow pieces of 0·5′ wide, nailed to kurries and beams, as required. The beams are over the cistern in the wheel-house, and the vaults in circular and vertical saw-rooms; the remainder of the flooring to be on kurries. In the vertical saw-room, the beams are laid along the top of the longitudinal brick walls; in the circular saw-room they are supported at the ends by the side walls; in the centre portion on cast-iron bracketed caps, on wooden pillars; all the floorings to be laid with close joints to prevent dusting.

Pillars in Vault.—In the vaults are good sound brick masonry pillars, with hoop iron bond for carrying the plummer blocks, and shafting for communicating the power.

Foundation Seats for Machine.—The seats for foundation plates for the vertical saw-frames are also to be built of the best description of brick-work with hoop iron bond; great care must be taken in building these pillars and foundation seats, and the holding down bolts must be carefully provided for.

Walls for Railway Vertical Saw-vaults.—Longitudinal arched walls are built in the vertical saw-vaults, of good brick masonry in mortar, 1 foot thick; on these are laid stout beams of timbers for carrying the railway and carriages which convey the logs up to the saws whilst being cut. The planked flooring is continued between these beams, and carried on bearing strips nailed to the beams.



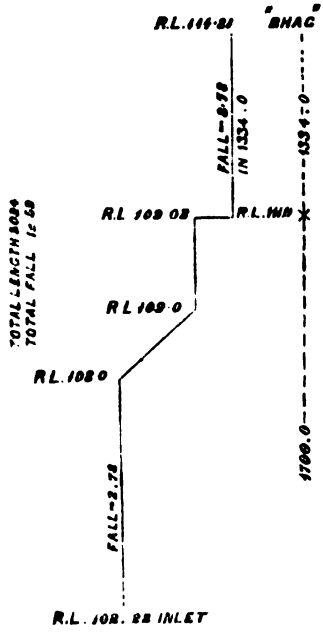
Passage for Shaft.—A passage runs from the vertical to circular saw-vault, in which is the shafting for communicating the power to drive the circular saws; two archways from this passage lead into the circular saw-vault, the leather driving belt passing through the first archway, across the passage; and in line with the side wall of vertical saw-house, an arch is

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thrown to strengthen the side walls. The planked flooring is continuous over all.

Water-wheel Seat.—The seat for water-wheel is to be built of good brick masonry with hoop iron bond, great care being taken to render it one solid mass; places are left for holding down bolts for plummer blocks; it is finished with brick-on-edge "herring bone" on top.

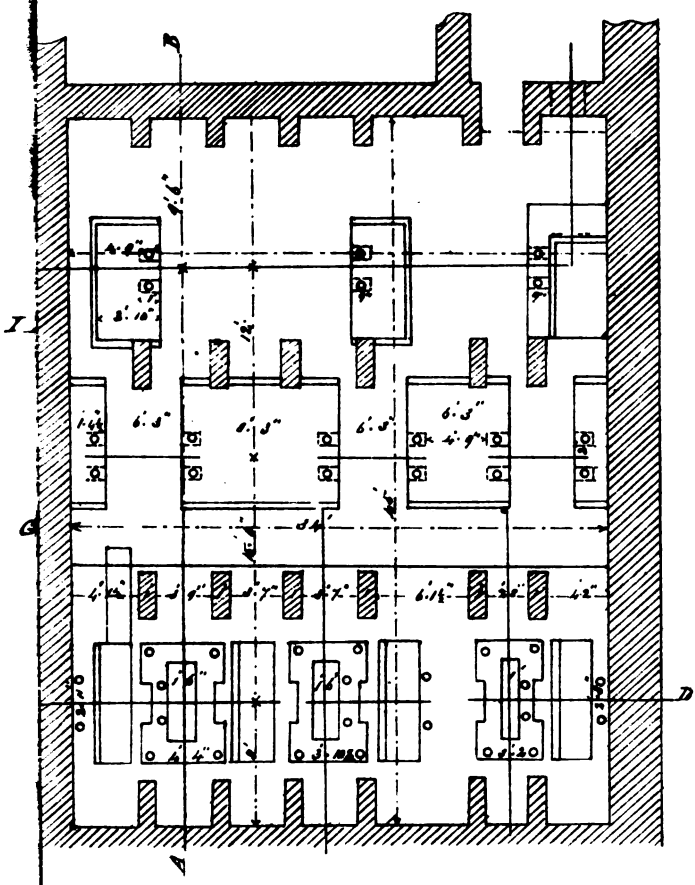
Regulator at Inlet of the Mill Channel.—The regulator inlet at head of mill channel is of the same description of masonry as the mill, boulders in mortar, partly faced and finished with brick-on-edge at top. The arch is an arc of 60° of 8·0 feet span for a depth of water of 2·4 feet on sill of bridge, built of three-half brick rings in mortar; the floor of bridge under arch to be boulders in mortar. The left bank up-stream re vetment wall is at an angle of 50° to centre line of mill channel, that being the general direction of the present bank. Grooves are provided for a gate at the up-stream face of bridge to shut off the water, and a small portion of paving in dry boulders forms a flooring above and below it; converging walls are provided for contracting the width to 4 feet, (the width of channel,) and also for finishing off the side slopes.

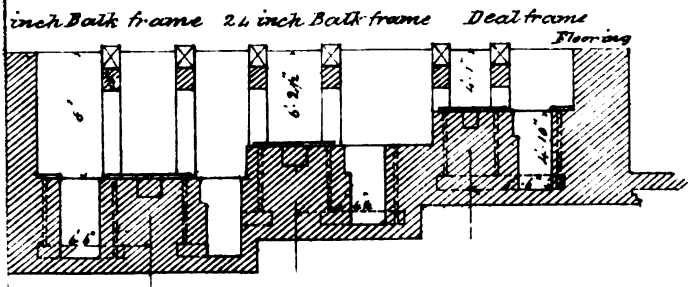


Mill Channel.—Cross and longitudinal sections of mill channel are shown in the drawings; the bottom width above wheel-house to be 4 feet, to be increased at wheel-house cistern to width of wheel (8 feet). Below the wheel-house, the bottom width decreases again from 8 to 6 feet in a length of 50 feet, and is continued at this width to the end. Below wheel-house, side slopes to be carried up in dry boulder paving to ground line of vertical saw-house; below which the slope widens out to 1½ to 1; the paving stops at end of curve. The side slopes of mill channel, from regulator inlet to escape at wheel-house to be also 1½ to 1.

Escape Channel.—The escape channel round wheel-house to be paved with dry boulders; the left side at a slope of ½

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Cross Section of Ver.l Scaw Vaults on C.D.

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to 1; the right side is formed by the foundation wall of wheel-house being carried up with a batter in pucka boulder masonry, the wall being widened out below to allow of this being done, and also to stand the action of the water along it. At the head of the escape channel, the fall into it from the upper channel is provided for by a well, and the water is regulated by planks put into the grooves provided at the face of the two bridges. At the end a cross wall is built 1 foot high. The escape channel has a slope of 0·25 in 100.

Converging Walls.—Converging walls are provided where it is necessary to finish the earthen side slopes against the masonry, these walls slope in plan 5 to 1 in width, and in elevation to level of bed; they are of boulders faced above ground, and finished on top with one brick-on-edge.

Water-Wheel.—The water-wheel is to be 20 feet diameter and 8 feet wide, the shaft is square of boiler plate, rivetted with angle, iron; along the inside at the centre where the boiler plates are joined, there is a cast-iron square T piece inside; the shaft is made in two lengths (to suit length of plates) and joined on the cast-iron T piece. At either end a casting is rivetted inside the shaft, and forms a boss outside for carrying the arms. The journal is of cast-iron turned and fitted in the end casting, being firmly fastened on with four wrought-iron keys. Places are cast on the boss for carrying the arms, which are of wood, fastened to the boss with bolts and nuts. The shrouding is of thick sheet iron, width of which is one-third the head of water, or 2 feet. The floats are also of sheet iron, curved and fastened to shrouding by angle iron rivetted on it; small screw bolts fasten the sheet iron floats to the angle iron at sides. The floats are in two lengths forming the width of the wheel, the division (or centre shrouding) being carried by intermediate arms halved across the centre of the shaft.

Gearing.—One end of the wheel shaft carries a large spur wheel with wooden teeth, working into a cast-iron pinion, (dressed teeth) on the long shaft which runs through an archway inside the wall into the vault; cast-iron pulleys on this shaft carry the leather driving belts for communicating motion to the machinery.

Speeds.—The water-wheel is to make 17 revolutions per minute:—

No. 1	frame,	108	strokes	per minute.
No. 2	„	129	„	„
No. 3	„	144	„	„

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The Circular Saws, 3 feet diameter, make about 500 revolutions, or travel about 4,700 feet per minute.

Sluice and Working it.—The sluice for letting on and shutting off the water in the wheel-house is built up of planking and iron straps bolted together; it is suspended from the back by two radial arms fastened to iron plates, built into the floor of the cistern. The rack above the floor of wheel-house is acted upon by toothed gearing and the s raised, a counterweight being attached to it by a chain running over a wheel under the floor. The radial arms allow the sluice to raise a certain amount as required for the passage of the water into the wheel; a wide strip of leather fastened to the side walls of cistern by sheet iron strips is kept close against the sheet by the pressure of the water, and a fair joint which allows little water to escape is formed.

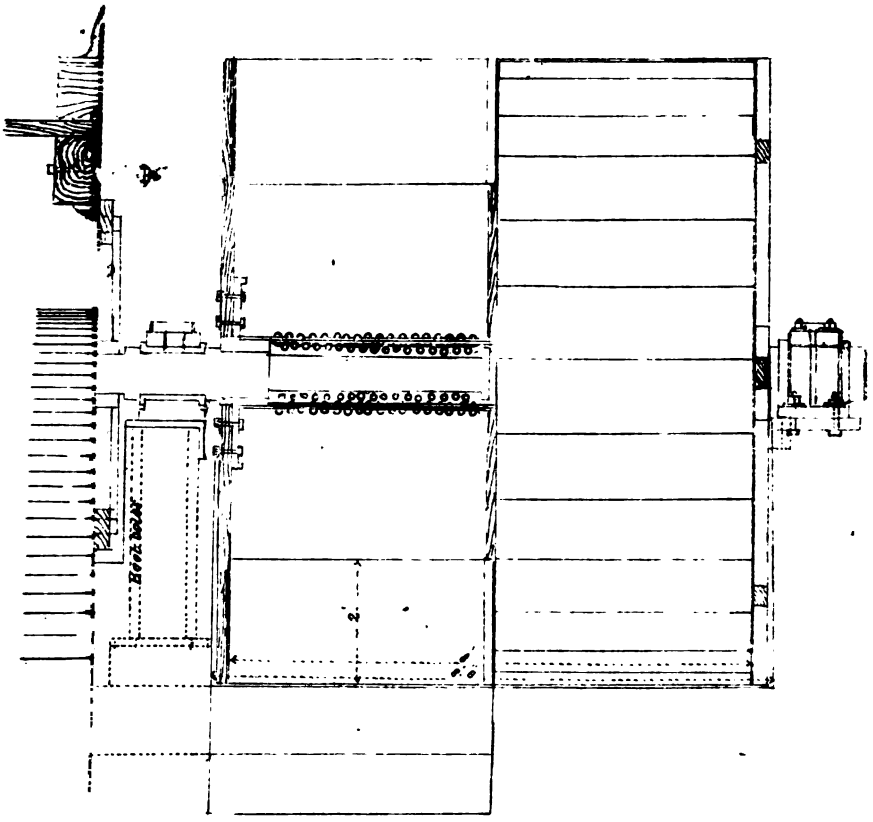
Circular Saw Benches.—Two circular saw benches are provided, the centre portion carrying the saw being of cast-iron, the lengthening at either end being timber framed and planked on top. The saws are arranged to rise and fall as desired, varying with the thickness of wood to be cut; the belts for working the saws come through openings in the floor close to the pulley. Levers are provided for passing the belts from fast to loose pulleys, and *vice versâ*, for each frame and the two circular saws.

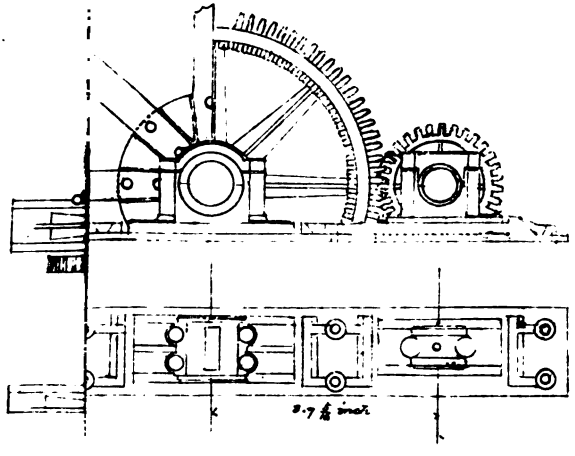
Gearing under Ground.—All gearing and pulleys for carrying belts are kept under the floor in the vaults and wheel-house, this leaves the floor clear for work, allows the superstructure being made light, and prevents accidents to workpeople employed about the building.

Leather Driving Belts.—There are seven large belts required, one for driving each frame and three from the main shaft to countershafts; one also from the longitudinal shaft to take power into the circular saw vault. These belts to convey the power must be well made of the best leather procurable. Five of them will be about one foot wide of three thicknesses of leather sewed together, with five rows of leather through the whole length. The other two will be a trifle less in width, but of the same thickness and construction. For the circular saws four belts are required, 7 and 9 inches in width, with double thickness of leather, and four rows of sewing; none but the best leather to be used in any of these belts.

Fitting Machines to Wheel.—Great care must be taken in erecting the water-wheel and vertical saw frames, also in putting the shafting into its place, the amount of attention that is bestowed on these works will very

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soon show itself after the machinery once commences to work. If erected carefully, the wear of brasses and journals will be imperceptible, the shafting will run smooth and the machines work without noise.

Abstract of Estimate.

Vertical Saw Room.

c. ft.		Rs.
10,194·64	Masonry, boulder, in foundations, at Rs. 9 per 100, ...	917·5176
698·00	Masonry, brick, plain, foundations, at Rs. 20 per 100,... ...	139·6000
119·38	Masonry, brick arching, foundations, at Rs. 28 per 100, ...	33·4264
568·75	Masonry, boulder, faced, in plinth, at Rs. 10 per 100, ...	56·8750
142·19	Masonry, brick, plain, in plinth, foundations, at Rs. 20 per 100,	28·4380
4,450·46	Masonry, boulder, faced, in superstructure, at Rs. 11 per 100,	489·5506
1,038·00	Masonry, brick, plain, in superstructure, at Rs. 20 per 100,	207·6000
508·95	Masonry, brick, arching, in superstructure, at Rs. 28 per 100,	142·5060
s. ft.		
3,519·00	Flooring, wood-work, including beams, at 12 as. per 100, ...	2,639·2500
8,216·00	Roofing, at Rs. 65 per 100, ...	5,340·4000
924·00	Doors, at Rs. 1, ...	924·0000
1,536·00	Filling in doorways, wood-work, at 12 as., ...	1,152·0000
c. ft.		
14,137·50	Excavation in water, at Rs. 8 per 100, ...	113·1000
	Total, ...	12,184·2636

Wheel House.

c. ft.		
3,765·43	Masonry, boulder, in foundation, at Rs. 9 per 100, ...	338·8887
348·12	Masonry, brick, plain, foundation, at Rs. 20 per 100, ...	68·6240
82·44	Masonry, arching, foundation, at Rs. 28 per 100, ...	23·0832
277·50	Masonry, boulder, faced, in plinth, at Rs. 10 per 100, ...	27·7500
69·37	Masonry, brick, plain, at Rs. 20 per 100...	13·8740
1,452·26	Masonry, boulder, faced, in superstructure, at Rs. 11 per 100,	159·7486
570·00	Masonry, brick, plain, in superstructure, at Rs. 20 per 100,	114·0000
157·00	Masonry, brick, arching, in superstructure, at Rs. 28 per 100,	43·9600
s. ft.		
293·00	Flooring, brick-on-edge, at Rs. 30 per 100	87·9000
490·00	Flooring, wood-work, including beams, at 12 as., ...	367·5000
320·00	Doors, at Rs. 1, ...	320·0000
1,118·00	Roofing, at Rs. 40 per 100, ...	447·2000
c. ft.		
14,403·12	Excavation in water, at Rs. 8 per 1000,...	115·2249
	Total, ...	2,127·7534

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Vertical Saw Vault.

		Rs.
c. ft. 3,329·25	Masonry, boulder, in foundation, at Rs. 9 per 100, ...	299·6325
1,683·12	Masonry, brick, plain, in superstructure, at Rs. 20 per 100,...	336·4240
362·85	Masonry, brick, arching, in superstructure, at Rs. 28 per 100,	101·5980
828·00	Masonry, boulder, dry, in flooring, at Rs. 10 per 100, ...	82·8000
s. ft. 1,680·00	Flooring, wood-work, including beams, at Rs. 1, ...	1,680·0000
c. ft. 16,560·00	Excavation in water, at Rs. 8 per 1000, ...	132·4800
	Total, ...	2,632·9345

Circular Saw House.

c. ft. 3,064·76	Masonry, boulder, in foundation, at Rs. 9 per 100, ...	275·8284
229·25	Masonry, brick, plain, foundation, at Rs. 20 per 100, ...	45·8500
352·50	Masonry, boulder, faced, in plinth, at Rs. 10 per 100, ...	35·2500
88·12	Masonry, brick, plain, in plinth, at Rs. 20 per 100, ...	17·6240
2,117·54	Masonry, boulder, faced, in superstructure, at Rs. 11 per 100,	232·9294
1,663·11	Masonry, brick, plain, in superstructure, at Rs. 20 per 100, ...	332·4220
235·62	Masonry, brick, arching, in superstructure, at Rs. 28 per 100,	65·9736
333·00	Masonry, dry, boulder, in flooring, at Rs. 10 per 100, ...	33·3000
s. ft. 1,225·00	Flooring, wood-work, including beams, at Rs. 1, ...	1,225·0000
420·00	Doors, at Rs. 1,...	420·0000
90·00	Filling in doorways, wood work, at 8 as., ...	45·0000
1,364·75	Roofing, at Rs. 40 per 100, ...	545·9000
c. ft. 1,681·65	Excavation, at 8 as. per 1000, ...	13·4532
	Total, ...	3,338·5306

Tail Race.

c. ft. 1,337·75	Masonry, boulder, in foundation, at Rs. 9 per 100, ...	120·3975
226·00	Masonry, brick, plain, foundation, at Rs. 20 per 100, ...	45·2000
12,888·00	Excavation, in water, at Rs. 10 per 1000, ...	128·8800
	Total, ...	294·4775

Regulator Inlet.

c. ft., 1,746·67	Masonry, boulder, in foundation, at Rs. 9 per 100, ...	427·2003
78·12	Masonry, brick, plain, foundation, at Rs. 20 per 100, ...	14·6240
178·62	Masonry, brick, arching, foundation, at Rs. 28 per 100, ...	50·0136
1,451·08	Masonry, boulder, faced, in superstructure, at Rs. 13 per 100,	188·6404

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c. ft.		Rs.
338	Masonry, dry boulder, paving, at Rs. 10 per 100, ...	33·8000
9,479·45	Excavation in water, at Rs. 10 per 1000, ...	94·7945
	Total, ...	809·0728

Escape Channel.

c. ft.		
2,869·82	Masonry, boulder, in foundation, at Rs. 9 per 100	258·2838
18·00	Masonry, brick, plain, foundation, at Rs. 20 per 100, ...	3·6000
69·44	Masonry, brick, arching, at Rs. 28 per 100, ...	19·4432
11,479·49	Excavation in water, at Rs. 10 per 1000, ...	114·7949
	Total, ...	396·1219

Mill Channel.

c. ft.		
16,8877·08	Excavation in water, at Rs. 9 per 1000, ...	1,519·8937
s. ft.		
99·00	Gates and planks, at Rs. 2, ...	198·0000
	Total, ...	1,717·8937

Escape and Mill Channel.

c. ft.		
4,254·40	Masonry, dry boulder, paving, at Rs. 10 per 100, ...	425·4400

Steps.

No.		
3	Wood-work, at Rs. 20 each, ...	60·0000

Foot Bridges.

s. ft.		
120·00	Wood-work, at Rs. 1-8	180·0000

Belts.

ft.		
291·00	Leather driving, at Rs. 3 each, ...	873·0000
136·00	Leather driving, at Rs. 2 each, ...	272·0000
	Total, ...	1,145·0000

Iron-Work.

ft.		
219·35	Wrought iron-work, at Rs. 28 per maund, ...	6,156·5000
259·5	Castings, at Rs. 20 per maund, ...	5,183·5000
42·17	Castings, at Rs. 17 per maund, ...	728·2250
	Total, ...	12,060·2250
	Add 10 per cent. for erecting,...	1,206·0225

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Machinery from England.

			Rs.
1	Large saw frame, actual cost at Madhopoor, ...		7,921·5000
1	Medium saw frame, „		6,481·0000
1	Small saw frame, „		2,282·5000
1	Set shafting, &c., „		3,736·0000
	Total, ...		20,371·0000
	Add 10 per cent. for erecting, ...		2,037·1000

Tools.

8	Large saw frames, No. 1, actual cost at Madhopoor, ...		99·0000
12	Medium saw frames, No. 2, „		138·0000
16	Small saw frames, No. 3, „		148·0000
4	Circular saw frames, „		270·0000
12	Dozen files, „		73·0000
	Total, ...		728·0000

Carriage.

259	5	0	Castings from Roorkee to Madhopoor, at Rs. 1-8 per maund,	388·6875
521	7	0	Iron work from Madhopoor to site, at 9 as. per maund, ...	293·1609
850	0	0	Machinery and tools from Madhopoor to site, at 9 as. per maund, ...	478·1250
			Total, ...	1,159·9734
			Add regulator for at the head of the mill channel,	5,073·8059
			Add contingencies at Rs. 5 per cent.	3,169·0000
			Grand Total Rupees, ...	66,542·0000

J. D. Smithe.

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No. XXXVII.

ALLYGURH FORT.

Report on the FORT OF ALLYGURH, *its state and requirements, as a permanent Military Post, with a European and Native Garrison.*
BY MAJOR H. WELLER, *Bengal Engineers.*

Allygurh, 24th December, 1857.

I.—PRESENT STATE OF THE FORT.

THE Fort, originally of Native construction, was captured in 1803 or 1804 by Lord Lake, by direct assault upon the only entrance gate, in the south face, and not without heavy loss. It had then, as now, a broad and deep wet ditch, with an earthen counterscarp, and block kunkur masonry escarp. The bastions were high and irregular in shape, and they were subsequently cut down and modernized, though to what extent I am unable to ascertain. A ravelin was probably added in front of the entrance gate, and another on the north-east face, with a wet ditch in both cases.

Up to 1831 the Fort was kept in good order; up to 1829, by the Head Quarters of the Sappers and Miners; and up to the end of 1831, by a company left for the purpose. I personally commanded the last company employed on the works, and marched it up to Delhi in the end of 1831. The Fort was then in excellent order, with numerous substantial pucka buildings; but of the latter all have since been dismantled, except five, which will be described hereafter, and no repairs having been made for about 26 years to the defences, they had of course fallen into a ruinous state prior to the outbreak in May last.

The Fort stands in an open country, about three miles north of the city

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of Allygurh (or Coel), with its enclosed area somewhat elevated above the general level. Towards the west the country is lower than usual, and there is a masonry inlet to the ditch on that side, which with a little arrangement may be made to drain off any lodgement of water that might otherwise be prejudicial to the health of troops. But if the levels do not admit of this during the height of the rains, a drainage cut should be made to the nearest canal escape or rajbuha.

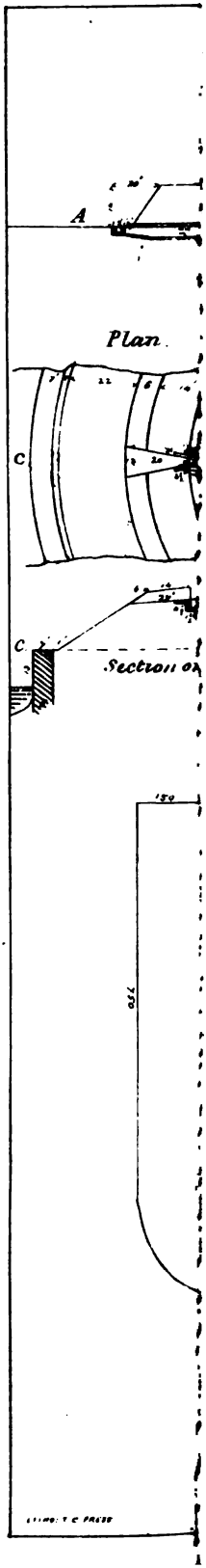
The *Counterscarp* of the ditch is a steep and rugged earthen slope, now from 12 to 15 feet above the water level in the ditch. It is cut through in many places for cattle walks to the ditch water, and the glacis is very short with occasional low spots at the foot that might afford partial cover for riflemen. But the crest of the glacis everywhere covers the whole escarp from external view.

The *Escarp* is of block kunkur masonry, and now about 12 feet above the water level, which appears to have fallen about 5 feet, since its highest level in the rains. The masonry has fallen down in several places, and in many others is shaken or damaged by the roots of numerous Peepul, and other trees. The trees have been recently cut down, but the roots should be more closely cut, and poisoned with a solution of corrosive sublimate.

The *Ditch* varies in width from about 300 feet, where greatest, opposite the curtains of the west face; to about 70 feet, where least, at the salient of the ravelin on the south-east. It is wet at all seasons, and has a depth at the present time of from 2½ to 9 feet, or more, which however will be particularly ascertained hereafter. Measurements all round give 9 feet 6 inches as the greatest depth. It must be plentifully fed by springs, and I noticed the water in a well outside on the west face to be only about 12 feet below the surface of the country. The ditch has no doubt been much silted up during the last 30 years, by drift, sand, and washings from the ramparts. It is shallowest close under the escarp, and if more depth is required there would be no difficulty in obtaining it by dredging.

The two *Ravelins* are small in area, with a height of about 8 feet of escarp above the water level, and ramparts about 15 feet above the escarp. Their ramparts, as are those of the body of the place, are earthen. The south-east ravelin communicates with the body of the place by a masonry causeway of 15 arched openings, about 10 feet 9 inches wide; piers, 3 feet 3 inches thick; and with the country outside, by seven openings of the

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same size. A drawbridge formerly existed at the inner end of each causeway, but has been since built up solid. The north-east ravelin has had its exit to the country lately blocked up. Its communications of eight openings (one pier fallen) with the country, and twelve openings with the body of the place, were spanned by wooden roadways, which have long ago been removed, and the drawbridges have been built up solid.

The body of the place is in shape nearly a square, giving a clear internal area from the foot of the interior slope of the terreplein of about 1,000 feet from north to south, by about 900 feet from east to west. It has eight bastions, which I have numbered one to eight, from the flagstaff bastion at the south-west corner, round by west and north. There are three bastions in each face, viz., one at each angle and one in each side, not very regularly arranged. The three bastions of the north face have been modernized with somewhat regular faces and flanks. The others are all more or less circular, and Nos. 2, 6, and 8 in the west, east, and south faces, are more or less long necked; No. 8 being particularly so. The terreplein which is of good width has a command of about 13 feet above the inner area of the Fort, with a banquette and rampart of about 7 feet more, and from the general elevation of the Fort above the outer country, which though not remarkable is decided, the ramparts may be said to have an excellent command over the surrounding country, and very fairly to defilade any buildings of moderate elevation that may be constructed within the Fort. A berm of 8 or 10 feet width formerly existed all round the foot of the exterior slope of the rampart, between it and the coping of the escarp, and the ramparts may have been about 15 feet thick at top. But from the ravages of time and weather, much of the rampart has been washed down on to the berm and into the ditch, so that the thickness at top is reduced to 6 or 8 feet, and all regular shape obliterated. The terreplein has been similarly injured, but Lieutenant Watts, Assistant Field Engineer, has during the last two months restored it and the banquette, also the interior slope of the rampart (less completely), and the Fort is even now in a very tenable position against attack with light guns.

The bastions are all full except No. 4.

The ravelins have no berm.

Embrasures are now being prepared, and are well advanced towards completion, partly lined with brick masonry as shown in the sketch on plan, as follows:—

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	For Guns.	For Howitzers.
In No. 1 Bastion,	6	2
„ 2 „	4	1
„ 3 „	6	1
„ 4 „	4	0
„ 5 „	4	2
„ 6 „	6	1
„ 7 „	5	1
„ 8 „	6	0
In curtain between 7 and 8, to command road leading to ravelin on south-east,	1	0
Totals,	42	8
	50	

and platforms of strong block kunkur masonry are being constructed. It would require more mature consideration than I can give to the subject, as my Report must be at once submitted, to decide whether this arrangement of the guns is the best that could be devised. But I think it is amply sufficient after the Fort is properly garrisoned and provisioned, to admit of successful defence against serious attack, especially with the help of a few light guns and howitzers for use wherever the attack should be most pressed; and, indeed, considering the noble ditch with its marked escarp, and the general commanding position of the Fort, this Fort may when in proper order be fairly considered a very strong one.

The inner area of the Fort is nearly level, rising gently from the sides towards the centre. It admits of perfect drainage, which formerly existed by means of open masonry drains round the foot of the interior slope of the terreplein, communicating by arched openings under the ramparts, and through the escarp with the ditch. These drains are now being cleared, and they appear in excellent order, together with several masonry reservoirs for water, probably for watering the roads and terreplein. They can therefore be restored and made efficient with very little trouble or expense. Strong inner and outer gratings should be fitted to the exit drains.

The only buildings remaining in the fort when the outbreak occurred, were—

A pucka vaulted guard-room of two rooms, near the entrance in the south face. This is much dilapidated, but with repairs and the addition of doors and tiled verandahs, it may be put into good order.

A pucka vaulted house near the above, probably used as a main guard

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or for officers' quarters. This consists of two good sized rooms with verandah rooms all round, and it is in excellent order, doors only excepted, and Lieutenant Watts has already supplied chokuts for them.

A pucka vaulted cook-room and privy, in fair repairable order are in rear (west) of the above.

A pucka vaulted magazine with masonry enclosing wall round it. This is in good order, massive and of excellent masonry. I doubt not therefore it will be found bomb proof, and with the addition of double doors, and opening out ventilation in the side walls, it will prove an excellent magazine for all the powder required. It stands close under the rampart near the north end of west face, and is now divided by a temporary wall into two compartments, occupied for magazine and commissariat purposes.

Near the rampart on the north face, a rather dilapidated pucka flat roofed building, now used by the commissariat. The roof had fallen in, beams only remaining, and Lieutenant Watts has given a temporary mud roof. This building is repairable, and if it does not interfere with other more important arrangements, may be found useful as a store room for European troops.

A pucka vaulted range in No. 4 bastion, now used as a bakery. This was in much disrepair but has been partially repaired by Lieutenant Watts, and may I think be rendered serviceable if desired. It is not badly situated for a bakery, but probably the bakery and commissariat cattle, and slaughter-yard, may with advantage be removed to the ravelin on the north-east side, in which case this building or its site will be useful for some other purpose.

Wells. There are nine wells in the fort, and the water in all is said to be very good; the depth of water varies from 2 to 15½ feet, at a distance below the surface of from 18½ to 34½ feet, and with proper clearing out these wells will afford an ample supply of water for all purposes.

There are no roads now in the Fort, but kunkur is plentiful in the vicinity, and when the arrangement of the buildings is decided on, the Fort roads can easily be laid out and constructed. The metalled road also from the city of Allyghur should be repaired, and a direct line opened to the Grand Trunk Road leading to Delhi and Meerut.

It only remains, in connection with the present state of the Fort, to mention the works and temporary buildings completed or in progress by Lieutenant Watts since the 22nd October, 1857.

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The interior of the Fort has been cleaned up.

The interior slopes of ramparts (partly) and the banquette, terreplein, and ramps, with a portion of the ramparts, have been substantially repaired with rammed earth.

Old buildings have been partly cleaned and repaired, with some doors, chokuts, and gates supplied.

Wells have been partly cleaned out.

Embrasures have been opened out in the bastions, and gun platforms of block kunkur masonry commenced upon.

Mounds outside the Fort have been levelled.

A temporary staging bungalow, thatched, with sirkee and grass tattie walls, of two rooms, has been constructed for the accommodation of travellers.

The metalled road leading from the city of Allyghur is being repaired.

55,000 large bricks, and 20 lakhs of small bricks, with 5 lakhs of small tiles, have been collected; and arrangements made for bringing in 2,000 cubic feet of block kunkur, and 500 maunds of kunkur lime, daily.

Five temporary barracks, and a hospital for European troops, also a range of officers' quarters, have been completed. Masonry, kutcha pucka. Roofs, of light thatch.

Six ranges of barracks for Seikh troops are well advanced towards completion, and will be ready in a few days. They are of kutcha masonry; the roofs are of small tiles; and with the addition of quarters for native officers at the west end, and a cooking shed at the east end of each range, I think these barracks will afford good accommodation for 300 Seikhs. A seventh range is sanctioned, but has not yet been commenced. It will be useful as an hospital for the Seikhs, if a native garrison is decided on, but upon this subject I beg to refer to the annexed memo. by Colonel A. Becher, Quarter Master General of the Army, and myself.

II. Requirements of the Fort, as a permanent Military Post with a European and Native Garrison.

To place the Fort in a proper state of defence the following work appears necessary:—

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Exteriorly, the demolition of two villages, about three-fourths of a mile from the west face.

Slight levelling of inequalities for a distance of at least 800 yards all round the crest of the glacis.

Filling in a little at the foot of the glacis, where some slight hollows might afford partial cover to riflemen.

And a careful repairing of the counterscarp which at present is much furrowed by rain water, and in many places cut through for cattle runs to the water of the ditch. The counterscarp should also be planted with *doob* grass next rain.

Further, as a sanatory measure, and to avoid giving cover to an enemy, no cultivation should be permitted within a radius of one mile all round the crest of the glacis.

The wet ditch has at present a depth of water varying from 2½ to 10 feet. It is shallowest near the escarp, and may hereafter with advantage be deepened by dredging.

Interiorly, the escarp masonry will require extensive repairs, with careful removal of the roots of trees, which have occasioned much damage.

The wooden roadways of bridges over main and ravelin ditches on north east side, should be renewed. Also drawbridges furnished at the inner ends of these bridges, and of the masonry bridges at the main entrance on south face. Substantial gates will also be required.

The earthen ramparts all round should be restored to a proper profile, and the whole carefully turfed during next rainy season. The soil is very stiff, and if once well repaired and turfed, I think only very trifling repairs can be wanted for many years.

It will be necessary to close the outer berm on either side of the entrance and exit gateways by a strong palisade, to prevent surprise of the gates by any party who might cross the ditch unobserved.

H. Weller, Major.

Memorandum by Colonel A. Becher, *Quarter Master General of the Army.*

Allygurh, 24th December, 1857.

It is considered that for permanent barracks for European infantry or artillery, the main ward should be 24 feet wide and 24 feet high, 8 feet of

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space is required for every 2 cots; that is, for a company of 100 men, 50 cots are required down each side of the main ward.

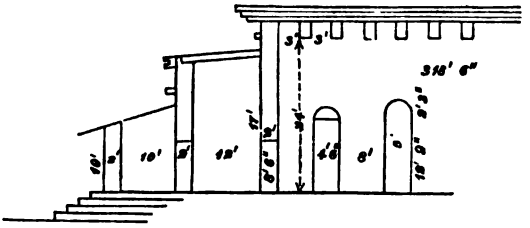
Say therefore for one side—

	Feet.	Inches.
2 end spaces for 1 cot each, at 4 feet, – – – –	8	0
24 spaces for 2 cots, each at 8 feet, – – – –	192	0
25 arched openings at 4½ feet, – – – – –	112	6
Add for 3 cross walls of 2 feet each, to strengthen the side walls and divide the barrack into 4 spaces each, for the section of a company, – – – – – –	6	0
Gives total length of main ward inside, – –	318	6
Add 2 walls of 2 feet each, – – – – – –	4	0
1 set of Sergeants' quarters (2 rooms) each 16 feet long by 10 feet wide, with 5 feet passage leading into barrack, –	16	0
Partition wall 2 feet; another set of Sergeants' quarters, 16 feet, – – – – – – – – – –	18	0
Outer wall 2 feet, inner verandah 12 feet, its outer wall 1½ feet, – – – – – – – – – –	15	6
Outer verandah 10 feet, its pillars 2 feet, – – – –	12	0
Gives total length of a barrack, outer dimensions, –	384	0

And for the breadth—

Main ward 24 feet, 2 walls 4 feet; 2 inner wards 24 feet, their walls 4 feet, – – – – – – –	80	0

Each barrack will therefore occupy 384 feet by 80 feet, inner wall 24 feet under beams, inner verandahs 17 feet under beams, outer verandah 10 feet under beams, plinth to be 3 feet high in 4 steps of 9 inches high each, all round.



The arched openings in main ward to be 15 feet high and 4½ wide.

Doors in outer wall of inner verandah to be 8½ feet high by 4½ feet wide; every third door half glazed, the others panelled, and all with semi-circular fanlights over them, pivoted in the centre to open or shut at pleasure.

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Three of these barracks to be constructed in the Fort of Allygurh to accommodate 200 infantry and 100 artillery, and if hereafter it is desired to increase the garrison, upper stories can be added; though perhaps if this is contemplated the main walls should be increased to 2½ feet thickness. Masonry to be all pucka of block kunkur slabs and lime mortar, arch work only excepted, which will be of brick and lime. Double arches segmental and semi-circular (unless the fanlights are made rectangular, in which case the arches may be flat and semi-circular) over the doorways, and invert arches in foundations under doors in inner verandahs, and arched openings in main ward. Roofs to be flat, lime terraced with three skylights if deemed expedient. Floors to be of slab stones from Agra.

All requisite subsidiary buildings to be provided. Also hospital accommodation for 50 men, or the size of half a barrack, which is about 16 per cent. on a strength of 300 Europeans.

Quarters for the Fort Commandant and Garrison Engineer, and Adjutant; also for Regimental Officers, to be provided upon a scale that has been approved of at Head Quarters, and will be hereafter furnished. These quarters should be pucka and flat roofed.

For a native garrison, if eventually decided upon, six ranges of barracks with mud brick walls and tiled roofs, now nearly finished, will accommodate 300 men, but quarters for native officers should be added at the west end, and a cooking room at the east end, which is near the ramparts.

Commissariat accommodation can be provided under the terreplein in pucka vaulted buildings, as many as are found necessary; so too for gunsheds and all artillery requirements, except the magazine. For the latter purpose the present magazine will, it is believed, prove ample and safe.

The commissariat cattle and slaughter-yard may be in the north-east ravelin, and as guns are not required there (so near to the body of the place) the terreplein can be cut away 15 or 20 feet and afford extra space.

Communication with the outer country should be restored through the north-east ravelin, as filth carts and commissariat offal can then be properly taken out and deposited in a field not less than three-quarters of a mile to the north, without inconvenience to the garrison.

Accomodation will be required for some horses (how many is doubtful) and can be afforded by revetting the lower 5 feet in height of exterior slope of rampart with block kunkur, and giving a wall 5 feet high along

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the coping of the escarp to such distance east and west of the gateway leading to north-east ravelin as may be desired. Or a small earthern *tete de pont*, with musketry profile, can be thrown up in front of the north-east ravelin bridge leading to open country, and in this the horses could be kept.

Regarding the strength of the garrison, (limited in Major Weller's instructions to 250 Europeans, with such proportion of natives as may be deemed necessary,) it appears desirable that at least two full companies of European infantry should be located in the Fort. The artillery should properly be equal to manning the guns of one complete face, or what is the same in essentials, the guns of one angle bastion and of the curtain bastions right and left of it. Provision is being made for embrasures for 50 heavy guns and howitzers, which against serious attack can hardly be deemed an excessive armament. This would give, say, 17 guns on the face attacked, exclusive of a few light guns and howitzers, to be used as required. Then 17 guns × 8 per crew = 136 gunners, or for three reliefs, 408 gunners. Allowing therefore for assistance from the European infantry in working the guns, provision for 100 artillerymen is the lowest strength that can be given in this arm; if indeed it is not, as seems probable, very inadequate. The minimum European garrison is therefore assumed at 200 infantry and 100 artillery. For the native garrison 300 men would be a fair and useful proportion, if the limited area of the Fort did not render it very difficult to provide adequate shelter for natives.

But with advertence to this difficulty, which is almost insuperable, unless the natives could be located in pucka vaulted quarters constructed under the terreplein, (against which the excessive heat of such quarters in the hot weather is the only objection,*) it appears worthy of consideration whether native troops should not be located outside the Fort, south or south-west, and a guard room for 100 men provided inside. This guard would be sufficient for all Fort duties in time of peace, and in event of attack there would be no hardship in placing the remainder of the native garrison in tents for the short time that would probably elapse before the place was relieved; or the quarters under the ramparts could be prepared, though only occupied in case of siege.

It is also worth consideration whether Allygurh will not be made a cantonment for at least one European and one native regiment with artil-

* Such underground quarters (tackhanas) are common in large native forts and are very cool.—[Ed.]

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lery. If so, it might be located about one mile south or south-west of the Fort, and furnish a sufficient guard for the Fort duties in time of peace.

Adverting to the limited area of the Fort, and the difficulty of providing sites for even three European barracks and a hospital, (besides which officers' quarters, and numerous minor buildings are indispensable), the accompanying plan shows what is considered the best and most convenient sites for the main buildings. It will be observed that very little available space is left, and consequently though upper storied barracks will be exposed to view from the outer country for probably the whole upper stories, yet this arrangement seems most expedient. And, if approved of, it would leave sufficient space for all other requisite buildings. The rampart might also be raised two or three feet, which would better defilade the upper stories though not completely.

A. Becher, Colonel.

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No. XXXVIII.

SILT TRAPS ON THE DEHRA DOON CANALS.

By R. E. FORREST, ESQ., *late Superintendent Doon Canals.*

AN old Italian writer on irrigation expatiates on the great advantages it would have been to canals, had "nature only provided that the rivers from which they are derived should always run bright and clear, and that their waters should never be intermixed with foreign substances!" Silt and sand are indeed the great enemies of all irrigation canals. They block up the entrance to their mouths, or raise the bed and necessitate embankments, or shut up the openings of the smaller irrigation channels; and their baneful influence is felt in many other ways. They form a component part of the economy of all great rivers; and in large canals, which are often in size merely regulated rivers, there seems to be no way of excluding or getting rid of the foe, or at all events of doing so at all effectually.

As might have been expected, this subject has largely engaged the attention of the Italian Engineers. Some of their most interesting writings treat of the depositions of Silts and Gravels, and of their efforts to exclude or get rid of the latter, with which they had chiefly to deal.

* "Some authors have proposed expedients to prevent any sort of gravels from entering canals. Eustace Manfredi, in treating of the means of drawing from the Lebir a fixed branch from below Porto Nuovo to below Perugia, proposed the construction of a weir, which in consequence raised the surface of the water eight Roman palms. He directed also

* These extracts are from Paul Frisi's book on "Rivers and Torrents," translated by General Garstin.

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that the sill of the entrance at the head of the canal should be five Roman palms below the heightened surface of the water, so as to retain in the canal the sufficient depth of five palms of water, and by the three redundant palms to prevent the introduction of any pebbles.

"Again, Belidor, in the sixth chapter of his book, above quoted, has suggested the idea of receiving the waters into a great reservoir in which they might deposit their gravels before they entered the canal; but although this plan has been practised in the famous canal of Languedoc, it is always liable to the objection that it is extremely difficult and expensive in the execution, and never applicable to any case in which it is necessary to draw a fixed channel from a great river running between mountains."

The above was for *excluding* gravels; and to *remove* them:—"They have sufficiently provided for the clearing out of the beds in the upper trunks of these two canals, where stones and gravels are brought down in great abundance with the stream, by placing in them a number of dischargers sufficient for the purpose, called bottom or ground sluices. This sort of outlet should be constructed in the bank of the canal on the side nearest the river, in such a manner that their sills may be lower than the bottom of the canal itself. The waters that are occasionally suffered to precipitate themselves into the river from such apertures acquire great velocity. * * * * * * *
As this acceleration extends a considerable way from the opening of the grooves, substances are detached from the bottom. * *
With several sluices of this kind, which are opened at proper times and which are so distributed that at the spot where the action of one ceases, the action of another begins, the gravels which had entered the canals are forced to throw themselves again into the river in the least space of time possible."

The large irrigation works in these provinces suffer from the more subtle and more annoying, if not more dangerous, of the two enemies, viz., Silt. And no steps have been taken to exclude or get rid of it on the large canals in the plains, as none seem possible owing to their great size and the large volumes of water they carry. But on the smaller water-courses in the Dehra Doon, measures have been carried out to intercept and remove the silt; and while the smallness of these water-courses allowed of this being done, it was a matter of absolute necessity in their case that it *should* be done as will be seen further on. One thing that made it

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necessary was, that they supply water not only for irrigation but for domestic use. And as this may one day make it necessary even to purify the water of larger streams, if used for this latter purpose in India as in England, it may be as well to say a few words with regard to the several methods of purifying water. A mention of the principles on which the action of the Silt Traps depend will be of use before proceeding to describe their construction.

The means by which water may be freed from its impurities are either 1st, Chemical; or 2nd, Mechanical. With the former we have nothing just now to do; Mechanical means are the only ones as yet employed in the Doon Silt Traps. All the methods of the second, or Mechanical clearing of water, are one or the other of two processes, viz., Subsidence and Filtration. "The first of these processes is of a negative character, consisting simply in letting the water remain for a considerable period in an undisturbed condition. It is well known that if a quantity of water having particles of any foreign matters of greater specific gravity than itself floating or diffused in it, be allowed to continue in a quiescent state for a sufficient length of time, these particles will subside to the bottom of the water which is thus left comparatively clear and limpid.

"The process of Filtration is effected by providing a bed of easily percurable materials, in which the water deposits the solid particles which it held in suspension, and finds its way to the lower bed in a comparatively clear state."

Both these principles have been brought to bear from the earliest times. The Romans had their Limaria and Conceptacula. The former were open air reservoirs or cisterns; the latter reservoirs vaulted over to shelter the water from the influence of the atmosphere. In the Limaria, the principle of subsidence was employed, and the stillness in the water requisite for it was obtained not merely by increased width and depth but also by change of direction. Thus *(Fig.* 1) the water flowed into the Limaria at the point A, and its exit was at B, or at right angles to its original direction, which it regained by another turn. Filtration was performed in many ways, principally by taking advantage of the height to which the water was brought before it was made use of, by building one reservoir over another, and letting the water from the upper one flow into the lower.

Both these principles are also employed in the arrangements made for purifying the water intended for the supply of towns in England. I need

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SILT TRAPS.

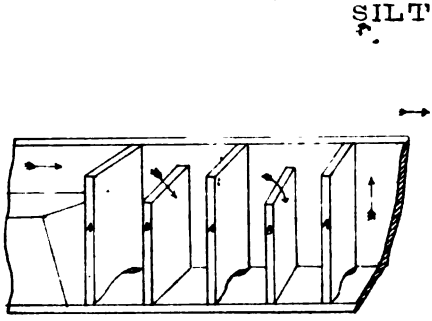


Fig. 3.

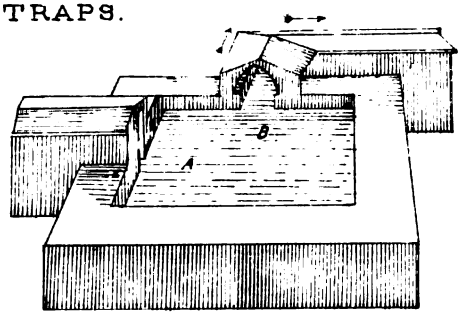


Fig. 1.

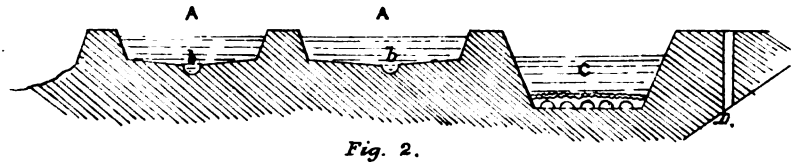


Fig. 2.

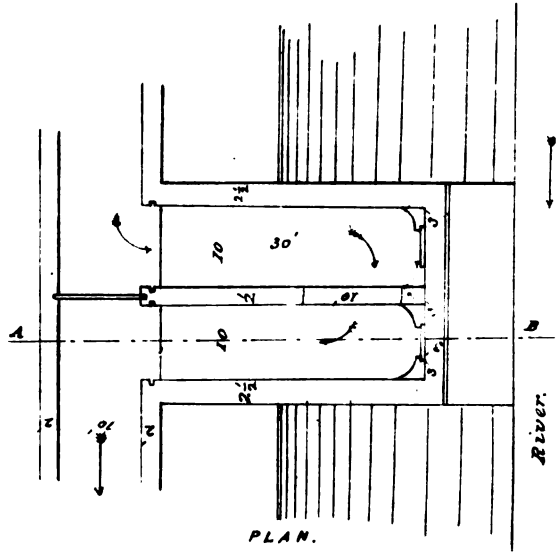
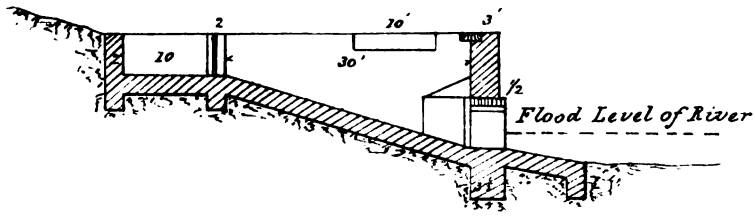


Fig. 5.



Section on A. B.

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not refer to those for filtering yet. Of the arrangements for the preliminary or settling process, I copy the following description of that employed by the Southwark Water Company, which bears most analogy to the method employed in the Doon.

"The system of cleansing adopted by the Southwark Water Company embraces settling reservoirs as well as filtering beds or reservoirs, and some peculiarities in the formation of the former deserve notice. The section *(Fig. 2.)* will clearly shew the construction. A, A, are the settling reservoirs, having an area of between four and five acres, and being 13 feet 6 inches deep and faced with gravel. The beds are formed with a slight inclination from the sides towards the middle, along which an inverted arch, *b*, is formed of brick-work in cement, 6 feet wide and 3 feet 6 inches deep. This invert is an essential improvement, and with the inclined bed gives great facilities for cleansing by sweeping the deposits into the invert and flushing it away with a current of water from an upper reservoir."

By this method the deposits are removed at once from the settling beds without these being kept out of use, which would be the case had the deposits to be removed by manual labor. But they are not thus got rid of once for all. In fact, as the clear water after passing through the filtering reservoir has to be raised to the surface by means of a pump, it would appear that the deposits were only removed by the above means from the settling reservoir, which has to be kept in constant use, to some side pit or reservoir, from which they could be removed at leisure.

In Switzerland a construction is employed which combines the actions of Settlement and Filtering. A long rectangular reservoir is divided into a series of small square reservoirs by means of parallel cross walls. (See *Fig.* 3). The water flows over the top and through an opening at the foot of each alternate one of these walls. *Fig.* 3 shews the mode of action at once, the water proceeding in the direction of the arrows. It is evident that this apparatus can be made to filter the water also if required. But here too there are no means shewn by which it may be rendered self cleansing.

The mere *impurities* ordinarily carried by water bear but a small proportion to the volume of the water itself. The accumulated sediment would form no great mass during a long space of time, and the above contrivances are adapted for this state of things. But other arrangements were necessary on the Doon Canals where large sized gravel had to be

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got rid of, and where, during the floods in the rains, the water-courses ran with silt and water in almost equal quantities.

The water-courses in the Doon are taken off from the different hill torrents which flow down from the Himalayas, and which all flow over boulder and gravel beds. Owing to the great velocity of these mountain streams, due to the steep slope of their beds, they are always more or less charged with silt. "Even during the winter months, when the water in three small canals appears to be flowing along in crystal clearness, a slight stoppage at any point will at once produce a deposit of a coarse blue sand." In the rains, when the hill torrents come down in floods, the gravel of their beds begins to move; heavy masses of shale and gravel are brought down from the landslips which they cause, as they impinge on the sides of the hills which bound their course; and the streams become nothing but moving lines of silt and water, and thus enter the different water-courses of the country.

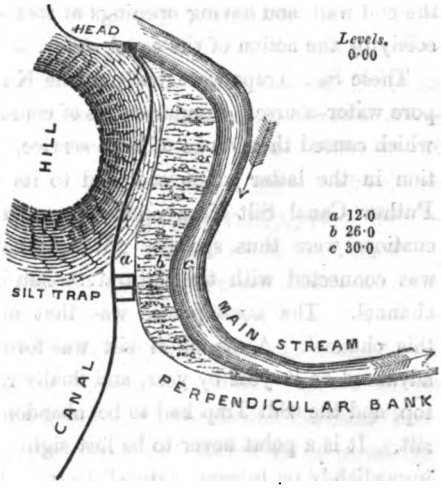
In the Canals of the plains the silt is a sufficiently great evil. But the evils are chiefly that it entails great trouble and expense in removing it. It may prevent some improvements (as for instance the introduction of the module) from being carried out, but it does not do any positive damage. It is, however, otherwise on the water-courses in the Doon. These water-courses are almost all of masonry. The slope of the country is so great that an earthen channel, which cannot in itself have a steep slope, would have to be provided with so large a number of falls that the expense would not be far below that of a masonry channel, to which a very rapid slope can be given, and which can thus carry water with a much less section, besides having a smaller number of falls. Besides this, every drop of water in the Doon is valuable, and a masonry channel prevents all loss from absorption. Thus the Doon water-courses may be described as long masonry conduits, having a section of from 5 × 2 feet to 10 × 4 feet, with a slope of bed of from 50 to 80 feet per mile, and still having numerous masonry falls, 5 and 6 feet in depth, on them. They also generally pass over numerous and long aqueducts. To these water-courses therefore the presence of silt causes immediate and absolute damage. The water rushes down these channels with tremendous velocity, and the gravels carried by it tend to injure all the masonry works over which they pass by the force of impact, while the silt acts even more injuriously, cutting into them with an action

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like that of emery powder. Even to a bed laid with large boulders great damage is caused; the mortar joints are washed out, the boulders lifted out of their places, and then rolled along the bed to add to the mischief. But it is to brick-work that the greatest injury is done. In fact it requires but time to make all brick-work disappear entirely in the presence of such action. In some of the old canals there was a flooring of brick-on-edge over the arches of the aqueducts. On one of these aqueducts I have seen not only the foot in depth of the brick floor entirely cut through, but deep ruts formed in the arch itself. But it was on the falls, which were all formerly built after the ogee pattern and of brick, that the damage was greatest as might be expected. Their surfaces were cut into deep striæ, and they were in constant need of repairs, which were difficult to execute.

It was therefore important as a matter of mere canal conservancy to keep the silt out. But it was also necessary for the sake of the people, as these water-courses not only supply water for irrigation but also for domestic use. In the high, healthy, and best cultivated parts of the valley, the water in the wells is 180 and 200 feet from the surface of the ground. Wells are therefore practically useless. The people are dependent for their water supply entirely on the canals, and it is therefore necessary to have the water in them as pure as possible.

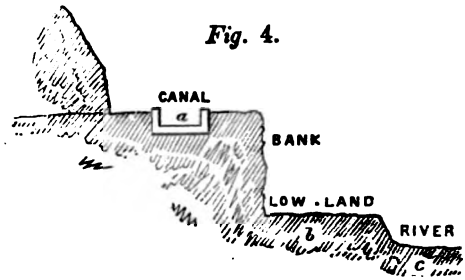
Thus, it was very soon after the construction of the water-courses themselves, that measures began to be taken to intercept and get rid of the silt. The relation between the courses of the canals and the natural features of the country afforded an easy method of doing this. Taken off from various hill torrents they rapidly rise above the bed of the parent stream; and for some distance from the head, and before they run on to the table lands they are meant to irrigate, they have to run along the



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side of the hill or high bank at the foot of which the present stream runs. It is evident how the drop and hollow space between the canal and the river afford an opportunity for the construction of a reservoir such as we need. *Fig.* 4 will convey an idea of this state of things. It is in fact almost an exact representation of things as they exist on the Kalunga Canal.

Fig. 4.



Section along a b c. (To no scale.)

It is evident that a reservoir or Silt Trap can be built at the point *a*, through which the water of the canal being made to pass, it will deposit its silt and gravel in it.

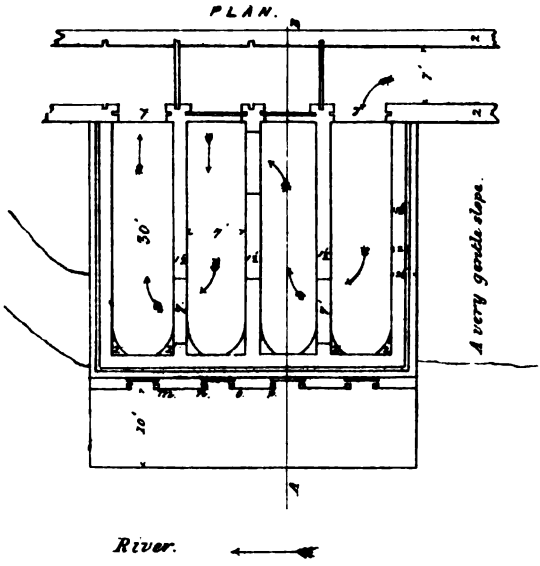
The first Silt Traps built in the Doon were of the form shewn in *Fig.* 5. The mode of action, and the application of the principle of subsidence are at once evident. The water is diverted from its straight course into the first chamber of the reservoir, pours through a slit in the top of the dividing wall into the next chamber, and from there returns again into the canal. The silt settles down into the deep and comparatively still water of the chambers. By giving the beds of the chambers a slope towards the end wall, and having openings at its foot, the silt was got rid of at once solely by the action of the canal water.

These Silt Traps were built on the Kutta Puthur Canal and the Rajpore water-course. Similar errors of construction attached to both of them, which caused them to be of little service. But there was an error of position in the latter which soon led to its total abandonment. The Kutta Puthur Canal Silt Trap opened on to the Jumna river, and its silt evacuations were thus speedily got rid of. But that on the Rajpore Canal was connected with the natural stream by means of a long and tortuous channel. The consequence was that heavy silt deposits took place in this channel. A mound of silt was formed at the foot of the Silt Trap, advanced on it year by year, and finally rested against the end wall to its top, and the Silt Trap had to be abandoned. It had in fact got buried in silt. It is a point never to be lost sight of that a Silt Trap ought to open immediately on to some natural stream. It ought never to be attempted to

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SILT TRAPS

Fig. 6.



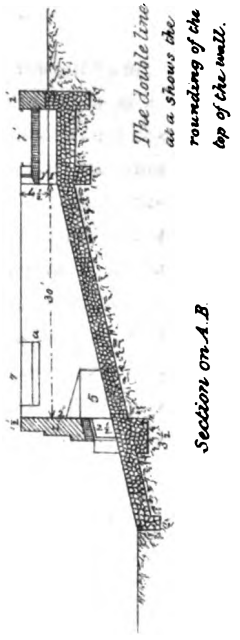


Fig. 8.

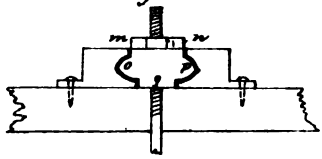
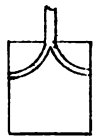


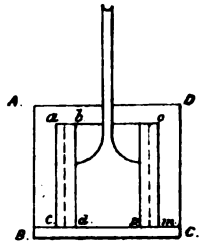
Fig. 7.



m. n. o p q. forms one piece, and contains the female screw. It is in fact a large nut.



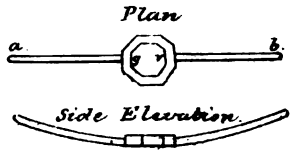
Iron Shutter.



Iron Shutter.

A. B. C. D. Corners of Wood-work seen against wall, a d, o p, sheet iron strips, fixed to wooden beams and acting like springs. Dotted lines edges of iron shutter under strips which hold shutter down.

Plan



Side Elevation.

Lever for turning fixed nut m n o p q.

The hollow Socket g. r fits over m. n.

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carry away the silt by means of flushes from the silt trap itself and along an artificial channel. If possible, the high water of the natural stream ought always to come up to the foot of the silt trap wall.

The errors of construction in these first Silt Traps were—1. That the dimensions of the canal were carried through each part of the Silt Trap, the width of the chambers and of the opening in the dividing wall being made the same as the width of the Canal. The consequence was that the water flowed through the trap with a considerable velocity, and thus carried on a great quantity of silt. 2. That the gates for the openings at the ends of the foot wall were large and clumsy. There was a great loss of water through them; and being 4 feet square, they were difficult to lift, more especially when the silt deposit quite covered them; it was then like trying to pull up a pile out of sand.

The next Silt Trap built was that on the Kalunga Canal in which these defects were remedied. Here, (*Fig.* 6,) a double set of chambers was employed. Greater stillness was obtained by having these additional reservoirs and also by placing the openings in the separating walls at alternate ends, by which means the water had three turns in its course through the trap. And with a double set of chambers, one set could be kept in action while the other was being cleaned out. Two different kinds of gate were employed. For the openings in one set of chambers they consisted merely of small rectangular plates of iron, 1½ feet deep by 1 foot broad, which rested against the sides of square beams previously let into the wall. They were held against the opening, and moved under two thin strips of sheet iron attached to the wooden beams, and which covered their edges for 1½ inches. (*Fig.* 7.) These plates were inside the reservoirs and the pressure of the water made them almost perfectly water-tight. They were moved up and down by means of a long iron rod attached to them, and which reached to the top of the end wall. The upper foot and a half of its length was cut into a screw. As the shutters could not descend by their own weight owing to the spring like-pressure on them of the strips of iron, it was necessary that the rods should push them down as well as pull them up, in fact that the screw should act both ways. This was effected by the arrangement shewn in *Fig.* 8. The double handled lever, *ab*, has an octagonal socket in the middle of its length. This fits over the octagonal nut, *mn*. When the lever is worked to the left, the gate is pushed down; when, to the right, the gate is lifted up.

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This is undoubtedly the best form of gate that can be adopted. There is no leakage through it, and the screw affords the most perfect mechanical agent for working it. But its very perfection was one objection to it; it was too good for the locality. If any thing happened to the screws there was no means of having it remedied within a distance of fifty or sixty miles. Again, while admirably adapted for a regulating gate it could not be used as a flood gate. And this last was absolutely needed, for when the chambers rapidly filled up with silt there was danger of the water flowing over the walls of the Silt Trap. Another form of gate was therefore employed in the other two chambers. The principle of their construction is extremely simple, and they can be made up by any village carpenter. Their mode of action can be easily understood from the diagrams. The gates open outwards so that the force which opens them is the pressure of the water. The bar, *ab*, which keeps down the gates (*Fig.* 9,) runs into two openings made in the side beams *cd*, *ef*, (which project a good deal beyond the surface of the gate), and its ends fix into two sockets, one of which runs upwards and the other downwards. The gate, as shewn in *Fig.* 9, is closed. If the end A be struck from above it will descend, while the end C will ascend till both ends come opposite the openings *m*, *n*, in the side posts, through which they fly out and the gate flies open from the pressure of the water within. It will be observed that the pivot *p*, on which the bar turns is placed so as to give the advantage of the leverage to the descending stroke. It will be observed also that the end of the bar being octagonal, it is only the pressure on the length of one side of the octagon which has to be overcome. Hence the gate is thrown open with the greatest facility. One man can strike open three gates, with a pressure of 14 feet in depth of water on them, with the greatest ease.

The bar may be struck from the top of the end wall with a pole, or from the tops of the small projections, *mn*, *op*, (*Fig.* 6,) built on each side of the gates. I do not know if this form of gate has been employed elsewhere. It seems to me that it might with great advantage be employed in the flood gates for dams and weirs. The fact of the gates swinging from above would militate against its employment in the centre of a dam or weir across a river subject to heavy floods. But from the extreme rapidity with which they can be struck open, they would be of great service for side sluices meant to relieve the first rush of water in floods. The simplicity and cheapness of their construction (no iron work at all

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SILT TRAPS.

Fig. 9.

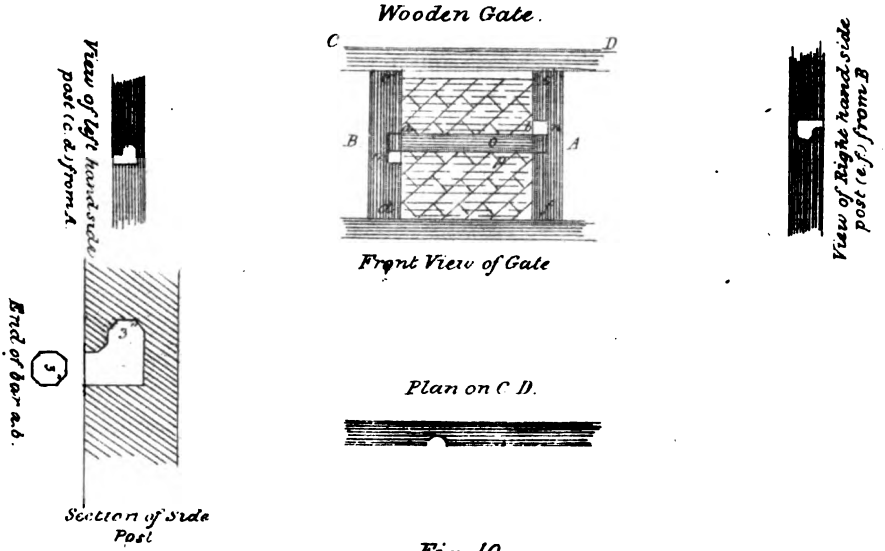
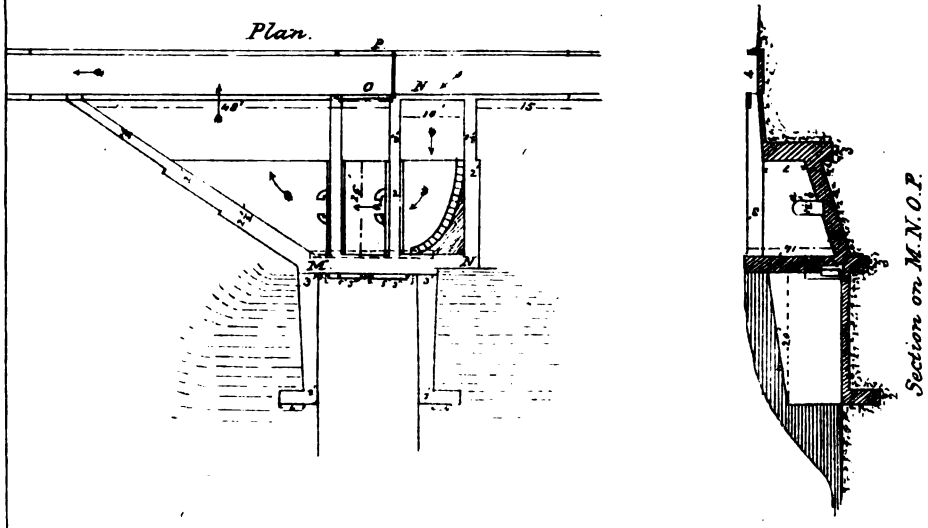


Fig: 10.



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being employed in them) render them suitable for the wild and uninhabited districts in which the heads of canals are generally situated.*

While the Silt Traps first built were of little service or had to be abandoned altogether, the Kalunga Canal Silt Trap has done good service for the past six years. The use of the double chambers becomes at once apparent on examining the quality of the deposits in each chamber. In the first two, is chiefly coarse heavy gravel; in the third, coarse silt; in the fourth, fine silt. The last was never deposited in the old Silt Traps, but was carried on into the Canal.

There were still, however, many faults in this form of Silt Trap. The dimensions of the canal being still carried through the trap, the velocity was very great; perfect stillness had not been obtained. It was obviously a mistake that the last opening out of the trap should be of the same size as the first opening into it. It was an error in Engineering to have so great a length of fall at the end wall, standing *en l'air*, while exposed to the full pressure of the water. From these considerations it became evident that an improved form of Silt Trap ought to have.—1. The opening for the exit of the water as wide as possible. 2. The openings for communication at the foot of the dividing walls of the chambers. 3. The end wall as short as possible. These principles were accordingly carried out in the Silt Trap last built, viz., that on the Rajpore Canal. It will be observed that the water passes out of the trap *(Fig.* 10) over a long weir. The length of this was calculated so that it should have only 3 inches in depth of water passing over it in the rains, and not more than 1 inch or 1½ inches at other seasons. Thus ordinarily, merely the surface water passed over it, and the water was cleaned of leaves, straw, and other substances, as well as of silt. The water was almost purified. The openings of communication, *ab*, are at the foot of the dividing walls of the chambers. The water thus passed on by means of pressure alone; there was no surface velocity. The water in the first two chambers was almost dead still. The end wall, MN, of the trap was made as short as possible. It was strongly supported by the side wall of the escape channel, and all danger of accidents was thus removed.

Other minor improvements were carried out in the construction of this

* This form of gate was devised by Lieut. Edmund Walker, of the Bengal Engineers, when Superintendent of the Canals in the Doon, to whom also most of the improvements in the construction of the Silt Traps are due. By his death, which took place before Delhi in July, 1857, the Indian Government lost one of its most promising officers; and his friends sustained a loss which they have not yet ceased to mourn.

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trap. It had been found to be very difficult for a man to walk down the steep slippery floor of the Silt Trap to the gates, which it was often necessary to do. Steps were therefore made in one of the angles of the first chamber of the new Trap and a small flat cut along the floor and through the openings along which a man could walk. Advantage was taken of the side walls of the escape channel to throw a wooden platform across immediately over the gates (not shewn in plans). Holes being cut into this immediately over the end of the bars of the gates, poles were kept ready slung through them so that the bars could be struck and the gates thrown open at any moment.

After the Silt Trap was built it was found that the action of a principle in hydraulics had been overlooked. The length of the dam had been calculated strictly so as to allow of the passage of the greatest supply of water over it at a certain depth. The tops of the side walls were fixed with regard only to this and the depth of water in the canal. The velocity of communication through the chambers was overlooked, and the heaping up of the water in the first two chambers was so great owing to this that the walls had to be raised to meet it. The different degrees of level at which the water stood in the three chambers was distinctly marked to the eye. Measurements of this would be interesting and useful.

The still water in the first chamber of the Silt Trap acts as a dam to the water in the canal. If possible there ought always to be a fall in the canal immediately above the Silt Trap.

Should it become necessary actually to purify the water by means of filtration, as may yet be the case for the supply of the rising town of Dehra, an apparatus for the purpose could easily be adapted to the Silt Trap. The dividing walls might have cisterns at their feet (sunk below the level of the flooring) which they would span by means of arches. Those cisterns would be filled with gravel, sand and animal charcoal, and covered with perforated zinc plates, to prevent these materials from being washed up. The water would be forced to pass through the cisterns and would be completely purified.

The operation of filtration would however be slow and the Silt Trap would have to be enlarged to meet this. In fact, filtering traps would be best kept apart from the irrigation works of the canal in which rapidity of discharge is the great point sought. There ought to be a separate construction for it.

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No. XXXIX.

ALLAHABAD SPECIFICATIONS.

[The following extracts are taken from a very useful book of Specifications, Rates, Contracts, &c., prepared for use in the 2nd Circle, N. W. Provinces, by Capt. F. W. Peile, R.E., Superintending Engineer. Other specifications will be published hereafter.]

Roads.

Maintenance of road.—The surface of metal, whatever its width, to be always kept free from holes, ruts, and worn-patches, and to be maintained as much as possible with its due central rise of 1 inch per 8 feet transversely, and to its full original width.

Immediately on the appearance of any failure of the surface such petty repair shall be executed as shall restore the portion to its original condition.

The repair shall be commenced always within 36 hours of the first appearance of failure.

In executing such petty repair of metal, the hole, or rut, or patch, shall be cut out to the full depth of the coat of metal in a rectangular form, enclosing the whole of the patch and parallel with the centre of the road; the sides of the excavation shall be sloped off.

Metal of the quality and description specified for annual repairs shall be laid into the hole and properly consolidated; the surface of the new patch when completed, lying perfectly even with the remainder of the road.

The metal for these petty repairs shall be supplied by the Contractor, and he shall be bound to keep up a constant supply of 1,000 cubic

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feet in each mile of road, to be stored separately from the annual repair metal in such convenient depôts as he may choose for each mile.

The earthen sides and slopes of the road shall be kept even, free from ruts and holes, and generally ranging in height with the surface of the metal.

The side drains and water channels shall be kept open and free for the discharge of water.

The surface of the road generally shall be kept free from accumulations of water.

The road side trees are to be tended and cared for, the lower branches of large trees to be lopped carefully during the months of December and January to the requisite height, to admit a free head way for the traffic, and no more, but without injuring the trees. All limbs of trees are to be *sawn* off. Young trees to be protected from injury by traffic or cattle in the usual manner with thorns or mud walls, where necessary.

Collection of metal for repairs.—The *kunkur* to be hard, clean, and fit for road metal in every respect, broken to 2-inch guage, to be sieved and cleaned, so as to be perfectly free from earth and other matters before it is brought to the road side.

The *moorum* to be hard and firm, so as not to be easily crushed under the foot, to be of a sharp gravelly nature, and free of soil: to be sieved at the quarry; meshes of sieve not less than $\frac{3}{16}$ of an inch square.

The *stone* to be of hard close texture, (not friable sand stones,) to be broken to a size to pass through a $3\frac{1}{2}$-inch ring every way for the lower layer, and $1\frac{1}{2}$-inch ring for the upper layer; no round or pebble-shaped stones to be allowed amongst the metal. The stones to be broken clear of the road and slopes, and must be perfectly free of earth or other matters.

The metal to be stacked on the berm, free from the sides and slopes and side drains. No metal to be measured until it has been so stacked.

In measuring the metal collection, the product of the length, breadth, and of $\frac{11}{13}$ of the height, will always be held to be the net cubic contents of the stack.

The metal collection for annual repairs is all to be effected between the 1st November and the 30th April next ensuing.

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Consolidation of metal for repairs.—The surface of the old metal is to be scored up with the pick in parallel diagonal lines at 6 inches intervals.

Two parallel mud walls 8 × 6 inches to be formed along the outer edges of the metalling, leaving an interval between them of the full width of the metal, to confine the metal and prevent its spreading under the action of the rammer.

The new metal to be spread upon the old surface closely packed with the hand, the larger pieces below and the smaller above.

The surface of the new metal to be laid with the usual central rise of 1-inch per 3 feet transversely. As a guide to the workmen 5½-inch cubes of wood will be laid at intervals of 16 feet along the centre, and 3-inch cubes along the side of the metalling, the upper surface of which after consolidation must coincide with the tops of the cubes. Care must be taken to bed all the cubes on one horizontal plane.

The metal to be saturated with water and rammed with rammers until thoroughly consolidated, that is, until the wheels of ordinary light vehicles passing over it cease to leave any impression. The surface to be watered for three days after this consolidation has been effected.

Earthwork for repairs of sides and slopes.—The earthen sides and slopes receive periodical repairs simultaneously with the renewal of the coat of metal. All other repairs to them will fall under the head of maintenance.

The repairs consist of making up the sides to a width of 8 feet from the edges of the metal coat and to the full height thereof, with a slight fall to the outside to throw off water; and in filling in all holes and channels in the slopes, and dressing them off evenly.

The earthen sides and slopes are to be repaired immediately after the adjacent portion of metal has been opened for traffic. The clods will be broken down, the surface rammed and smoothly dressed.

Excavations for supply of the necessary earth will in no case be opened within 36 feet of the centre of the road. The Executive Engineer will give special directions in this matter where necessary.

Earthwork—To include all embankments raised and excavations cut—tanks, hollows, or channels filled, or excavated in any gravel or clay soils, but to exclude excavation for foundations and wells.

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One foot vertical lift to be taken as equal to 10 feet horizontal lead. In the case of an embankment, this proportion for lift to be added to the horizontal lead.

In filling an excavation or hollow, the horizontal lead only to be allowed.

The lead to be measured in the case of a road, from the centre of the excavation to the centre of the bank.

In filling a hollow or excavation, from the centre of the cutting to centre of hollow.

In case of tank cutting, &c., from its centre to centre of spoil bank.

If the soil has to be carted, the excavation will be paid for under that head without lead, and the cartage separately at the Schedule rate for that work.

Earthwork shall be measured from sections of the bank to be raised, or hollow or excavation to be filled, or bank or channel to be cut. In the first and third cases, cross sections shall be taken at no greater intervals than 330 feet, and each portion between two sections shall be calculated separately as a pyramidal frustum or from published tables.

In the second case, the hollow or excavation shall be measured before the work is commenced, and the Executive Engineer and Contractor shall agree in writing as to the quantity of work to be done.

If the Contractor commence the work, it shall be evidence that he is satisfied with the measurement proposed by the Executive Engineer.

All embankments shall be raised in successive layers of 1 foot depth, slightly concave at the centre and consolidated.

The side cuttings shall never be made nearer than 10 feet clear from the toe of the slope of the bank, and they shall not be continuous, but shall be broken at intervals of not more than 300 feet, by a block of earth not less than 10 feet wide.

The sides of all side cuttings shall be sloped at the natural slope of the soil.

No kunkur shall be quarried in the side cuttings.

In cuttings for hollow roads, the cutting shall always be taken out square to the width of the travelling surface down to the formation level, and the slopes be cut afterwards.

Turfing, grassing, and sodding.—Turfing and grassing slopes and surface with *dhoob* or other grass, or cutting and placing sods.

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In turfing and grassing the grass seed may be sown or the roots of dhoob, khus khus, or other grass planted according to orders, and watered until they vegetate. On slopes the seed should be drilled in horizontal lines.

Sodding will only be executed in situations where good strong turf sods can be cut within a mile. The sods are to be cut nearly of a size, and arranged so as entirely to cover the surface.

Sods may be used built as retaining walls to steep slopes; in this case their length, breadth, and thickness must be in the proportion of 6, 3, and 1 inches; they will never be less than 3 inches in thickness, and must be laid in courses alternately header and stretcher; the beds at right angles to the batter; and the successive courses breaking joint with the one below. Each course when laid must be beaten down with large flat rammers so as to pack the sods closely; but without breaking them. The backing of soil must be built up evenly with the retaining wall, course for course.

The rates for sodding will be based on the assumption, that sods can be cut within 300 yards of the work, a charge for extra lead will be allowed, if they be carried more than that distance.

No grassing or sodding will be executed to embankments, or other made earthwork, until they have stood one rainy season.

Brick-work.

First class brick-work will consist of first class bricks laid in cement; the bricks to be of uniform size, thoroughly and equally burnt, of a deep red or copper color, not vitrified, ringing clearly—to be well and squarely shaped, hard burnt, and sound.

Every brick to be bedded and drawn up in cement, to be laid with a true bond, with only such proportion of half bricks as shall be necessary to complete the bond. Every course to be throughly grouted.

No batts to be used in the brick-work.

No joint to be more than three-eighths of an inch in thickness.

Every brick to be saturated with water before it is put into the work.

When the brick-work is not to be plastered, bricks of a uniform color are to be selected for all face-work.

In building brick arches and cylindrical rings of every description,

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the voussoir joints are to be properly summered; bricks forming skew back joints are to be moulded or cut so as to radiate truly. The rings are to be bonded with each other, and the whole work executed in the best manner. The rates to include cost of centering up to 16 feet span, above which the cost of centering will be paid for separately according to its construction.

The top of unfinished masonry to be kept at all times flooded with water.

The walls to be carried up regularly in all cases where the nature of the work will permit.

In all cases, returns, buttresses, counterforts, &c., are to be built up, course by course with, and carefully bonded into, their main walls. These are never to be joggled on afterwards.

Where the masonry in one section of a building cannot be carried up in even courses, the break is to be left in regular steps, so that the new work to be added may be built on over the old.

The *mortar* to be composed of kunkur or stone lime, mixed with soorkhee or sand, in such proportion as the Executive Engineer may direct, according to the quality of the lime to be used. If necessary a proportion of stone lime will be added to mortar made of kunkur lime. The mortar will be thoroughly ground and mixed under edge stones.

The kunkur lime may be burnt in kilns with charcoal or wood, or stacks with ooplah, as the Executive Engineer may direct.

The soorkhee is to be finely pounded, made from well-burnt bricks or from properly tempered and approved clay or loam, worked into lumps with the hand, and well burnt.

If sand be used, it is to be sharp, coarse-grained river sand, clean and free from clay or earth.

Not less than 24 cubic feet of mortar (dry) to be used to the 100 cubic feet of masonry, when the bricks measure 9″ × 4½″ × 2½″. More will be required if the bricks be smaller, less if the bricks be larger, but no alteration of the rate will be made on this account.

Second class brick-work will be executed of similar workmanship generally as first-class, but with second-class bricks, viz., of uniform size, burnt throughout of a light red—not straw color.

No joints to be more than half an inch in thickness.

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Mortar not to be ground under edge stones, mixed in a trough.

This work will, with very few exceptions, be plastered.

Third class brick-work will be executed with bricks similar to those described for second-class laid in mud.

The execution of the work in bond and other details to be as for second-class brick-work.

The mud to be well tempered—if very plastic, a proportion of sand to be added. To be worked down with water till it is perfectly free from lumps and of the consistency of thick paste.

Fourth class brick-work to be executed similarly to third class, but with bricks not thoroughly burnt, being of a straw color, or what is generally known as peelah.

Minor buildings, enclosure walls, &c., will sometimes be built of sun dried bricks laid in mud, as specified for third class masonry. The bricks must be well and squarely moulded, of well tempered clay or loam, and be thoroughly dried before they are used.

The floors of bakers' ovens are generally formed of 6 inches of sand and salt, overlaid with brick-on-edge, the bricks rubbed so as to form a perfectly close clean joint and laid without cement. One maund of *karai noonuk*, the salt given to cattle, suffices for 100 superficial feet of floor.

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No. XL.

RAILWAY BRIDGE OVER THE JUMNA, ALLAHABAD.

Description of the Sinking of the Masonry piers, by JOSEPH F. STRONG, Esq., C.E.

(Abridged from the Civil Engineer and Architect's Journal.)

THE Bridge of which the foundations are described is on the main line of the East Indian Railway from Calcutta to Delhi, and spans the river Jumna at Allahabad, about 1¼ mile above its confluence with the Ganges. It is composed of fifteen openings of 205 feet clear span each, crossed by wrought-iron girders, and giving a total waterway of 3,075 feet, the distance between the abutments being 3,278 feet; the height of the top of the piers is 58 feet 6 inches, and of the rails 80 feet above low-water level. *Fig.* 1, is a general elevation of half the length of the Jumna bridge, and *Fig.* 2, a transverse section: *Fig.* 3 gives a section of the bed of the river, the vertical scale being enlarged five times. For the foundations of the bridge, ten Brick Cylinders AA, of 13 feet 6 inches diameter, are employed in each pier, sunk to a depth of 43 feet below the low-water level, as shown in *Fig.* 4, which is an elevation of one of the piers taken transversely of the bridge. *Fig.* 5 is a vertical section of the pier to a larger scale, taken longitudinally of the bridge, showing a section of a pair of the brick cylinders. *Fig.* 6 is a corresponding half sectional plan of the pier taken through the brick cylinders AA, the outline of the pier being shown by the strong dotted line.

The Jumna, like most of the Indian rivers, winds about much in its course and varies in width and depth considerably; and within a distance of three-quarters of a miles above and below the railway Bridge, it is 65

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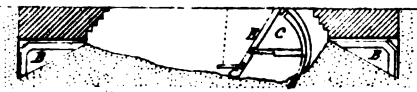
JUMNA BRIDGE PIERS.

Fig. 2.
Transverse
Section.

Fig. 1 One half of General Elevation.



Scale for Fig. 1.
12 6 0 10 20 30 40 50 60 feet.



Scale for Fig. 7.
12 0 1 2 3 4 5 10 feet.

Fig. 6. Half Sectional Plan of Pier.

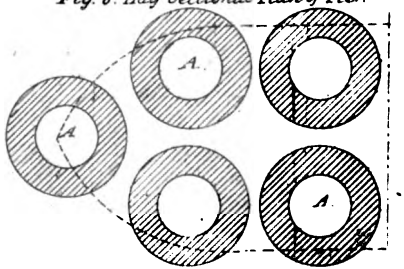
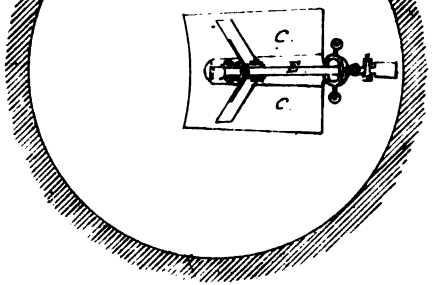


Fig 8.
Plan of Scoop.



Scale for Figs. 5 & 6.
12 6 0 10 20 30 feet.

Scale for Fig. 8.
12 6 0 1 2 3 4 5 feet.

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PLATE LI.

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and 72 feet deep respectively at low-water, but this depth is reduced to only 15 feet at the spot selected for crossing by the chief engineer, Mr. Edward Purser. A number of experimental brick cylinders were sunk to ascertain what the bed of the river consisted of, and at a depth of 35 feet, nothing but sand partly mixed with clay was found. Generally speaking the water is so low in the Indian rivers between the months of November and May that there are no great difficulties to be got over in beginning operations for sinking the cylinders to form the foundations of the piers: but in the Jumna, which is never dry, it was unavoidable that the piers had to be begun where there was deep water: and as the means of pitching iron curbs under water were not at hand, the question arose, what was the best mode of commencing the building of the cylinders preparatory to sinking them?

The simplest plan seemed to be to form an artificial island for each pier; and this was done in the following manner:—Taking the centre of a pier in 15 feet depth of water as the starting point, and setting out a space of 175 feet length by 120 feet width, sand bags were sunk on the down stream and two adjacent sides, thus forming three sides of an enclosure, in the centre of which loose sand was thrown, which was carried by the stream and deposited against the upper side of the lower boundary of sand bags, where it formed a ridge; in due course the surface of the water was thus reached, when the sand was all thrown on the up-stream side, and an island was thereby speedily formed 100 feet long by 60 feet wide at the top. On this island the ten iron curbs were pitched to form the bases for the ten brick cylinders composing the foundations of the pier, being pitched at a distance of 15 feet 6 inches from centre to centre transversely of the pier, and 15 feet longitudinally.

The iron curb is shown in *Fig.* 7, which gives a vertical section of one of the brick cylinders to a larger scale, showing the cylinders AA partially sunk. The curb B is 13 feet 6 inches diameter outside, and 8 feet 6 inches inside, the interior of the brick cylinder diminishing to 6 feet 9 inches diameter. The curb consists of a flat horizontal ring of $\frac{3}{8}$ inch boiler plate, 2 feet 6 inches wide, rivetted by an angle-iron to an outer cylindrical ring of similar plate 18 inches deep, and having gusset plates connecting the two rings underneath. The outer cylindrical ring extends 3 inches above the horizontal one, forming a support all round to the base of the brick cylinder on the outside; and an angle-iron upon the inner edge of the

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flat ring forms a similar support within. To keep the curbs in place they are sunk till the top plate of the curb is bedded on the sand; then 12 feet height of brick-work, 3 feet 4½ inches thick, is built upon the curb, the first 5 feet of which are sunk by simply taking out the sand from the underside of the curb by hand; after which the *jham* must be used.

The results of numerous trials with many kinds and forms of the tool gave a jham* such as is shown at C, in *Fig.* 7 and *Fig.* 8. The jham is made of wrought-iron with a scoop 2 feet 2 inches wide, and 2 feet 4 inches long, made thin and sharp at the front edge, and supported by two stays fixed to the sides of the scoop, and also made thin and sharp at their front edges for penetrating the ground readily; the whole weighing about ¾ cwt.

The mode of using this jham is as follows:—By means of a couple of ropes D attached to the tail end of the arm E, the jham is lowered by hand to the bottom of the well, till the cutting edge of the scoop C and the outer end of the arm E rest upon the sand, as shown by the full lines in *Fig.* 7. Then with the weight of two or three men bearing on the top of the vertical pole F, which is held in place by the pin at the bottom passing loosely through a hole in the tail end of the arm E, the scoop is raised a short distance by the ropes D, the outer end of the arm resting upon the sand and forming a sort of centre of motion; and the scoop is then dropped with the weight of the men bearing upon it, and its cutting edge is thus forced into the sand. By repeating these strokes the scoop is forced into the sand, the workmen knowing by the feel when the scoop is deep enough in the sand. Then with the weight of the men still on the vertical pole F, the jham is hauled up by means of the windlass G, round the barrel of which the chain is wound that is attached to the extremity of the arm E; the jham being thereby tilted into position is brought up filled with sand as shown dotted in *Fig.* 7. It requires ten men at the windlass to move the jham when bedded and covered with sand; it is then drawn up to the top, when it is emptied, and the process repeated.

After the first length of 12 feet of brick cylinder has been sunk down to the water level, an additional 15 feet is added, as shown in *Fig.* 5; and the process of sinking continues till the 15 feet added has been sunk, when an additional 16 feet is added, making a total of 43 feet depth. As a precaution for preventing the curb and lower portion of the brick cylinder from parting from the upper portion, which is found some-

* The kind of jham employed and the method of using it are very similar to the practice in sinking the piers of the Solani Aqueduct, on the Ganges Canal.—Ed.

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times to occur, provision is made on the curb for attaching six holding-up bolts, which are built into the brick-work for a length of 16 feet, as shown in *Fig.* 5, and at intervals of every 5 feet a ring of flat iron is dropped over all the bolts and cottered down on to the brick-work.

The rate of sinking of the cylinders is far from regular; at starting the progress is pretty even, the cylinders going down from 15 to 9 inches per day; but the average rate of sinking when down to 20 feet is not more than 4½ inches per day; and beyond that depth the rate of progress gradually decreases till it is not more than 1½ to 1 inch per day of 24 hours. The plan that is adopted where the sinking goes on slowly is to add extra weight on the top of the cylinder, either by building extra brick-work or adding a load of rails. In very bad cases both means are used, till a weight of 40 tons on each cylinder has been added; and even with this additional load on the top great difficulty has been met with when the sinking has reached a depth of 40 feet; which is not surprising when it is considered that there is then a constant pressure due to 40 feet head of water acting upon the sand round the exterior surface of the cylinder at the bottom.

When the cylinders have been got down to the depth of 43 feet they are ready for the concrete H, *Fig.* 5; but before throwing in the concrete, a diver supplied with Siebe's diving apparatus is sent down to clear away any rubbish that may be left at the bottom of the well, and level the space under the curbs for the reception of the concrete. A depth of 15 feet of concrete is then thrown in, composed of 1 part of fresh-burnt unslaked lime, 1 of broken bricks, and 2 of underburnt lime; these are the usual proportions of the concrete used in stopping the cylinders, and about 18 days are generally allowed for it to set. A disc made of two thicknesses of 2 inch planking is let down upon the surface of the concrete, weighted by 3 feet thickness of brick-work; this disc is a little less in diameter than the inside of the cylinder, so as to pass freely down on to the concrete, the space between the edge of the disc and the sides of the cylinder being then filled in with wood wedges driven by divers. The object of putting in this disc is to prevent the concrete being disturbed by the pressure of water underneath, whilst the water is being baled out from above the concrete, preparatory to building the cylinder up solid.

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The mortar used was made of 1 part of lime to 1 or 1½ parts of soorkhee, which consists of bricks pounded and passed through a sieve of 8 meshes to the inch: this mortar is of the best description, being hydraulic, and setting almost better in water than out of it.

The next operation after having made tight the wooden disc upon the top of the concrete is to bale out the water, and build up the void inside the cylinder solid with rubble stone, as shown in *Fig.* 5, this is carried up to the top of the cylinders, and their tops are thus reduced to an even bed ready for the covering stones. As a precaution to prevent these stones from spreading, a groove is cut in the top of the cylinders 6 inches deep, and extending lengthways of the pier, as seen in *Fig.* 4; into this groove the large stones are laid, and they stretch across the space between the cylinders, and have a good hold on each cylinder. The stones are all cramped at the joints with 1½ inch square iron, and the stones in the next course above are dropped into joggles in the first course. The hearting of the cylinders is then carried up in brick-work, diminishing by a set-off of 2½ inches at each course to form a core or centre for the corbelling or over-sailing of the brick steining of the cylinders. A similar provision is made on the outside of the cylinders, by throwing in concrete between the cylinders, and building concentric rings of brick-work upon that: over these the corbelling on the outside of the cylinders is carried. There are twelve courses of brick-work between the top of the cylinders and the top of the second course of the covering stones; and at this level there is a through or bonding course of ashlar, running transversely to the piers, as shown in *Fig.* 5. Up to the top of the plinth there are similar courses faced only with ashlar, the backing or hearting being of large rubble. The piers between the plinth and cap are built with ashlar facing to the cutwaters, blocking courses between the shoulders of the cutwaters, and rubble backing behind throughout the whole length of the piers. There are large stones for carrying the cast-iron bed-plates, upon which the saddles supporting the end standards of the bridge rest.

The section of the river bed, *Fig.* 3, shows the body of water in the river at low-water, and the lower dotted line shows the ordinary rise of the river at flood time, being about 45 feet rise; the level of the underside of the girders is fixed at 14 feet above the ordinary flood level. The upper dotted line shows the extraordinary rise of 51½ feet that took place in the years 1838 and 1861. During the time of the last extraordinary

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flood of 1861, the current of the river increased to the rate of 9 miles an hour, the ordinary rate when not flooded being only 2 to 3 miles an hour.

In the course of the discussion upon the paper—Mr. Strong said,—the means adopted for keeping the cylinders vertical in sinking was to move the windlass round through a quarter of a circle every six hours, so as to take the sand with the scoop from every side successively of the cylinder. In taking the sand from the inside, some of the sand outside necessarily got forced in at the bottom of the cylinder by the external pressure, which had also to be got out by the scoop; and this, with the continually increasing density of the sand, was the reason why the rate of progress diminished so rapidly when the depth sunk was considerable.

Mr. H. Woods asked whether any other plan of getting up the sand had been tried besides that described, in order to raise it more quickly. He had made about six years ago, for Mr. Ward, a set of machines like vertical dredgers, intended to be used on some of the railways in India for getting up the sand in sinking pier foundations, and he believed it was intended to use ten of the machines at a time. Each dredger had about thirty light wrought-iron buckets, 12 or 15 inches long, and the same breadth at the widest part, with the mouths steeled; there was an adjustment for sinking the dredger down to work to a depth of 30 feet, and the buckets delivered the sand into a moveable spout worked by a cam, which brought the spout forward to receive the charge of each bucket as it came to the top, and then drew it back again out of the way to allow the empty bucket to pass down clear. He did not know, however, about the working of these machines.

Mr. Strong replied that the dredgers referred to had been used, but only to a depth of 10 or 12 feet. In shallow water they might be used advantageously, but at a greater depth the inclination was too steep for them to work well. The brick cylinders of 43 feet depth, and 6 feet 9 inches inside diameter, had so small space inside for the dredgers that the buckets had not room to deliver themselves in working at a great depth.

Down to a depth of 10 feet from the surface of the ground the rate of sinking was about 18 inches per day. The cost of sinking each separate cylinder by this plan was 10*s.* per foot down to 5 feet depth; between

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5 and 10 feet it was 20*s*. per foot; between 10 and 15 feet, 30*s*. per foot, and so on, increasing regularly 10*s*. per foot at every additional 5 feet of depth, down to 40 feet depth, beyond which the rate was 90*s*. per foot. Those were the rates paid to the men for labor only, the materials being found for them. The work was all done by contract: one contractor undertook the sinking of one or more cylinders at those rates, and paid his own men. All the cylinders were sunk together in one pier, as it was easier and much quicker work to sink them all together.

Mr. J. Fernie asked what determined the depth to which the cylinders were to be sunk; and whether at the bottom of the deepest pier the material was still the same, or was found to vary.

Mr. Strong replied that during the dry season, when the water was low, sections were taken across the rivers, and the depth of the river bed was never found to vary to any great extent, the average greatest depth at low-water being about 15 feet; but the deepest part was seldom found in the same place two seasons running. The piers were generally sunk to a depth of 43 feet below the low-water level; and borings had been taken, but nothing but sand was found at a depth of 80 feet below the water level. Sometimes the sand was found to be mixed with clay and loose stones, but nothing like rock was ever met with. The only failure there had been with the brick piers occurred during the high floods of 1861, when the four up-stream cylinders out of the ten in one pier fell over. This was owing to the sand inside the cylinders having been scooped out in the process of sinking to as great a depth as 18 feet below the curbs, so that the cylinders were hanging as it were in their places, held up only by the friction of the sand outside. When the flood came down and the water began to eddy round the cylinders, the sand was set in motion and gradually loosened round them; and eventually, the support being taken from them, they slipped down, and in so doing quietly fell over on their sides. It was subsequently ascertained by probing with steel rods that the convex side of the cylinders was unbroken; they had simply fallen over, but had not broken to pieces. The cylinders had not been replaced when the author left India last year: a coffer-dam had already been made round the spot where they lay, and an excavation was being commenced for the purpose of getting down to them. When got at they would have to be broken up in order to be removed.

Mr. F. J. Bramwell, suggested that the cylinders might be sunk much

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more rapidly if they were weighted with an additional load for the purpose, as there appeared to be an objection to increasing the height of the cylinders in order to get a greater weight. If they could be made to go down quicker, he thought there would not be so much sand running in from the outside, which was the cause of the delay in sinking; and it would not be necessary to shift the scoop and windlass round several times during the day to make the cylinders go down straight. When the shaft of the Thames Tunnel, on the Wapping side of the river was sunk, the brick-work was built up to a height of 25 feet on the iron curb before the excavation was commenced, in order to make it go down rapidly and steadily; and it was afterwards loaded two or three times during the sinking, to get it down.

Mr. H. W. HARMAN concurred in the desirability of loading the cylinders in order to sink them rapidly, so as to prevent the material outside from getting forced in at the bottom by the pressure of the water. He had found some difficulty with the iron cylinders of the Trent bridge, and had loaded them with 35 to 40 tons of railway rails; they then sunk rapidly, and nothing had to be excavated except the material inside the cylinders, as none of that outside found its way in.

Mr. E. A. COWPER thought that not only was weighting necessary to sink the cylinders rapidly enough, but a different form of iron curb was desirable, to avoid having such a large flat surface at the bottom of the cylinder, which must oppose a great resistance to its easy descent. He suggested that if the outer edge of the iron curb were prolonged considerably in advance of the bottom of the brick cylinder, so as to present a cutting edge all round, the cylinder would then sink faster, because the projecting curb would reach so far down into the sand as to prevent the external sand from getting forced up into the cylinder.

Mr. STRONG said that no experiments had been tried as to what weight it would take to sink the cylinders deeper in the sand after they had been sunk to their final depth; but they had tried an experiment as to the supporting power of sand under water, for some fear had been expressed at first that if the pier cylinders should ever be left partially unsupported, by the sand being scoured away from the sides, they would under the weight of the piers and superstructure sink deeper into the sand. To ascertain whether this would really be the case, the following experiment was tried. Two $\frac{3}{8}$-inch boiler plates, 6 feet long by 3 feet wide, were

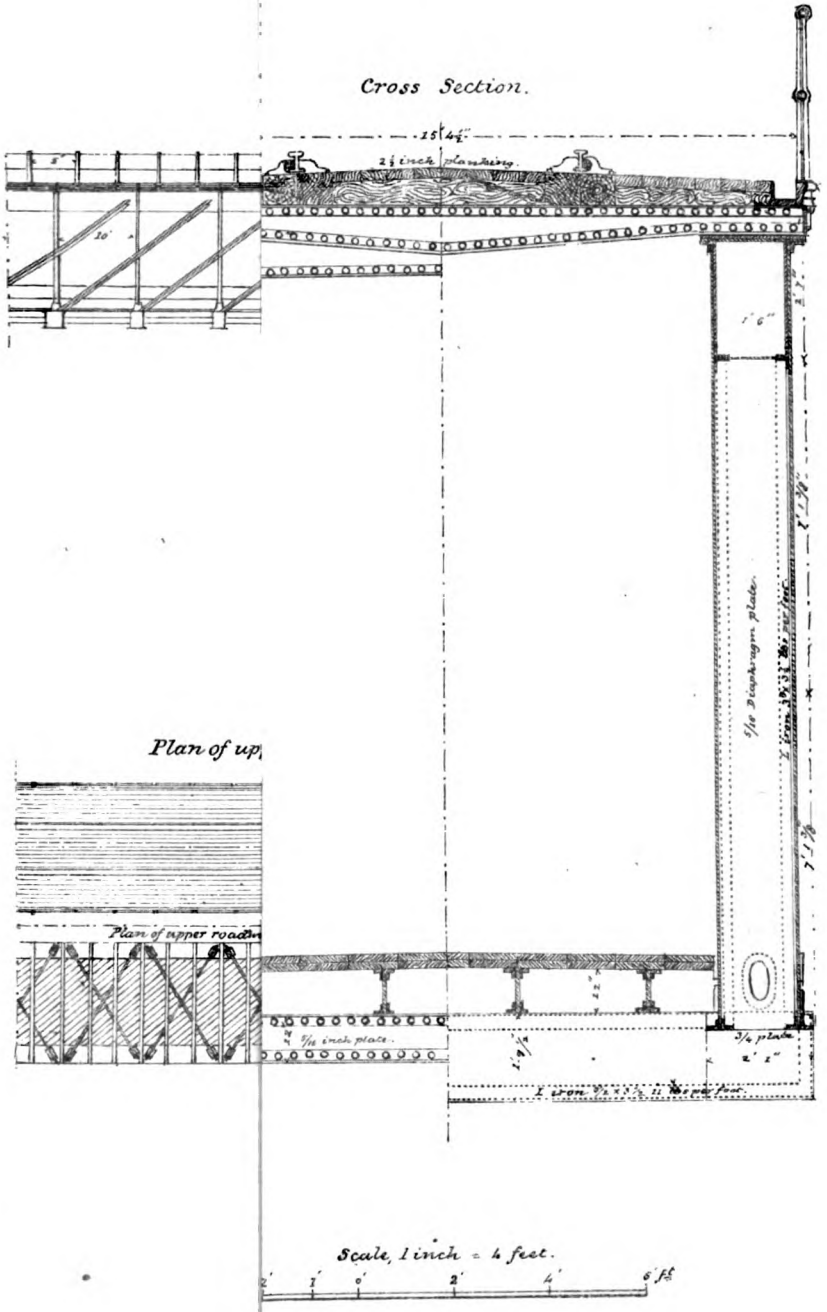
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rivetted together, and 20 holes to a scale of 1-100th of the actual diameter of the brick cylinders were drilled through them in the relative positions of the cylinders in two piers of the bridge. The plates were then bedded on sand, which was kept constantly wet by water standing at the same level; and the plates were weighted till there was a pressure of 18 lbs. per square inch, equivalent to 42 feet head of water, on the sand, which was then assumed to represent the actual condition of the sand under the pier cylinders when sunk 42 feet. A model to scale of one span of girders was made, resting on ten cylinders at each end, 1⅝-inch diameter each; the ends of these cylinders were dropped through the holes in the plates, which were drilled slightly larger to let them pass freely through, so that the ends of the cylinders rested on the sand under the pressure of 18 lbs. per square inch. The girders were then loaded with weights, and it was found that with a total load of 15·7 lbs. per square inch on the cylinders they sunk ⅜ths inch into the sand; and under a load of 31·4 lbs. per square inch they sunk 1-16th inch deeper; but from that point up to the heaviest weight imposed of 157 lbs. per square inch they sunk no further, the total sinking not exceeding 7-16ths inch, and that weight remained on for three months without the cylinders sinking any deeper. The load of 157 lbs. per square inch was equal to 10 tons per square foot; but the actual weight of the foundation, pier, and superstructure was 5,650 tons on each pier; and the total area of the ten cylinders of 18½ feet diameter in each pier being 1,430 square feet, the actual pressure on the foundations was not quite 4 tons per square foot. The experiment therefore proved that the piers were quite safe from sinking deeper in the sand, even under a load of more than double what they had actually to carry.

Description of the Iron Superstructure, abbreviated from "Humber's Iron Bridges."

The design provides for a double line of Railway and Roadway, the rails being carried on the tops of the Main Girders at a height of about 17 feet from the surface of the roadway. Each span was intended to consist of two distinct bridges, placed side by side, and each bridge was designed to carry a railway and roadway, The structure, however, has

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LITHO. T. C. PRICE.

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only been completed for a single line, though the Masonry and Iron superstructure of the piers have been executed in accordance with the design shown in the plate. The Main Girders, of which there are two to each bridge, are composed of the following parts, viz., a top compressive member formed of wrought-iron boxes or cells, a bottom tension flange of wrought-iron bars or links, and a web which is of the triangular principle, and consists of a series of wrought-iron struts and ties, the former of which are placed in a vertical position. The cross girders for the upper roadway are placed at distances of 1 foot 6 inches apart, and are of the construction shown in figure; those for the lower roadway are placed in pairs at a central distance of 4 feet 6 inches between each pair. The platform of the lower roadway, which is formed of a double thickness of 2-inch planking, is carried on 4 wrought-iron continuous longitudinal joists, which rest upon the cross-girders just mentioned; these joists are braced together on the under side by wrought-iron bars 3 inches wide, and ¼ inch thick.

TOTAL WEIGHT OF BRIDGE.

	Tons.	Cwt.	Qrs.	Lbs.
15 Girders,	3769	15	2	14
14 Platforms,	23	16	0	0
7 sets of bed-plates, with roller arrangements,	124	4	2	7
7 sets of bed-plates for fixed bearings,	99	6	1	0
1 for land pier,	9	15	0	0
1 for land pier,	7	19	1	21
Weight of superstructure for one line of railway and roadway,	4034	16	3	14
Weight of ironwork in piers,	159	4	0	0
Total weight of ironwork in bridge as executed,	4194	0	3	14

which, for a length of 3,330 feet, gives a total weight of iron per foot-run of 1·235 tons.

The following are the principal points in the Specification:—

The whole of the *Wrought-iron* used for the work, is to be free from scales, blisters, laminations, and all other defect. No plates, bars, or angle-irons, will be approved which are found to exceed, or fall short, of the specified weights and dimensions, more than 5 per cent.

The *bars*, and all parts of the girders whatsoever, which may be subjected to tension, are to be capable of bearing a tensile strain of, at least, 20 tons on the square inch of section, under the concussion of a blow struck with a heavy hammer.

The *rivets* are all to be of the best quality of Staffordshire rivet-iron.

The *bolts* and *nuts*, and the *horizontal braces*, are to be made of the Mosk Bridge

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"best," or of Bradley's B. C. crown iron, or of such other iron of equal quality, as shall be specially approved by the engineers.

The *frames of the expansion roller bearings* are to be forged from Low Moor, or Farnley, or the best Monk Bridge iron.

All the *Castings* are to be clean, sharp, true to form, and free from air-holes or other defects. The *bed-plates* and *rollers* are to be cast from a mixture specially selected for hardness.

The *bolt-holes* in the bottom bars, and in the diagonal ties, are to be made as follows:—Holes not more than 1⅛ inches in diameter, are first to be punched through the bars, as nearly as possible over the centres of the finished holes, their position having been accurately marked off with a template. The bars, in sets of from six to twelve, are then to be stacked on, and bolted firmly, to the bed-plate of a boring tool, made or adapted specially for the purpose. In this position all the holes are to be bored, without the bars being shifted from the bed-plate, the boring tool being passed through the holes punched in the bars, and guided in steel bushes, both above and below the tool.

All *angle-irons* whatsoever, not expressly excepted, are to be in single lengths, without welds, or joints. In the struts and intermediate girders, they are to be carefully bent at a sufficient heat, to the required form without being cut.

The *plates of the horizontal boxes* are to be in one length, without joints; and throughout all the girder work no joints or joint-plates will be permitted, beyond those shown on the drawings.

The *lugs* by which the horizontal braces on the girders are affixed to the top boxes are to be of forged scrap-iron; after being drilled to take the rods, they are to be rivetted on the boxes accurately in the line of the braces.

The *braces* themselves are to be rods of 1¼ inches in diameter for their general length, but having pieces of rod of larger diameter welded on their ends, to take the screwed portion without reducing the section below that due to a diameter of 1¼ inches. They are all to be screwed at each end for a length of not less than 6 inches, and provided with double hexagonal nuts.

Lower Roadway.—1st. Four rows of continuous wrought-iron joists are to be laid from end to end of the bridge, to carry the lower roadway. The outside rows consist of bars $7'' \times \frac{5}{16}''$, with two angle-irons at each edge, each $2\frac{1}{2}'' \times 2'' + \frac{1}{4}''$. The lower flange is strengthened by a plate $10'' \times \frac{1}{4}''$, also running the whole length of the bridge. These joists, with the 10″ plate rivetted to them, are to be sent out complete in 20 feet lengths, the connections between the plates being made as shown.

The intermediate joists consist of bars $8'' \times \frac{5}{16}''$, with two angle-irons, $2\frac{1}{2}'' \times 2'' \times \frac{1}{4}''$ at each edge, to be made up in 20 feet lengths as before.

All these lengths are to be so arranged as to break joint with each other.

The cross-girders are to be punched out where these joists cross them, so that they may be rivetted together in India.

These joists are to be braced together on the underside, by wrought-iron bars 3″ wide, by ⅜″ thick.

2nd. The vertical struts are to be connected together at the lower ends, with plates ⅜″ thick, 15″ deep, and of such width as will fill up the distance between the vertical angle-irons of the strut rivetted to the struts with four ¾″ rivets on each side.

3rd. The end bars of the lower member of the girder are to be stiffened by the insertion between each pair of ¼″ bars, of a bar $3'' \times 1''$. All these bars are to be rivetted together.

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The pairs of bars on each side of the girder are to be further connected together by 3″ × ¾″ bars, forming a bracing as shown. None of the rivetting is to be executed in this country, except what is necessary to form the intermediate bars into a bracing.

Accuracy required.—It is to be expressly understood, that as a rule, the greatest possible accuracy is to be attained in every part of the work, the object being to facilitate the erection of the bridge in India by perfection of workmanship in this country. It is therefore intended that all similar parts shall fit indiscriminately in all similar places and in any span. To ensure this, every similar piece is to be tested on completion, as to the accuracy of its form and dimensions, in a gauge-test, and all those that do not correspond with such gauges will be rejected.

Testing.—Every span of the bridge is to be erected rivetted together, and finished complete in every respect, except as regards timber-work, on the contractors' premises, so that it may be tested under load. For this purpose it is to be put together upon a timber platform, as specified in the following paragraphs, and bearings are in addition, to be provided at two ends to carry the girders when the wedges beneath the platforms are withdrawn.

These bearings are to be of solid masonry, built upon concrete, and (if necessary,) piled foundations, to prevent the possibility of settlement during the testing of the span.

Should any settlement take place whilst the whole or any portion of the load is on the bridge, the contractors will be required to remove all such load, to reinstate the bridge in its proper position by means of the platform wedges, and to recommence anew the testing. The load to be placed is 450 tons of pig-iron, ⅔ of which are to be put upon the upper roadway, and the remaining ⅓ upon the lower roadway. It is to be laid upon temporary planks of sufficient strength, and distributed uniformly over the roadway.

On the receipt by the contractors of the Engineer's certificate of the satisfactory completion of the testing, the temporary rivets are to be cut out and the span taken to pieces, packed, and delivered for shipment.

The girders are to be erected on timber platforms, and must rest immediately on cross cills, with carefully-made folding wedges of hard wood beneath each cill, the cills and wedges being sufficiently close to admit of the girders being readily raised or lowered by driving or withdrawing the wedges.

These cills are to be carried on piles, if the nature of the ground renders piling advisable, or if not, they are to be secured by other means from the slightest settlement.

The required camber must be carefully given to the platform in the arc of a circle, the chord or camber in the centre being 4½ inches.

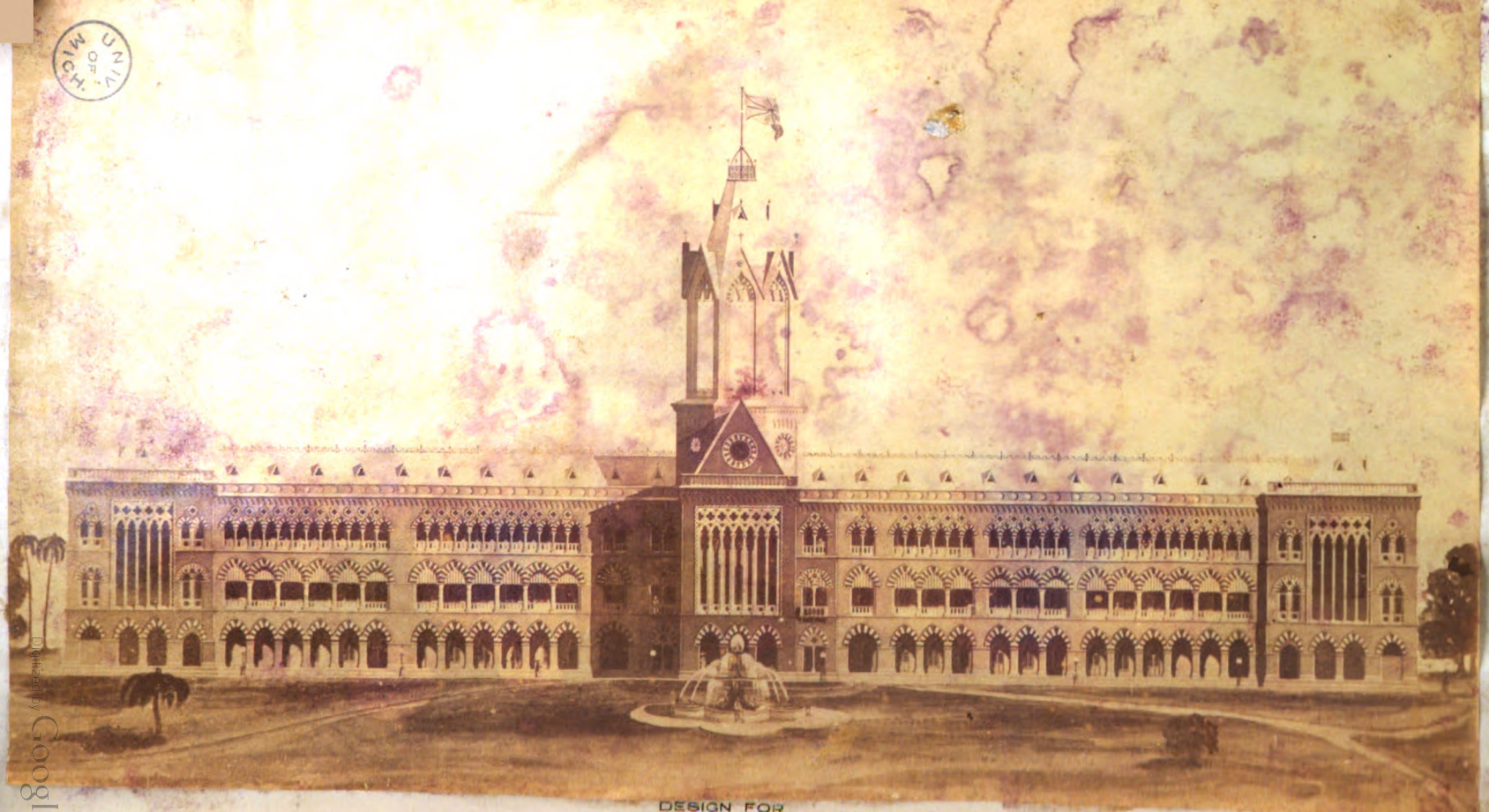
Painting.—The whole of the materials delivered under this contract are to be painted with two coats of good zinc paint, or of Woolston's Torbay paint, of any color the engineers may desire, one to be laid on as soon after the formation of the parts, and the other subsequent to the taking to pieces of the parts after their temporary erection.

The superstructure of this fine bridge was designed by the Messrs. Rendel, and executed at the Canada Iron Works, Birkenhead.

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DESIGN FOR

EUROPEAN GENERAL HOSPITAL—BOMBAY.

UNIV. OF WICH.

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PECULIARITIES OF INDIAN ENGINEERING.

With the present Number is given a Glossary of Indian terms used in the First Volume, chiefly for the benefit of subscribers in England, and on the same account also, I propose to draw attention to some of those peculiarities in Indian Engineering, which will serve to show the conditions under which work has to be executed in this country, and how far they differ from English methods; the sketch will not, perhaps, be altogether destitute of interest to many who are in India.

First, as to the Agency.—Except Forts, Arsenals, Dockyards, Barracks, and the like, there is scarcely a single Public Work in England in which the Imperial Government is directly interested, for even such works as Jails, Roads, &c., belong to the counties, or to recognized local interests, while the great mass of important works, such as Railways, Harbours, &c., belong to Joint-Stock Companies, and are private property.

In India, the Government is the constructor and maintainer of nearly every public work throughout the country. Not merely works which specially appertain to an immense Military Establishment, but every Road, Bridge, Church, Court-House, Jail, &c., has to be built from Imperial Funds, and through Government Officers. Nor can even the Railways be excepted, for though the capital employed is not its own, yet the controlling power possessed by Government is so great,* that not the smallest work can be under-

* This arises from the Guarantee system under which the capital has been raised, the Government guaranteeing a minimum rate of interest (5 per cent.) to the shareholders on all sums passed to capital account. The controlling power is exercised through the Government Consulting Engineers, who have a veto on almost every action of the Company's Engineers. The system, though perhaps the best that could be devised at the time, has been productive of much delay, and no little dissension. It would be a

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taken, nor the salary of the least official paid without its written authority.

For the above work, a great Department of State, the Department of Public Works, is specially provided, by which a systematic control is maintained over a vast body of officials, European and Native, acting as Engineers, Overseers, &c., from the Secretariat down to the meanest *employé*.

But another distinctive difference between the Agencies employed in England and India is, that in the former country, work is executed almost invariably by contract, while in the latter, daily labor employed and paid by the Engineers is as invariably used. It is true that every effort is being made to introduce the contract system, and that it is generally in vogue in the Presidency Towns, and on most of the great Railway Works, but over the whole country the vast mass of the Government work is done by daily paid labor, and the extra work thereby thrown upon an Engineer may be easily conceived.

In another very important matter do the functions of the Indian Engineer differ much from his brother in England. In many parts of the country there is no organization of labor whatever, and when works have to be executed, the Engineer has to collect and train his workmen, to make arrangements for carriage,* to make his own bricks, burn his own lime, cut his own timber, and in a word superintend a hundred petty details, which in a civilized country are

preferable course for Government to grant a certain subsidy to the Railway Company for every mile of line, as completed and open for traffic, and some such arrangement will probably be adopted in future.

* This difficulty of carriage alone, in a country where the distances are so vast, and the means of inter-communication so incomplete, is most serious. The greater portion of the Permanent Way on the East Indian Railway was brought by Native boats up the Ganges, and £100,000 worth of rails &c., now lie at the bottom of that river. On the Punjab Railway, the materials were brought in boats up the Indus, which were often seven months on the voyage (800 miles), the cost of freight between Kurrachee and Moultan being *double* the freight from England to Kurrachee. The locomotives after getting to Moultan, were dragged up an unmetalled road to Lahore on trucks, by elephants and bullocks—six weeks being occupied in accomplishing the 200 miles. On this line too, which runs through a desert, the first steps of the Engineers were to dig wells and build huts for the workpeople, and induce grain merchants to live in the desert to supply their wants. When the writer went down to inspect the first trace of the line with the Chief Engineer, water and provisions had to be carried on camels to supply the whole party.

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undertaken by a hundred different men, each skilled in his own peculiar business.

Of the Workmen themselves, much good may be said. That they have the usual prejudices of ignorant men to the introduction of new ideas, and new methods of working, is to be expected, but they are not worse than others in that respect, and if well managed, are as a rule both intelligent and teachable. Excellent masons, carpenters, and smiths abound in the country. The machinery in the various Railway Workshops is managed by Natives under European superintendence, and though there are no Native engine-drivers as yet, we shall doubtless have some before long.*

The most striking thing to the Engineer fresh from England, is the total absence of the ordinary mechanical appliances for executing work. Vast earthworks are still made by the help of the *phourah*, or native spade, and baskets carried on the heads of women and children. Wheelbarrows are scarcely ever seen; horse carts still more rarely. For getting water out of foundations, &c., pumps are coming into use, but in general the primitive native modes of baling, or the *Churus* (leather bag), or Persian wheel worked by bullocks, are still employed. Bricks and Tiles are almost invariably hand-made, and the pug-mill unknown; the saw-pit is never used.

Of course the principal reason for this is the comparative cheapness of labor, but if the rate of labor increases for a few years longer, as it has done for some time past, the introduction of more elaborate appliances will become essential. At present, except the Railway Workshops and those established at Roorkee, there is no Steam Machinery in the country, unless at the Presidency Towns. Machines driven by wind power are also unknown, it is difficult to say why. Of the enormous water power available on the numerous canals and rivers, very little is utilized. Sawing Machines are here

* In the Railway Workshops at Lahore, a short time ago, I saw the carpenters working at regular benches instead of in their own *squatting* position, and turning out some beautiful specimens of work. The whole of the Rolling Stock (except the iron-work, which is brought from England,) has been made at Lahore for this line by Native workmen.

At Goojranwalla I saw a Colt's Revolver, copied so exactly even to the engraving on the cylinders, that only very close inspection could tell it had been made by a Native smith.

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and there put up, and the common *Punchukkee*, or native corn-mill is everywhere seen where there is an available fall. Machinery worked by animal power is confined to water-raising for Irrigation purposes, and to one or two primitive inventions employed in Manufactures.

Having said so much of the Agency employed, let us glance at the materials used and the works turned out. In Central India and the Hilly Districts all over the continent, many varieties of excellent building Stone exist, and are abundantly used. In the great plains of Bengal, Hindostan and the Punjab, however, Brick is the only available material. The English sized bricks or those of a still larger size are now coming into general use. The Native bricks are very small, excellently burnt, laid with little attention to bond, and with a profuse expenditure of mortar. Bricks are burnt with wood fuel* in kilns of several kinds, or in stacks like English clamps with dried cow-dung instead of coal.

Excellent Lime is everywhere abundant, produced either from limestone "in situ," or the boulders found in hill torrents, or the kunkur found in the plains. It is mixed with various substances for mortars, of which pit-sand and soorkhee (pounded brick) are the chief ingredients. For very strong or fine mortars, coarse sugar and egg shells are sometimes added.

A great variety of fine Timber is found in India, generally brought from the forests in the Hills—among which may be noticed *Saul*, a dark, heavy, straight and strong wood, and *Deodar*, nearly the same as the Cedar of Lebanon; the former used in the North West Provinces, the latter in the Punjab for every kind of building purpose. Both of these are found in the hills alone, at an elevation of from 2,000 to 5,000 feet; the trees are cut down and thrown into the rivers, and when these rise the logs are floated down to the plains. In West and South India, *Teak* is in general use. It abounds in the forests of Burmah, being one of the most valuable productions of that Province. *Toon*, an inferior sort of Mahogany, is exten-

* Except in the few places where coal is found. No coal worth working has yet been discovered in Northern India. The locomotives burn wood, and fuel is scarce and dear.

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sively used for furniture; *Sissoo* or *Sheeshum*, and some of the varieties of Acacia, are hard, heavy, crooked woods, used for strength and toughness.

Iron ores of fine quality are abundant in many parts of India, but from the want of fuel and carriage are little worked, and English iron is generally used. Government have made, and are now making, several praiseworthy attempts to develope the manufacture of iron.

Here it may be as well to note one or two specialities of Construction employed in India.

In *Roads*, stone metalling, laid as in macadamized roads, is common enough, but in the great plains of Upper India the peculiar material *Kunkur* is used, and laid in a peculiar manner. It is a species of concretionary oolitic limestone, found in beds close to the surface, and has to be drenched with water, rammed quite smooth, and then suffered to dry before any traffic is admitted. It then makes a white, smooth, and very excellent road covering.

In Southern India, Laterite and *Moorum*, a sort of red gravel are commonly employed.

In *Foundations*, piles are rarely employed, for so many destructive agencies are at work that they would not be lasting. The majority of the water-courses are nearly dry at one time of the year, and this affords great facilities for getting in the foundations of Bridges or other works in water. For these the general substitutes for piles are Masonry Wells or Blocks, which are sunk close together, arched over, and on them the piers and abutments are raised; they are also used as foundations for houses in places where the soil is very treacherous. The beds of most rivers in Northern India when bored, show sand to an immense depth. In Bengal alluvial mud is found to as great a depth, and necessitates as much precaution as sand. The dry state of the river beds also gives great facilities for turning arches without the use of expensive centerings. A simple arrangement of dry bricks and timbers are constantly used, built up in the bed of the stream; of course the work is subject to accidents from sudden floods, but these are very rare.

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The greatest Works as yet executed in India, belong, as in England, to the Railways. Indeed there are none in the world more interesting or important than the Bhore Ghât Incline, the Soane and the Jumna Bridges, and other works little inferior to them which might be enumerated. The East Indian Railway, 1,000 miles long from Calcutta to Delhi, with the branch to Jubbulpore now under construction, is probably the longest line in the world owned by a single company, as it is certainly one of the greatest triumphs of Engineering. The Great Indian Peninsular, and other lines, though inferior in length, are some of them, at least, of equal Engineering interest.

With them may be classed the great Roads, though the system like that of the railways is still far from complete. The Grand Trunk Road from Calcutta to Lahore, 1,300 miles in length, comprises every variety of construction, from the heavy gradients through the Rajmahal Hills, to the massive and level embankments between the Jumna and the Sutlej. The Lahore and Peshawur Road, a continuation of the Trunk line, 270 miles long, and now rapidly approaching completion, may challenge comparison with any in the world; while in the formidable extent of drainage crossed by it, it probably stands alone. Of others, the Hindostan and Thibet Road when finished, may take its place by the side of any of the famous Alpine Roads; while the great Deccan Road, the Assam Road, and many others still in hand are works of considerable magnitude.

Besides the length of the distances to be traversed, it is in the formidable character of the flood waters that have to be crossed, that the specialities of their construction are to be sought. Nothing but actual experience will convince the English engineer of the enormous water-way required to pass drainage lines, which, seen only in the dry season are so shallow and often perfectly dry, and scarcely a season passes without the most ample experience being set at naught by the results of some extraordinary flood. The Indus has been known to rise 50 feet in a single night, where confined between its rocky banks at Attock. At a distance of 800

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miles from its mouth, I have been in a boat in the middle, and was unable to descry either shore, while the deep channel in one single season has shifted its place laterally as much as 3 miles. Cross this river in the dry season and the track lies over 10 miles of quick-sand and mud, while a channel of 1,000 feet in width passes the whole body of water. To carry a road across the valley of such a river, and to bridge such a stream, may well daunt the boldest Engineer.

This describes the rivers of Northern India only; those of Southern and Central India have also their peculiarities which it would be tedious to detail here.

It is, however, in the great Irrigation Works that have been or are being constructed in India, that the peculiarities of Indian Engineering are more especially to be sought; for, except in Italy, those works have no counterpart in Europe. The Ganges Canal, 900 miles long with its branches, and pouring its waters over a million of acres through 3,000 miles of distributing channels; the East and West Jumna Canals, 200 and 500 miles long, respectively; the Baree Doab Canal, also 200 miles in length, are works of which any country may be proud, and in the principles and construction of which Engineers have to learn much which they cannot be taught in England. An entirely separate class of works are the great Weirs and Tanks of Madras, whereof the works on the Godavery are the finest examples, and which are also purely Indian specialities.

Next, a word may be said as to Indian Architecture. The Architect and Engineer are generally one, and he also is the constructor as well as designer. The requirements of the climate necessitate modes of construction differing from those in England, but until lately we have not managed to combine coolness and ventilation with much Architectural beauty. A reform in this respect is however in progress. We are at least erecting handsomer buildings, and attention is being directed towards cooling them effectually. The difficulties are great, for what does for the moist heat of the Lower Provinces will not answer for the fierce dry heat of Upper India, which it is necessary to exclude for many

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months all day long, unless the air is artificially cooled before being admitted.* Moreover, the cold in the winter is often excessive, the average extreme range of the thermometer between summer and winter being fully 100° in the Punjab, while in Bengal the temperature is much more equable, the range not exceeding 70°. With all these draw-backs however, many fine public buildings have been completed, many more are being constructed and projected, and Churches, Railway Stations, and Government Offices are rising fast, which would do no discredit to any capital.

Some specialities of construction which are common to most Indian buildings attract the attention of the new comer. Except in the Presidency towns, they have no upper-storey, partly from considerations of expense and partly because the upper-rooms get very hot during the dry months. The roofs are either thatched or tiled, or else are flat and covered with brick and lime plaster. The thick beams supporting the roof, are as a rule left exposed below, as ceiling cloths are apt to harbour vermin and conceal the depredations of white ants. The room walls are very rarely papered, being usually plastered and white-washed. Wooden floors would be too perishable and dear, so floors of flat tiles or of lime plaster are substituted. Doors are numerous and are invariably double, opening in the middle. Verandahs all round a house are considered indispensable.

In many of the most important and interesting branches of Engineering little has been done as yet in India; in Drainage, Water Supply, and Gas Lighting, we are now only making a commencement even in the Presidency Towns. A fine scheme is however in progress for the drainage of Calcutta, and a similar project will shortly be submitted for Madras, while the drainage and conservancy of Native towns, and European cantonments are engaging much attention.

In the Improvement of our great Rivers for inland navigation, little or nothing has been done, but many Navigable Canals are at work in Madras and Bengal, and others are in progress. In Bengal, Inundations from the sea and rivers have also given us

* The temperature of the air at *midnight* in Upper India during the months of May and June is often over 100°.

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practice in the important subject of Embankments; and the Hidgelee Sea Dyke, when completed, will, it is said, be a noble work.

Of Military Engineering not much has to be said. Like the Romans of old we encamp our troops in the open instead of shutting them up in Forts. Our Arsenals are for the most part inside old Native Forts slightly improved, and except Fort William and the outposts on our N. W. Frontier, there is scarcely a single Fort of modern construction in the country.

Closely allied as it is to Engineering, a word must be said in praise of that noble work the Indian Survey, of which too little is known to the scientific world. The report and map in the present number will give some general idea of what has been done, and I am in hopes of inducing some one of our accomplished Survey officers to give me a paper describing the modes of working and the results turned out. While the Trigonometrical Department is covering the country with a net-work of triangles, fixing the position of the principal stations with an accuracy that has not been surpassed (if it has been equalled) in any European country,* the Topographical Department is busy in delineating the features of the Mountain Districts in a series of maps,† whose fidelity is only equalled by the difficulties which have attended their completion, and the Revenue Department is mapping the plains to a degree of detail which shows not only every village but every *field* in each village.

Incomplete as this summary has been, I cannot take up more space to make it more elaborate, but I will hope that it may be useful in arousing some interest in my subscribers in England in the peculiarities of Indian Engineering.

J. G. M.

* The Supdt. G. T. Survey, Major Walker, R. E., has lately proceeded to Europe to confer with the Russian Government on the means of connecting the great series of Indian triangles with that of the Russian Survey.

† The Map of Cashmere lately completed by Capt. Montgomerie, R. E., has elicited the warm approval of the distinguished president of the Royal Geographical Society. Many of the Trigonometrical Stations were above the line of perpetual snow, where the Surveyors had to stay for days together waiting for favorable weather for their observations.

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No. XLI.

EUROPEAN GENERAL HOSPITAL, BOMBAY.

Designed by CAPTAIN H. ST. CLAIR WILKINS, R.E.

COMPETITIVE designs for the European General Hospital were called for by the Bombay Government in 1863, from Architects in England and India. Estimates were also called for, and the cost of the building was not to exceed Rs. 3,80,000. Seventeen sets of plans were received, including five or six from England. A Committee was appointed to adjudicate upon the designs, for which two prizes were offered, Rs. 2,500 for the best, and Rs. 1,000 for the next in merit.

The Committee awarded First in Merit to the design here illustrated, but stated their opinion that none of the designs submitted complied fully with the conditions, as their cost would exceed the amount specified. The Bombay Government replied that they did not wish to withhold the premiums. The Committee then, contrary to all practice, melted the two prizes in one crucible, and divided the contents amongst seven competitors.

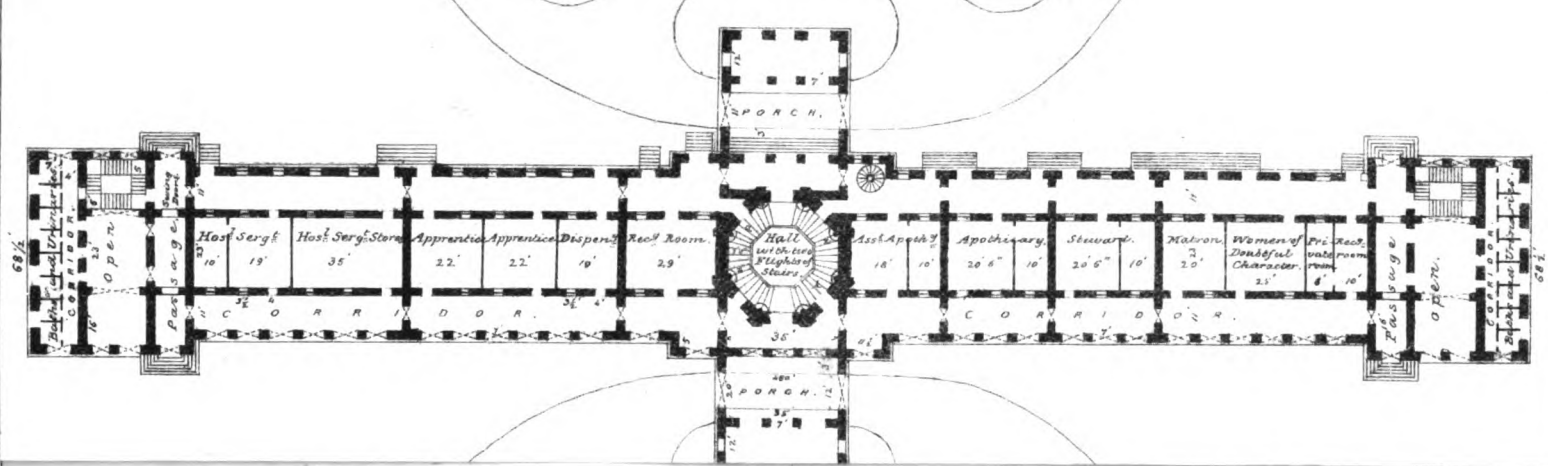
The author of the design given in the present number naturally declined to receive the mutilated premium offered. Competitions are objectionable for many reasons, but if it be considered desirable in this country to seek out Architectural talent, which would otherwise lie dormant, it would be better to offer the usual Architectural fees, (viz., 2½ per cent. for plans,) authorized by the Architectural Association in London, and when competitors comply *bonâ fide* with the conditions specified, the prizes should not be withheld.

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PLATE LIII

BOMBAY GENERAL HOSPITAL.

GROUND PLAN.



Scale, 60 feet to an inch.

60 30 0 60 120 180 feet.

LITHO: T. C. PRESS.

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Descriptive Remarks.

The Hospital is designed in the Gothic style of Architecture, which the author believes to be the style of all others best suited to the requirements of a tropical country. Arcades are always pleasing, and arcaded verandahs or screens of a variety of forms and sizes are obtainable in this style. In the present design, that type of Gothic worked out in the South of Europe in the middle ages has been preferred to the more Northern type, the architectural requirements of India being more nearly allied to those of Italy than of England; various modifications of this style now universally adopted to meet modern necessities have been made. The design will also show that the author is not opposed to judicious eclecticism, and he is bold enough to avow it. In Italy the roofs of Mediæval buildings were generally low, which is to be attributed more to classic tradition than to the direct effects of climate; the roof of this building has been designed at an elevation of 45°, to throw off speedily the heavy rain of Bombay.

The Hospital, is 480 feet in extreme length, and 145½ feet in breadth at the centre, the projecting end terminations are 68½ feet in breadth, the ordinary breadth of the building being 58¼ feet. The building is entered at the centre on both the East and West facades through covered carriage Porches, that on the West carrying above a small Chapel. An open Arcade leads from the portico steps into a large Octagon Hall, in which are placed two flights of stairs conveniently situated for those entering the building from opposite sides. The two flights are carried up to the upper floor of the building, and they are lighted from above by four rose Windows. To increase this moderate light to a strong one and to add to the vertical ventilation of the building, as well as to produce a feature giving by its external appearance a unity of effect to the whole, which otherwise from its enormous size would be wanting in that unity, a lofty octagonal Lantern has been designed as the crowning member of the composition.

The urinaries, though included in the main building are completely cut off from the wards. Lofty openings slightly screened by shafts and simple tracery admit of a very thorough ventilation.

The building was intended to be constructed of Coorla rubble, a reddish trap, the arch rings being formed of alternate stones of Porebunder

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(whitish lime-stone) and blue Basalt. The roof to be of iron, well ventilated, with numerous Dormer windows above the ceilings fitted with louvers.

SCHEDULE OF MEASUREMENTS.—GROUND FLOOR.

Verandas 11 *feet clear all round.*

Left Wing.

	Feet.
Hospital Sergeant's bed room, partitioned off, ...	29½ × 23
Hospital Sergeant's Store, ...	35 × 23
Apprentices (3), ...	22 × 23
„	22 × 23
Dispensary, ...	19 × 23
Receiving Room, ...	29 × 23
Entrance Hall, with stair case, ...	38 × 29
Back and front verandas at entrance, ...	9 feet wide.

Right Wing.

Assistant Apothecary's bed room, partitioned of, ...	29 × 23
Apothecaries' Quarters, „	31½ × 23
Steward's Quarters, „	31½ × 23
Matron's Quarters, „	20 × 23
Women of doubtful character,...	25 × 23
Private Room, ...	8 × 26
Receiving Room, ...	10 × 23

At each end, an open passage, 26 feet wide, with free thorough draft of air, connects the baths and urinaries with the main building.

In the rear a Porch 38 × 22, and beyond it a room 38 × 13.

The front porch is not shewn; a small Chapel might be constructed over it, dimensions at the discretion of the Architect.

FIRST FLOOR.

Left Wing.

Naval Seamen, ...	66 × 23½
„	65½ × 23½
Merchant Seamen, ...	29½ × 23½

Centre.

Stair-case, ...	38½ × 29

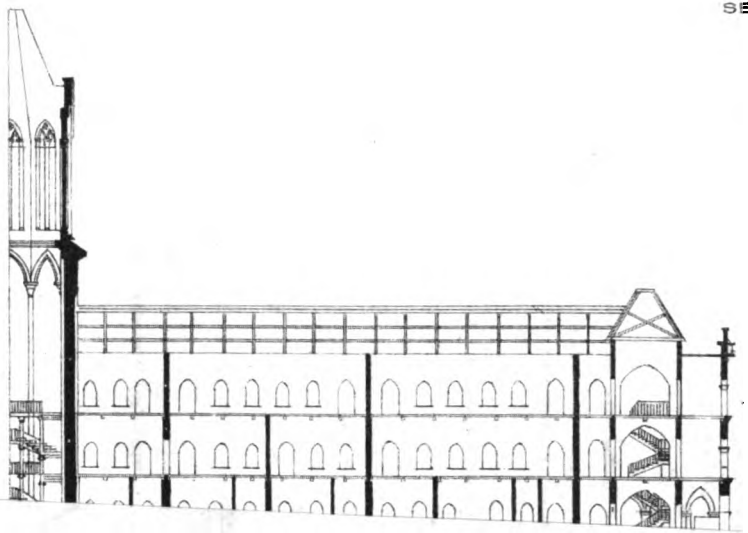
In Rear.

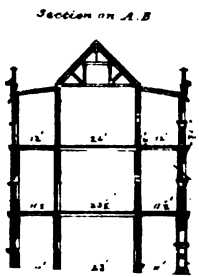
Open passage with free current of Air to Baths and Urinaries, ...	38½ × 22½ 38½ × 13½

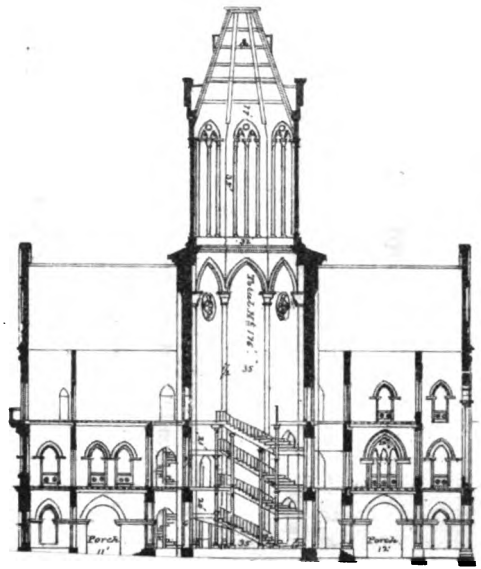
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BOMBAY GENERAL HOSPITAL.

SECTIONS







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UNIVERSITY OF WISCONSIN

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Right Wing.

Merchant Seamen, ...	64 × 23½
Surgery, ...	32 × 29½
Female Ward, ...	66½ × 29½

At each end, open passage and bath, &c., corresponding with those on the ground floor.

SECOND FLOOR.

Left Wing.

Paupers, ...	67½ × 24
Military Patients, ...	66 × 24
Warrant Officers, ...	30 × 24

Centre.

Drawing Room, ...	22 × 29½
Stair-case, ...	16½ × 29½

In Rear.

Bed Room, ...	25 × 23
Dining Room, ...	25 × 12
„	13½ × 23
Bath Room and W. C., ...	13½ × 12

Right Wing.

Warrant Officers, ...	30 × 24
Steam Telegraph and Mint Departments, ...	66 × 24
Clerks of Public Offices, ...	67 × 24

At each end, open passage and bath-rooms, &c., as on the ground floor.

ABSTRACT.

c. ft.		R.	A.	P.
111,920	Excavation, at Rs. 1 per 100, ...	1,119	3	2
111,920	Filling foundation of rubble-stone and lime masonry, at Rs. 18 per 100, ...	20,145	9	7
347,68½	Plinth of do., of rubble-stone and lime masonry, at Rs. 20 per 100, ...	6,953	11	2
115,348	Superstructure, ground floor, at Rs. 23 per 100, ...	26,530	0	7
99,685	Superstructure, 1st floor, at Rs. 25 per 100, ...	24,921	4	0
81,210	Superstructure, 2nd floor, at Rs. 28 per 100, ...	22,738	12	9
87,90½	Brick masonry, at Rs. 30 per 100, ...	2,637	2	4
211,87½	Cut-stone masonry, ground floor, at Rs. 2 per foot, ...	42,374	8	0
1,133	Cut-stone pillars and caps, 1st floor, at Rs. 3 per 100, ...	3,399	0	0
68,87½	Cut-stone arches, 1st floor, at Rs. 2 per 100, ...	13,775	0	0
691	Cut-stone pillars and caps, 2nd floor, at Rs. 3 per 100,...	2,073	0	0

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		R.	A.	P.
c. ft.				
45,92½	Cut-stone arches, 2nd floor, at Rs. 2-2 per foot,... ...	9,759	1	9
s. ft.				
147,57½	Doors and windows, at Rs. 1-12 per foot, ...	25,826	1	0
189,300	Chunam plaster, at Rs 7 per 100, ...	13,251	0	0
c. ft.				
2,62½	Cut-stone steps, at Rs. 1 per foot, ...	262	8	0
s. ft.				
980	Cut-stone pavement, at Rs. 75 per 100, ...	735	0	0
No.				
186	Steps in staircase of lantern, at Rs. 15 each, ...	2,790	0	0
2	Staircases for bath-rooms,...	744	0	0
s. ft.				
840	Weather boards, at Rs. 80 per 100, ...	672	0	0
r. ft.				
1,704	Parapet walls on top of verandah, including 2 feet masonry below, at Rs. 5 per 100, ...	8,520	0	0
3,684	Cut-stone cornice, at Rs. 2 per foot, ...	7,368	0	0
s. ft.				
40,694	Plank floors, at Rs. 144 per 100,...	48,832	12	9
17,720	Iron roofing to main rooms, at Rs. 50 per 100, ...	8,860	0	0
17,540	Iron roofing, verandahs, at Rs. 75 per 100, ...	13,155	0	0
7,584	Ceiling to main rooms, at Rs. 20 per 100, ...	1,516	12	9
9,159	Paving verandahs, bath-rooms, &c., at Rs.40 per 100,...	3,663	9	7
7,268	Chunam floor for main rooms, at Rs. 25 per 100, ...	1,817	0	0
1,368	Shafts in front of lantern, at Rs. 2 per foot, ...	2,736	0	0
3,266	Shafts in front of bathing rooms, &c., at Rs. 1 per foot,	3,266	0	0
	Total Rupees, ...	320,442	0	0
	Add for completing lantern to a height of 145 feet with all the gables and other ornaments, ...	41,458	0	0
	Contingencies, at Rs. 5 per cent,...	18,095	0	0
	Grand total, Rupees,	379,995	0	0

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No. XLII.

VAULTED ROOFS IN SIND.

Memorandum on Vaulting Roofs with Hollow Voussoirs, without the aid of Centering. By Lieutenant-Colonel Fife, R.E.

In a description of the "Syrian roof," at page 69, of No. VI. of the "Roorkee Papers," it is suggested that voussoirs might be made hollow and accurately shaped, and as I adopted this plan myself in 1851, in vaulting the roofs of buildings in Upper Sind, a description of the method employed in making the voussoirs, and the degree of success which attended their use, may be interesting to those who are called upon to construct buildings where insects destroy wood-work very rapidly, or where seasoned and sound timber is not readily procurable.

In Upper Sind there is no Teak wood except what is brought up from the Sea coast, far south of Sind, at enormous cost, and there are only one or two kinds of indigenous timbers which are even tolerably secure from the ravages of the white ant.

Upper Sind being almost a rainless country, a terrace roof of a very common construction, and covered with mud plaster was generally used. The destruction of the wood-work by insects, however, was so rapid, and the weight of the mud plaster so great, that the falling in of a roof was really almost a daily occurrence, and among even the very small number of European residents there were some very narrow escapes, notwithstanding the constant watch that was maintained over the roof timbers. A shower of rain, when it did come, invariably brought down some roof or other from wetting the clay plaster, and increasing the weight over a beam which was previously on the point of falling, and nothing was so

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common in Brigade Orders as "the Executive Engineer will be pleased to to replace 14 (or 20 as the case might be) beams which have given way in the————Barracks."

This very unsatisfactory state of things led me to think of the "Syrian roof," a very interesting description of which had been written by Major Underwood, of the Madras Engineers, and published in the first number of the "Corps Papers." Then it occurred to me that by adopting the principle of the hollow tile, but making it a complete voussoir, and hexagonal in shape, and cutting its ends off obliquely, a still more perfect construction might be attained, which would be stronger than the Syrian roof, and more economical from not requiring the aid of centering. I therefore turned my attention to the making of a hollow hexagonal voussoir with its ends obliquely cut off, and after a great many failures, succeeded in making one which answered extremely well. It was only one-fourth the weight of the solid voussoirs, and could not be made lighter without making it too weak, and its oblique shape admitted of its being used much as thin bricks are used in Upper Sind and in other parts of India, as well as in Italy, for constructing vaults without the aid of centering.

In order to ascertain whether a vault made with these voussoirs was really as strong as it promised to be, I constructed a semi-circular vault of 15 feet span from haunches, 5 feet in height, resting on the ground (see *Fig.* 1,) and loaded it with sun-dried bricks till they were 1½ feet deep over the crown, and rather more over the haunches. The bricks were loosely piled without cement and the vault settled by measurement (ascertained from the rods *a*, *a*, *a*, previously fixed) half an inch at the crown during the process. The loading was removed after three days, and the vault was taken down; only two out of the 700 voussoirs employed were broken, and the injury that occurred to these was evidently owing to their being originally faulty, one being mis-shapen, and the other imperfectly burnt. The load carried by the voussoir part of the vault was 13 tons.

To get some idea of what thickness of wall would suffice to carry such a vault, a small building, *Figs.* 3, 4, 5, was constructed. The span was 12 feet, and the thickness of walls 1½ feet. The walls it will be noticed were very light from being pierced with openings. This building was allowed to stand for six weeks. It appeared clear from the result of this experiment, that the verandah of a building vaulted on this plan with

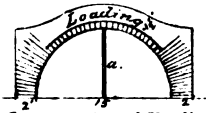
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VAULTED ROOFS IN SIND.

Plans for making Vaulted Roofs of Hollow Voussoirs.—

1st Experiments.—

Fig 1.



Cross Section of Vault.



Longitudinal Section.

Fig.2.

2nd Exp.ts

Plan.

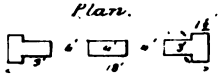


Fig.3.



Section.

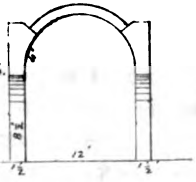


Fig.4.

Longitudinal Section.

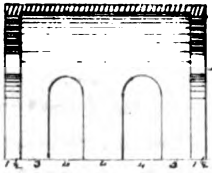


Fig. 5.

Fig. 6.

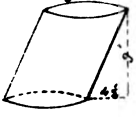


Fig. 7.



Fig. 8.



Fig. 12.
Section of Moulds & Circular Wedge.—

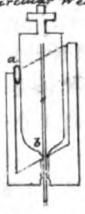


Fig. 13.

Wheel.

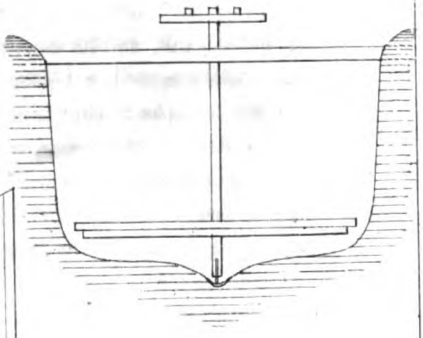


Fig. 9.

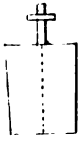
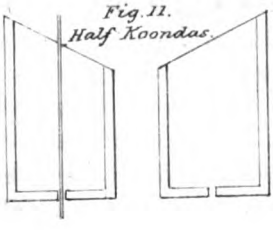


Fig. 10.



Fig. 11.
Half Koondas.



Section of Hollow Voussoir.

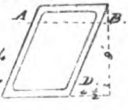


Fig. 14.

Section A.B.

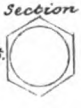


Fig. 15.

Section. C.D.



Fig 16

Developed plan of Vault in course of construction.

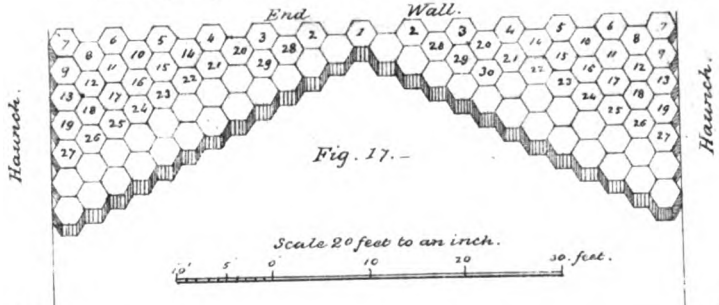


Fig. 17.—

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walls like those in common use in Upper Sind for verandahs, would act as a flying buttress to the main vault.

Several buildings were constructed on this plan both by myself and my successors, and where there was a reasonable amount of supervision the result was invariably satisfactory. Of course, without proper supervision, the voussoirs may from carelessness be made almost as heavy as solid ones, and a bulging wall is the inevitable result.

In the buildings latterly constructed, no binding brick arches* at intervals were used, as they were found to be unnecessary, and unless made so small in span as materially to interfere with the interior space of the building, they increased the thrust against the walls.

The largest building on which the plan was tried was the Collector's kutchery at Shekarpore. This building contained eighteen rooms of 18 feet and 20 feet in width or span. The vaults were plastered outside with lime as the building was of a permanent construction.

As an instance of the rapidity with which a building thus vaulted may be constructed, I may mention that I constructed a District Bungalow, consisting of two rooms of 18 feet span, with verandah rooms all round, in less than five months from the date of receiving the order, and there was no appearance whatever of the work having been hastily or badly done, and no repairs were ever needed, except the usual mud plaster to the exterior, which has to be annually inspected, and renewed where the rain may have washed it off. The only timber used in the building was for the doors and windows, and much difficulty was experienced in getting even this small quantity of seasoned timber. Had a timber roof been used, the building could not have been completed in less than a year, and even then the timber would not have been properly seasoned.

The vaulted roof used to cost 8 Rs. per 100 square feet, measured on the voussoir portion only, which was about equal to the area of the floor of each room. This rate covered the outside plaster of mud. Where lime plaster was used, of course the vault cost proportionally more. The bricklayers became very dexterous at last in using the voussoirs, and the roof of one of the rooms (18′ × 22′) of the District Bungalow, was vaulted in two days by two bricklayers.

The Syrian roof of course possesses the same advantage of quick con-

* Binding brick arches at intervals are recommended for the "Syrian" roof by Major Underwood.

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struction, where seasoned timber is not procurable, but it is not quite so quick as the voussoir plan, as the construction and removal of the centering occupy time.

The Syrian roof possesses superior simplicity in the preparation of the material, as natives can already make the cylinders required. In fact, every potter at his wheel makes the clay which is to form the chatty pot or almost any thing else, go through the single cylinder form before it arrives at its final form, and the manipulation the clay undergoes while on the wheel, renders the cylinder as sound and equal in texture as the best voussoir I could make in a mould.

The, I fear, rather tedious description I have given below, of the mode of making the voussoirs should not, however, lead to the belief that the plan is too troublesome to be attempted under ordinary circumstances. The making of the voussoirs cost me far more trouble than any thing else, and I have therefore thought it right to give the minutest details. But if the making of a chatty pot, which is sold for a pice in the bazar, were described with equal care, the description of the simple process would also be long.

The echo, which is an objection to vaulted roofs in dwellings may be reduced to such a degree as to be unobjectionable by ornamental mouldings in the wall and ceiling-plaster, or by nailing a cloth ceiling to the ceiling-plaster.

Where rapidity of construction is aimed at, it is perhaps hardly necessary to mention that the construction of the voussoir moulds or cylindrical tiles, whichever plan may be adopted, should be commenced at the same time as the foundation, otherwise the material for the roof will not be ready by the time the walls are raised.

I may mention, in conclusion, that light and nicely balanced as the Syrian and hollow voussoir vaults are with the heavy haunch and light crown, the thrust should by no means be disregarded. In small vaults the cohesion of the cement bears so great a proportion to the weight of the voussoirs, that practically there is no thrust, but in large vaults the thrust is considerable. Nothing however is easier than to provide for this, by using buttresses* either for the main or verandah walls, and such additions will more often improve than injure the architectural effect. In designing vaulted buildings, great strength may be secured also by placing the cross walls in such positions as to make them act as buttresses.

* Or wrought-iron tie-rods, as in the case of an ordinary arched roof.—[Ed.]

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Description of the Method of Making Hollow Hexagonal Voussoirs, and Vaulting Roofs with them.

To form the moulds, a solid wooden voussoir is first made in the following manner:—A piece of wood about 15 inches in length, and 9 inches in diameter, is shaped into a tolerably accurate cylinder. Its ends are then sloped off, till it becomes oblique, as shewn in *Fig.* 6. Hexagons are then inscribed in circles of about 8 inches diameter, at each end, (*Figs.* 7 and 8,) care being taken, by previously drawing a straight line from top to bottom of the cylinder, to make the hexagons parallel. From the sides of the hexagon at the bottom, half an inch or whatever may be required, is cut off (*Fig.* 8.) The superfluous wood is then pared away, leaving the solid voussoir, as shown in *Figs.* 9 and 10, a piece of wood being inserted at the broad end as a handle.

Some common earthern *koondas* (*Fig.* 11) are then made, in the ordinary manner, having their tops sloped at the same angle as the voussoir, but accuracy in this case is not necessary. When the koondas are dry, they are sawn in two; after this they may be burnt. They may also be made of wood; but the earthen ones only cost a few annas each, and are not liable to warp.

To make the moulds, clay mixed the day previous, and containing rice bhoosa, to prevent cracking, is beaten into flat cakes with the hand, and placed in the half koondas, and well pressed against the sides and bottom with the hand. The two pieces of koonda are then bound together with a piece of rope. An iron rod something less than a quarter of an inch in diameter is then inserted into a hole at the centre of the bottom of the koonda. Next, the wooden voussoir, which has a hole bored through it for the reception of the rod, is forced into the koonda, pressing the clay against the sides and bottom. This is repeated four or five times, care being taken to keep the voussoir wet, to prevent it adhering to the clay. If there appears to be too little clay in the koonda, from the cakes having been too thin more can be added, until the wooden voussoir, by compressing it, forms a mould as accurate as itself. The voussoir ought to be carefully withdrawn from the mould, otherwise the mouth will be spoiled.

The mould ought not to be removed from the koonda for four or five days, as the mass of clay being great, it is liable to crack; it ought,

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moreover, to be kept in the shade, and while drying, any cracks that may appear ought to be stopped with moist clay. As the moulds are removed from the koondas, the weight may be greatly reduced by taking an adze and paring the exterior into the form of a hexagon, corresponding with the inside of the mould. When they are dry, holes should be made in the bottom, to correspond with the tenons on the wheel (*Fig.* 13,) on which the hollow voussoirs are formed. By doing this before the burning, much labor is saved, the dry clay being easily cut with a chisel. The moulds may then be burnt. Litter is the best fuel for this purpose, wood creating too great a heat, and causing them to lose their shape from fusion.

Two coolies, after a few days practice, will make from six to eight moulds per day, and a carpenter can reduce the weight, and otherwise complete fifteen in the same time. A great number are required, but this is only troublesome at first, for they last a long time. If they do break, it is in the burning, or the first or second time they are used afterwards, and the damage is always caused by carelessness in not mixing the clay well, or in not pressing it into the koonda sufficiently.

I used three different moulds for my vaults. They were radiated to suit spans of 8, 15, and 22 feet. I, however, discontinued those for the 8 feet span circular arc, as I made the vaults flatter. To enable the workmen to readily distinguish the different kinds, I inserted small pieces of wood into the bottoms of the wooden voussoirs. In this manner all the moulds are stamped; and, consequently, all the hollow voussoirs receive the same distinguishing mark. Before commencing the mould making, the wooden voussoirs should be kept under water for two or three days, and afterwards they should never be allowed to dry; otherwise from increasing or diminishing in bulk, while they are being used, the moulds made with them will not be of the same size.

To make the hollow voussoirs, the clay used should be what is commonly called "strong earth," or what is used for pottery. It should be beaten into dust, and then mixed with dry horse-dung, also beaten to dust. Water should then be added. An hour or two afterwards, when the clay is completely saturated, it should be well mixed with the hand, sufficient water being added to make it of the consistency of paste or putty, so that it can be taken up in the hand and easily compressed into any form. It should remain in this state for twenty-four hours, after which it is fit for use.

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The mould is filled in the same manner as the koonda. A piece of clay, taken from that beforementioned, is well worked up with the hands on a piece of plank, in the same way in which a native makes his bread. It is then beaten out with the palm of the hand into two flat cakes, which are carefully placed against opposite sides of the mould, and overlapping each other a little. The clay should then be well pressed into all the angles of the mould with the knuckles. After this, a piece of clay, about the size of an apple, should be thrown smartly to the bottom of the mould. If this is well done, it drives the clay previously placed most effectually into the acute angle at the bottom. The pressure of the knuckles is not sufficient there; and, moreover this last piece of clay makes the circular wedge or mandrill (*Fig.* 12,) act more effectually. The mould is then placed on the wheel, and a small chip of wood (*a*, *Fig.* 12,) an eighth of an inch thick, inserted between the clay and the lower side of the mould. This is to prevent the wedge from making that side of the voussoir too thin. There is no necessity for a similar precaution for the other sides. An iron rod like that previously mentioned, is then passed through the bottom of the mould into the top of the wheel. Next a circular wedge or mandril (*Fig.* 12,) about half an inch less in diameter than the breadth of the mould, so as to leave round it about a quarter of an inch of clay for the thickness of the voussoir, and having a hole bored through it for the rod, is placed in the mould, and plenty of water sprinkled on it. The wheel, with the mould on it, is then set in motion with the foot, the wedge being thoroughly held with the hands and gently pressed downwards.

If it descends very rapidly, it will be found on taking it out, that the cakes of clay are too thin; whenever this appears to be the case, more must be added with the hand. If the wedge does not descend to the bottom, it is owing to there being too much clay, and this will have accumulated under it. This should be removed, care being taken in doing so not to tear the sides of the voussoir. The hand should be conveniently placed against the clay, and the wheel set gently in motion. The surplus clay is neatly cut off in this manner. The wedge should then be again inserted, and the process continued, till the inside of the voussoir is perfectly smooth and free from flaws. The wedge should be slowly removed from the mould, the wheel being kept in motion. The wedge ought to go to the bottom of the mould. This is ascertained by looking

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at the indentation made in the clay by the projecting piece, *b*, at the bottom, and which is made to prevent the wedge descending too far and destroying the bottom of the voussoir. It will be observed, from the manner in which the voussoir has been made, that the acute angle at the bottom is solid. This must be scooped out with the hand; and, at the same time, the water which collects there during the process above described, should be removed with a piece of cloth.

The next process is the closing of the mouth. The surplus clay and chip of wood are first removed. A good piece of clay, tolerably stiff, is then rolled between the hands, until it is almost a foot long and an inch in diameter. One end of this is attached to the mouth of the voussoir, and the wheel being set gently in motion, it is carried all round, and well joined to the voussoir, by pressing it and the side together with the thumb and the fingers. This effected, the projecting clay is lightly held between the thumb and finger, and the wheel being kept in motion, the mouth is gradually closed. If there is not sufficient clay, a small cake about the size of a rupee should be gently placed on the aperture, and the escape of the air inside immediately stopped by adding water, and joining the cake to the clay previously placed. If this is not done quickly, the mouth will sink.

The mould containing the voussoir may then be placed in the sun to dry, and when the clay begins to stiffen the mouth must be hammered flat, a small hole being made to allow the air to escape. In three or four hours the voussoir is sufficiently dry for removal from the mould; the mould being turned upside down, the voussoir drops out.

In four or five days the voussoirs are dry enough for burning. This is done in the same way as with common pottery. A layer of dry sheep's dung is first laid on the ground, and over this a layer of light litter. On this bed two layers of voussoirs are placed, and over the whole is another layer of litter, covered with ashes. The ashes prevent the flame from escaping too soon.

One coolie,* with two assistants to fill the mould for him, will, after a month's practice, make 70 voussoirs per day. Allowing the first, in consideration of his skill, ... Rs. 0 2 6

And paying the assistants at the usual rate (viz., 2 annas each), . „ 0 4 0

We have Rs. 0 6 6

for the cost of making 70, or say 10 annas per 100.

* These were the prices in 1861.

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Again, one *buttee* maker, assisted by two coolies, will prepare a buttee containing 700 voussoirs in a day. Allowing the buttee maker for his work, and for watching the buttee during the night, ... Rs. 0 5 0

Paying the assistants at the usual rate of two annas each, . . . „ 0 4 0

And allowing one cart and a coolie 8 annas per day for two days for collecting litter, ... Rs. 1 0 0

We have Rs. 1 9 0

for the cost of burning 700, or say 4 annas per 100. Adding this to the cost of making, we have 14 annas for the cost of making and burning 100 voussoirs.

Until the coolies are expert, of course the voussoirs cost more than the above; but if the work is only cautiously commenced, and the number of hands gradually increased, the difference is not very great. I employed the carpenter, who made the wooden voussoirs, to superintend the mould making. I found this a good plan, as he readily detected flaws. I also employed a potter to show the coolies how to mix the clay and manipulate it on the wheel.

In order to employ convicts to make voussoirs for a Barrack for the Police, I used two wheels; on one the convicts made the voussoir in the rough, on the other the surplus clay was removed, and the mouth closed by a potter. The potter finished 150 voussoirs per day, with ease, in this manner. I, however, found, that from the voussoirs being frequently left standing in an unfinished state, they were not so well made, the clay becoming too stiff. By giving a man a wheel, and making him do the whole of the work himself, he can be held responsible for the quantity and quality of his work.

The first voussoirs I made had a hexagonal interior, as well as exterior, and were formed outside a mould; one of my reasons for preferring the hexagonal voussoir being, that of all regular figures which fit accurately together, the hexagon is that which has the greatest area compared to the perimeter, and is therefore the lightest form that can possibly be chosen. After a great many trials, however, I was obliged to relinquish this form for the interior, as the voussoirs could not be made free from flaws. I also found that the weight was but little reduced by using the hexagonal interior, and the circular interior gave the voussoirs more substance and strength at the angles, which was an advantage.

It may appear from the preceding description that these voussoirs can only be made with clay of rare quality; but I feel sure, that wherever the clay is good enough for common pottery, (and there are few places where it is not,) they can be made equally well.

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Construction of the Vault.—The haunches and end walls having been carried up to the requisite height, the first voussoir is let into the end wall at the crown of the curve, (*Fig.* 17,) other voussoirs at proper intervals are then similarly let into the wall, till the haunches are reached. About one-half of each voussoir ought to project outside the wall, and the interval between each should be sufficiently large for the reception of half a voussoir and its cement. The vaulting is then commenced at the angles, which are gradually filled in, each course of voussoirs being commenced at the end wall, and carried obliquely down to the haunch in the following manner. The sides of voussoirs 6 and 7, (*Fig.* 17,) and the wall in front, being covered with cement, No. 8 voussoir is thrust in (care being taken in doing so to keep the top parallel to the direction of the vault) with two or three blows from the hand. It penetrates like a wedge, making the joints quite smooth. After this, the joints should be closed above and below, to make them air-tight, till the clay has stiffened a little. No. 9 is then thrust into its place in the same way as No. 8, forcing the latter, if it is possible, still tighter into its place. This completed, No. 10 in the next course is placed; and so on throughout the whole length of the vault.

It will be observed, that by keeping the haunches of the vault advanced at this angle, any settlement at the crown is prevented. Two sides of each voussoir being perpendicular to the direction of the course, they are directly opposed to any settlement. The vault is kept in the proper curve by a circular piece of plank, standing on the projecting bricks of the cornice; and so little settlement takes place, that this can be made to slide back under the completed portion of the vault.

The voussoirs run about 450 to 100 square feet, and a workman tolerably expert can vault 40 square feet in a day. From the small number of voussoirs required, and the small quantity of cement used, he requires very little assistance.

In all the vaults constructed on this plan, mud and bhoosa has been the cement used, and it has been found quite sufficient. Being thrown against the voussoirs, and spread with the hand, it will be found more expeditious than chunam, and of course more economical.

With regard to the haunches, it is evident that they should be carried up as far as ever they will stand securely without the assistance of the thrust from the vault, for the more the centre of gravity of the wall and haunch

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is brought inwards in this manner, the greater is the stability of the structure when completed. I found from experiment that the haunches of a semicircular vault of 15 feet span could be carried up to a height of 5 feet. To prevent accidents from a number of workpeople congregating on them before the vaulting was commenced, I carried the haunches up to a height of 4 feet in the first instance, completing them to the requisite height while the vaulting was being executed.

J. F.

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No. XLIII.

DRAINAGE AND IRRIGATION OF THE TERRAIE.

Abridged from a Report by CAPTAIN C. S. THOMASON, R.E., *Superintendent of Terraie Irrigation.*

A RECAPITULATION of the past history of the Terraie is unnecessary here. Its progress within the last few years admits of no question, and no one now visiting this district, having in his hand the Report of Captain Jones, published in 1855, and referring to its state as far back as 1843, would venture to question this progress. New tracts brought into cultivation, swamps drained, nullahs bridged, and straight communications established between the eastern and western extremities and elsewhere, in place of the tortuous cart-tracts of bygone days—all bear their own testimony to improvement; and the steadily-increasing influx of cultivators from the adjacent districts confirms this testimony, were confirmation necessary. The Terraie, with its unlimited supply of water and large extent of virgin soil under an Indian sun, seems to possess every requisite for agricultural improvements. The one drawback has been its climate, which, though doubtless improving to a considerable extent with the extension of cultivation, must still be reckoned one of the most deadly.

The physical characteristics of the Terraie and the adjacent tracts have been so fully entered on in Captain Jones' Report, that I shall only allude to them here as briefly as possible. At the foot of the Himalayas, between them and Rohilcund, lies the tract of country known as "Bhabur." With some interruptions, the Bhabur tract lying north of Rohilcund extends from the Ganges to the Sardah. Though its nature is in parts much modified, it has a slope varying from fifty to seventeen feet per mile, and may

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be roughly defined as a forest tract with a subsoil more or less open. I shall in this Report restrict my observations entirely to those portions of the Bhabur which I have seen, and at present particularly to that portion of it to the north of the Terraie, between the Kylas and Kosee (or Kosilla) rivers. Its nature here is pretty uniform, and consists of a rather shallow but rich surface-soil, overlying a boulder-bed which gradually assumes the form of gravel as it approaches the Terraie to the south. In this boulder-bed the rivers issuing from the hills disappear when their discharges are small, as in the cold and hot seasons, but the water thus lost re-appears at lower latitudes in the form of springs. The greater portion re-appears in this form in the Terraie, but some streams have their origin even at more southern latitudes than this, thus leading to the conclusion that the soil underlying the boulders in the Bhabur is not a perfectly retentive one, and that possibly its nature may be alternately partially retentive and porous, the springs issuing to the surface wherever a more porous soil crops up. The beds of the hill streams are well defined across the Bhabur, but, except in the rains, the water in them disappears gradually as we leave the hills, and only re-appears as the Terraie is entered. The Terraie springs discharge into the beds of the hill rivers, so that the discharge of these rivers steadily increases as they progress southwards. The average breadth of the Bhabur between the Kosee and Kylas rivers is about ten miles, and the Terraie about the same. The average slope of the Terraie may be taken at a little more than ten feet per mile. The vegetation of the Terraie consists chiefly of jungle grass: patches of forest exist, but the wood is not considered valuable for many purposes except fuel.

There seems to be good ground for supposing that, had the Terraie streams been allowed to flow uninterruptedly, few swamps would have been formed and consequently that the climate would never have assumed its present deadly character. But the temptations to irrigate with water within such easy reach were too great, and the evil effects of irrigation without drainage were then too little understood to deter cultivators from grasping at the enormous profits accruing from irrigation: hence the construction of earthen dams across the Terraie streams and rivers and the commencement of irrigation. The results of such a system in such hands are now apparent, and prominent amongst them may be noticed the formation of such swamps as the Cobra, and the diversion of streams from their original beds. The natural tendency of all such swamps is to gradually increase, and, as in

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doing so they must to a greater or less extent saturate the adjacent soil, it is not difficult to account for the deadly nature of the Terraie climate.

I shall now proceed to consider what measures the British Government has taken towards the drainage and irrigation of the Terraie, and the results of these measures.

In the first place, many of the swamps have been penetrated by surface drains. The Sissonah Swamp, formerly one of the largest in the Terraie, is now a swamp no more; many minor ones have been similarly got rid of, and before long we may reasonably expect to reckon the Cobra Swamp as a thing of the past. So far, an indubitable benefit has been conferred upon the Terraie. In many places the fevers which swept off their victims in the course of a few hours have now assumed the milder form of intermittent —a beneficial result, aided no doubt in a great measure by the clearance of jungle caused by the extension of cultivation.

Irrigation, as a necessary concomitant of cultivation, has increased largely, and the Revenue Returns of the Terraie speak for themselves. But an increase of revenue is by no means the sole object of Government, and, attended as it is with such a fearful loss of life, we may well pause to consider whether we are justified in thus enticing such numbers to a climate which, if not actually fatal, must undoubtedly produce a degeneracy in physique in succeeding generations.

Our present system of irrigation in the Terraie in principle differs in no respect from that formerly practised, which is universally acknowledged to be one of the chief sources of malaria. It is in the supervision alone that we excel. With such supervision the formation of such swamps as the Sissonah is impossible, but every earthen dam across a stream in such a soil as that of the Terraie must choke the pores of the adjacent soil with stagnant water, and such stagnancy must produce malaria.

The question then arises—"How are these evils to be remedied?" There seems to me to be but one remedy open to us, and regarding the success of this we can but argue from analogy. This remedy is the combination of *Sub-soil* Drainage with irrigation.

Artificial Sub-soil Drainage is a practice almost unknown in India. Major Brownlow, R. E. (Supdt. Eastern Jumna Canals), mentioned to me the case of an experiment with sub-soil drained land in the vicinity of Meerut. The experiment did not succeed, but the only cause of failure which I could learn was a deficiency of fall. The general slope of the

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country about Meerut is, I believe, about two feet per mile. From what I can gather, there are few areas in Rohilcund where we cannot command a much greater slope than this, and in the Terraie there are few places where we cannot get ten feet per mile. The efficacy of Sub-soil Drainage as a sanitary measure is undoubted in England, a very marked improvement being visible in the health and physique of the inhabitants of every district wherein it has been introduced.

The absence of Sub-soil Drainage in India forms the subject of most frequent comment in the Report of the Sanitary Commission appointed to enquire into the state of the British Army in India. It is there remarked, and with great justice, that all our efforts for the amelioration of the sanitary condition of our Cantonments must fall far short of success as long as Sub-soil Drainage in the fields is left to nature alone. The remark, if I recollect rightly, was made without any reference to irrigation, but it must be evident that it applies with double force wherever irrigation is carried on. My own impression is that well-regulated irrigation on thoroughly sub-soil drained land would be perfectly innocuous, whatever the crop might be.

The main objections to the irrigation works which I have visited in the Terraie are—

1*st*. *Inefficient Head Works.*—The masonry regulators which have from time to time been constructed on the hill streams have been destroyed, and I have above alluded to the dangers and evils which are the results of the earthen dams which have been substituted for the masonry ones.

2*nd*. *Too great slopes of Canal beds.*—The natural result of this has been retrogression of levels, which evil increases annually, to the great detriment of the irrigating capabilities of the canals. A fair instance of this is seen in the Bygool Canal, the water in which, near the head, now stands many feet below the surface of the country which formerly it used to irrigate. The general slope adopted seems to be that of the country; the action on the canal beds can scarcely, therefore, fail to be the same as that on the beds of the rivers.

3*rd*. *The formation of silt beds in the Canals* (naturally caused by their dependence during the rains on flood-water).—The removal of this silt entails a great annual expenditure and (as may be seen in the Western Jumna Canals) an annually increasing difficulty.

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4th. A want of method in the construction of the Irrigation Works.—The Terraie water-courses seem to be specially constructed to meet the wants of individual cultivators as they take up ground in the Terraie; consequently, as cultivation extends from the south to the north (up-hill) the length of water-channels must eventually be much greater than the necessities of irrigation demand. The Terraie water-courses are, moreover, especially designed with a view to meet Terraie wants; these wants once satisfied, the surplus water is suffered to flow back into the drainage lines instead of being kept on the water-shed for the use of lower lying fields. This system necessarily increases the number of dams, each of which is an evil in itself, independent of its expense.

5th. The tendency to generate malaria, which I have already noticed.

6th. The clogging, and therefore inefficient irrigation of the soil, owing to the want of aeration and warmth in the sub-soil arising from defective drainage.

The comparative immunity from injury in dry seasons, enjoyed by thoroughly sub-soil drained lands, is one well understood in England. Sub-soil Drainage in its consequences is equivalent to an actual deepening of the soil and a change of climate, thereby ensuring an early as well as rich harvest.

All these objections have received my serious consideration, and the system which I propose to adopt for their obviation will now be described.

As a preliminary to all interference with the Terraie, I would strongly urge the necessity for a good contour-survey. Without such a survey, whatever be the system finally determined upon, we cannot avoid many of the evils which now exist, and to which I have alluded above. Such a survey is absolutely essential for the carrying out of any systematic drainage and irrigation scheme; without it, we must be working in a great measure, in the dark; with it, the design of efficient works is a comparatively easy matter.

The following is an illustration of the system which I propose to adopt.

Annexed is a sketch Plate LVI representing an ideal tract of country such as we might expect to find at the foot of the hills. Immediately south of the hills I have here represented as forest land what we may call the Bhabur. It will be seen that three rivers are here represented as crossing the Bhabur. These are hill streams, with which I do not think it necessary as yet to interfere.

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LITHO. T. C. PAKES.

DRAINAGE AND IRRIGATION OF THE TERRAIE.

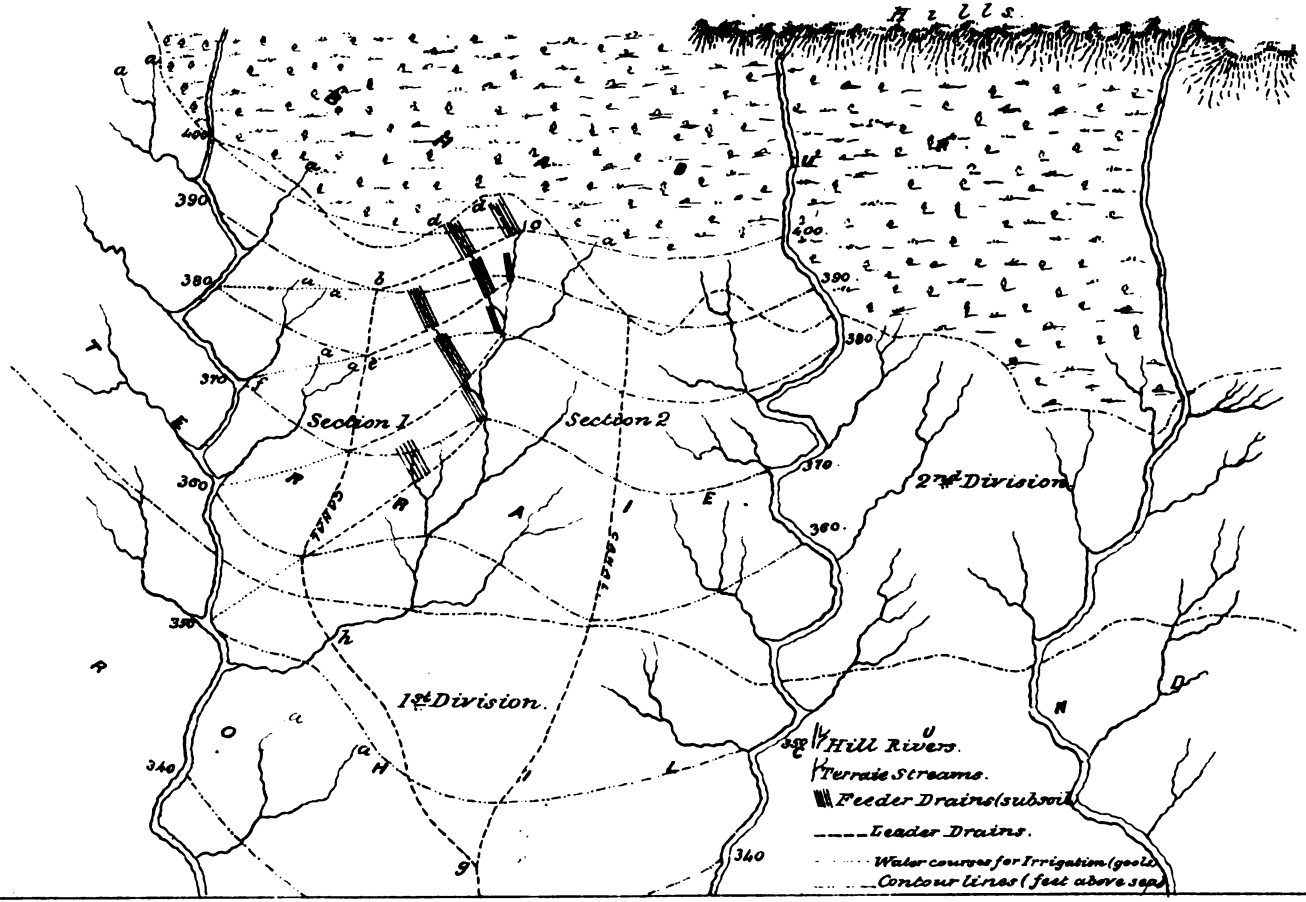


PLATE LVI.

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The hill streams almost, if not entirely, lose their dry weather supply in the boulder-beds underlying the forest, and the supply thus lost re-appears in the form of springs, as at *a*, *a*, *a*, in the Terraie, and the districts south of the Terraie. From the points (*a*) the discharges of the springs revert to the hill streams, as shown in the plan. I suppose the centre District here represented to be divided into Divisions 1 and 2 by these hill streams; other Divisions lie east and west of these. For the more economical working of the system, owing to the peculiar lie of Division 1, as shown by the contour lines, I have sub-divided it into Sections 1 and 2.

The most northern contour line is supposed to represent 400 feet above the sea according to the Great Trigonometrical Survey. The next contour line south of this represents a level of 390 feet, the next 380 feet, and so on—each successive contour line representing a drop of ten feet.

The canals are shown as following the salient points of the contour lines, and thus are dug on the water-sheds of each section.

It is evident if a channel (say four feet deep) be dug from *b*, on the second contour line to *c*, on the first, that this channel will have a slope of ten feet. The channel from *b* to *c*, and the corresponding channels south of it, are "leader" drains: how far it may be necessary to have them open, and how far closed, local circumstances must determine; probably they might be pipe-drains at the points furthest from the canal, and open as they approach the canals, discharging into the canal through a pipe. A similar drain is supposed to be constructed to the west of the canal, but, in order to render the plan more distinct, I have reserved the portion of the sections east of the canal for showing the drainage arrangements, and that west of the canal, for showing the irrigation. It must, however, be borne in mind that both drainage and irrigation exist on both sides of the canal, the latter overlying the former.

Where the eastern and western leader drains converge at *b*, is the commencement of the canal, which combines the purposes of drainage and irrigation, as will be shown hereafter. At *d*, *d*, I suppose springs to ooze out from the soil, and as I wish to keep the water of these springs clear of silt, I convey their supplies into the leaders as much as possible by sub-soil pipes: such pipe-drains I propose to call "feeders." I do not expect these feeders to convey away the whole produce of the springs in every case. They *may* do so, and, if so, an advantage will be gained; but, if not, a provision will be made for catching the surplus water free of silt by a work to

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which I shall allude presently. Under any circumstances, a provision will have been made against the stagnation of water in the sub-soil, to which I have already alluded as one of the defects of the present system.

If we now suppose the canal to be excavated with a slope of 2 feet for its bed up to the point *e*, on the next contour line of 880, it is evident that at this point the bed of the canal will be well above the surface of the country and in a position to irrigate east and west. The bed would, in fact, be four feet above the level of the country at the point *e*, and if an irrigating channel (or "gool") were constructed from *e* to the western extremity of the 870 contour, the channel would have a slope of no less than fourteen feet from beginning to end.

At the point (*e*) a fall of ten feet would be constructed, and, as I presume the water to be clear, a cheap form of fall might be constructed, as shown in longitudinal section in *Fig.* 1, Plate LVII. Instead of the usual masonry falls, I have here shown the southern extremity of the canal closed by an earthen dam, which might be made of sufficient thickness (if necessary) to serve as a road across the canal. At a convenient distance to the north of this embankment, a pipe is shown descending from the bed of the canal at *a*, and merging into the lower bed with a trumpet-shaped delivery at *b*. At (*a*) there would be a simple regulator (not shown). The object of the trumpet-shaped extremity to the pipe is to break the force of the water, the natural tendency of which would be to rise to its original level at (*a*) and cause erosion of the banks. This idea is taken from the Edinburgh Water-works, where the precaution is rendered necessary as a guard against disturbance of the filter beds. A gool (such as *e*, *f*) is shown in elevation issuing out of the canal at *c*, and a leader drain (similar to *c*, *b*) is also shown discharging into the canal at *d*. The regulator (at *a*) would in principle be similar to a screw-top, a wooden plug being worked up or down by means of a screw, so as to open or shut the orifice of the pipe at pleasure. This is a common form of regulator used in the mill-dams in Scotland, and is found to be very effective and cheap of construction.

The main difficulty in such a work as that here described is in the pipe, which must be made capable of withstanding a considerable pressure, which an ordinary clay-pipe will not do; but I hope to overcome this difficulty by a system of concentric pipes of different diameters,—the interstices being run in with cement, asphalte, or some such substance. We have, moreover,

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DRAINAGE AND IRRIGATION OF THE TERRAIE.

Fig. 1.

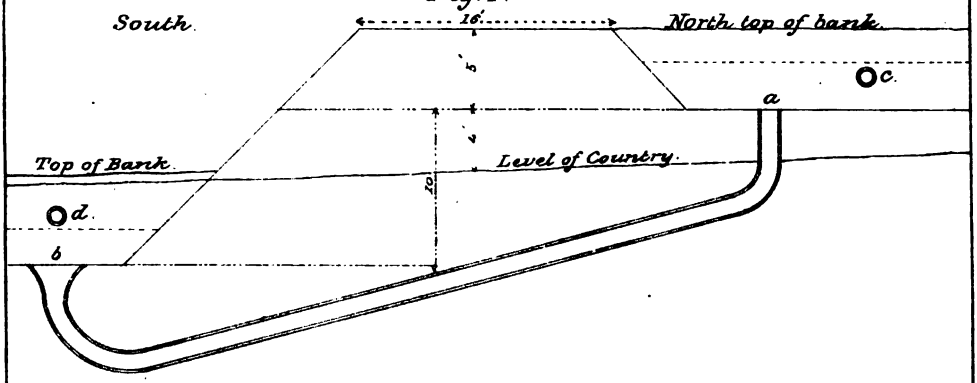


Fig. 3. Asphalt or Cement.

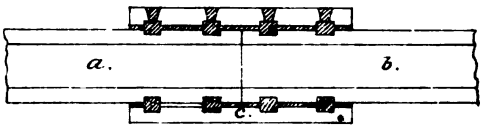
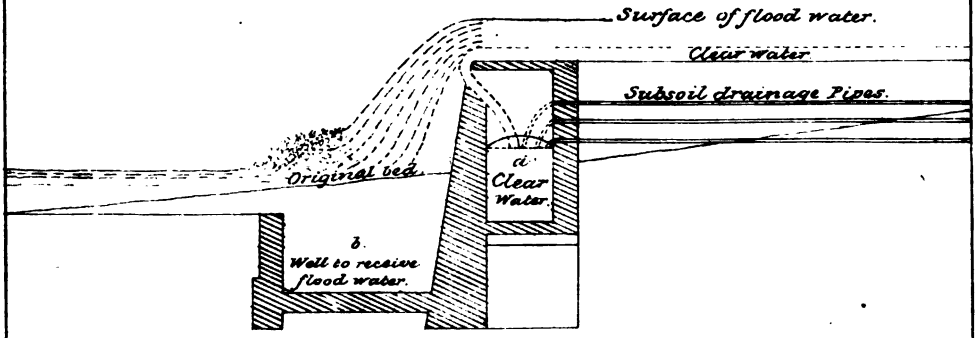


Fig. 2.



LITHO: T. C. PRESS.

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fire-clay in the hills, and in England fire-clay pipes have been proved capable of withstanding a pressure of many feet.

I will now proceed to show how I hope to avoid the silt difficulty. I alluded to a particular form of work that would be necessary for this purpose in the management of the Terraie streams. The principle of this work may perhaps be understood from reference to *Fig.* 2, where the work is represented in longitudinal section. The Terraie springs, in the cold and hot season run perfectly clear and free of silt, but in the rains, like all other streams, they become more or less muddy by reason of the soil washed into them by the rain water. If the whole country could at once be thoroughly sub-soil drained with pipes, and divided off into small kiarees with ridges say four inches high, there would be no surface flow of water over the country, no abrasion of the earth's surface, and consequently no mud in the streams. The rain-water would in this case fill all the kiarees up to a certain height, pass through the soil into the pipes, thus into the leaders, and eventually into the canal in a filtered state. The Terraie streams would in such a case receive little or no accession of water in heavy rain. But it is no part of this scheme to thoroughly sub-soil drain the whole of the land as works progress. The first sub-soil drains must be those rendered necessary by swamps, such as must more or less exist where dams or other works interfere with the free flow of the streams, and the extension of the Sub-soil Drainage system must depend upon the extension of cultivation to render it remunerative. The original bed of the stream is modified to the extent shown in *Fig.* 2, by a fall say of ten feet. The fall is, as far as the southern portion of it is concerned, an ordinary vertical one with a well, which experience has shown far excels the old ogee pattern. At the lip of the fall it will be noticed that there is a peculiarity. The top ot the fall consists of a slab separated, except at bearing points, from the drop-wall. Behind the drop-wall, at the top, is a masonry channel (*a*) supported on arches or by some other means. Supposing the stream to be running south, this masonry channel (*a*) would be running east and west. Its northern wall is perforated so as to allow sub-soil pipes (under the remodelled bed of the stream) to discharge into it. As I have never seen this experiment tried, I cannot say how much water we might thus obtain from the sub-soil pipes. The object of this feature in the work is to obtain a clear and filtered supply into the masonry channel (*a*) during heavy rains, when, from the construction of the

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work, it would otherwise be empty. At times when heavy rains are influencing the streams and charging them with silt, the water will over-shoot the channel (*a*) and discharge into the well (*b*), and thus proceed southwards; but in seasons when there is no silt, and consequently less water, if the length of the work be sufficient to lessen the velocity, it is evident that the water, falling gently over the edge of the slab, must be received into the channel (*a*). The efficient working of this plan depends upon the width of the slab and the length of the work. I saw a work similar to the above forming a part of the Manchester system of Waterworks, where none of the water is ever filtered. It had been constructed for some years, and gave perfect satisfaction. The simplicity of the contrivance must, I think, strike every one.

His Honor the Lieutenant-Governor, in the course of conversation, suggested to me that a difficulty might arise in carrying out Sub-soil Drainage in the Terraie owing to the numerous roots which abounded everywhere, and I ought not to omit allusion to this difficulty.

When in Scotland, I was fortunate enough to make the acquaintance of Mr. Murray, one of the Drainage Commissioners for Aberdeenshire, in which country the Sub-soil Drainage system has made most rapid progress within the last ten years. Having obtained from Mr. Murray much valuable information regarding the clearing out of sub-soil pipes when they become choked, I suggested the same difficulty as that now advanced by His Honor the Lieutenant-Governor. In reply, Mr. Murray remarked, that artificial Sub-soil Drainage was not adapted for forest lands, but that, where it was found necessary to cross a belt of trees, a method similar to that shown in longitudinal section in *Fig.* 3, had, within the influence of roots, been adopted with great success. Two drainage pipes, *a* and *b*, are here brought into contact, end to end, with a loose collar (*c*) covering the joint. By a simple contrivance two annular shavings are taken off the exterior of each pipe *a* and *b*, previous to baking, and four corresponding annular shavings from the interior of the collar (*c*). Four holes (as shown here in section) are bored from the exterior of the collar (*c*) to each of the annular excisions. In placing the pipes, *a* and *b* are brought together as here shown, with the collar (*c*) covering the joint. Asphalte or some other cement is then poured into one of the holes of the collar so as to fill up the space between the collar and the pipes, care being of course taken to prevent the escape of the cement at the two extremities of the collar. The

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cement must be thin enough to flow pretty freely so as to thoroughly fill the space between the collar and the pipes, and still not so thin as to run in between the two pipes, *a* and *b*. An air and water-tight joint is thus formed, effectually preventing the intrusion of roots. No asphalte, artificially made, has yet been found to equal the natural asphaltes of Seyssel, Trinidad, and elsewhere. In my estimate, therefore, I have made a provision for procuring a sufficient quantity for our more immediate wants. Further experience may probably suggest a more economical substitute.

I ought perhaps to mention that the slopes and other dimensions which have been here assumed for the different drainage and irrigation channels are purely arbitrary, and are simply adopted to illustrate the principal which I propose to follow.

A reference to Plate LVI will show how this description of the works down to the point (*c*) is applicable to each "step" of the system in its progress downwards. It will be seen how the water is constantly being conveyed back to the water-shed after use, unavoidable waste being more than compensated for by constant recruiting from fresh springs in the progress of the system southwards. The canals of the two sections eventually unite (in *g*), so that the ravine dividing them is crossed at one point (*h*) alone, whereby considerable economy will be effected.

The chief difficulties in the execution of this scheme lie—

1*st*.—In the presence of water so close to the surface, which, though perhaps affecting the rates of channel excavation to some extent, would affect the rates of masonry foundation work still more so, rendering the work, in some instances, extremely difficult with the ordinary appliances at our disposal.

2*nd*.—The scarcity of workmen in the Terraie, where consequently we are obliged to give rates so very much in excess of what I have seen obtaining elsewhere.

3*rd*.—The glazing of the pipes, which very much improves them for some purposes, but which is as yet an impracticability in India.

The first two of these difficulties I propose to overcome by the use of machinery. The pipes for which we shall have such a demand must be made by machinery and the same machine, if furnished with the proper dies, might be of great use to us in many other ways; as, for instance, in the construction of light bridges and roofs, substituting hollow bricks and pipes for the quickly-decaying timber, the use of which is now so universal

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in the Terraie. The third difficulty of glazing I propose to overcome temporarily by the substitution of Ransome's process, of which I have had some personal experience. The results obtained by Ransome's process are very satisfactory, though the process itself is not so economical as the ordinary process of glazing practised in England. When our works are fairly started, and our kilns in good working order, I anticipate little difficulty in introducing the art of glazing with common salt and other substances.

The portion of the Terraie which to me seems best adapted for commencing operations is that lying between the Kylas and Sookhee rivers. The tract here is narrow, the cultivation extends up to very near the Bhabur, the present irrigation works there are very troublesome to maintain, and the population perhaps greater than in most other parts. The health of this population must be very injuriously affected by the proximity of the Mahadeo Swamp, which, though much silted up, is still undrained. The Sissonah Swamp, though surface-drained, would most probably benefit greatly by the addition of sub-soil drains. Moreover it would no doubt add very greatly to the sanitary condition of the tract of country surrounding Sittargunj if the Kilpoorie forest were opened up more, thus permitting of a more free circulation of air. The timber of the forest would afford us an unlimited supply of fuel for the steam-engine, which I look to as our great auxiliary. The Sookhee, though forming the western boundary of our first division, would not be the limit of our first operations, as, to form a just idea of their value in a sanitary point of view, I think the removal of the neighbouring swamps on its western bank would be essential. I should therefore, to the west of the Sookhee, confine myself in the first place, chiefly to drainage operations, keeping irrigation in view as a future contingency, and between the Sookhee and the Kylas carry on drainage and irrigation simultaneously.

I feel how incomplete this present Report must be without an Estimate of the probable cost of Sub-soil drainage in the Terraie. It is with extreme diffidence that I approach this subject; for, in the first place, never having carried on any work in the Terraie, I can form only a very vague idea of the rates which obtain there. The pipes (which form so essential a part of the scheme) have never, to my knowledge, been made by machinery in India; and even if they had, the rates for Terraie labor seem to me to be so exceptionable, that the rates of other districts, even

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if available, would hardly be any guide. Moreover, all such questions as these must resolve themselves into one of remunerative value, which again must depend in a great measure upon the market-value of the land upon which we propose to operate.

I think it, therefore, fair to myself to place before Government the data upon which I base my calculations. My wish is to over-estimate rather than under-estimate, and if the cost of our first operations should exceed my expectations, I trust that due allowance will be made for my scanty means of obtaining information. Many—and amongst them officers whose experience entitles them to consideration—consider that we are not yet sufficiently advanced for the introduction of Sub-soil drainage. I have been frequently told that it will not pay, but as I have never yet had presented to me any substantial grounds for the supposition, or the ground-work of the calculations upon which this opinion has been formed, I must beg to be allowed to retain my present conviction that it will pay, till results have proved to the contrary. The main objection, as I have already stated, is the expense; let us therefore consider, with the data at our disposal, what this expense is likely to be.

First, as to the pipes. No one has yet ventured to tell me what these are likely to cost, and it is rather an important part of the calculation. At Roorkee I had some experience in constructing Syrian roofs. These roofs are arched, the voussoirs of the arch consisting of baked earthen bottles, ten inches long, five inches diameter at the bases, and slightly tapering towards the necks, which latter form the intrados of the arch. Every bottle (made by the potter) was turned by the hand, and must have been the result of a considerable amount of labor: it was baked in the rudest native kiln at a great expenditure of fuel, and fuel at Roorkee has to be carted from some distance. This is the nearest approach to the average-sized drain-pipe for which I can furnish a rate. The bottles were supplied to me on the spot, after a carriage of more than a mile, at the rate of ten rupees a thousand; and for this rate I was allowed to reject all unsound or under-burnt ones. I never had any difficulty in procuring any number at this rate; so I am sure it paid the manufacturer well. The drainage pipes which I propose to make for the Terraie will be made in a machine, which will turn out, I suppose, fifty pipes to one bottle made by the potter. The kiln I propose to use will be of the most approved English pattern, admitting of drying and manufacture at all

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seasons; the fuel is on the spot; and in the first place my labor will be furnished by steam-engine, most likely to be supplanted, as our works progress, by a still more economical motive power—water. Under such circumstances, I assume that my drainage pipes will not cost more than *five* rupees a thousand, which is one-half the English price. Adding, say one rupee a thousand for carriage, &c., they will cost *six* rupees a thousand when laid.

The next item for consideration is the cost of excavation. The rate for excavation I will take as that given me by Mr. E. Colvin, high as that is, viz., *two* rupees *eight* annas per thousand cubic feet. For similar excavation I have repeatedly paid less than one rupee per thousand cubic feet on the Ganges Canal, and, should we extend our operations and import labor, I have little doubt that we shall succeed in reducing Terraie rates to something like a par with those of other districts; and as the progress of our works renders the Terraie more healthy and habitable, our difficulties in the matter of rates will be still more favorable affected. However, we must start at least with prevailing rates, and as anticipation on my part might be objected to, I have adopted these rates in my Estimate, adding one-half as much again for refilling after the pipes have been laid. The rates for excavating and refilling are therefore placed at *three* rupees *twelve* annas per thousand cubic feet.

The following Table will then show the estimated cost of a few likely cases of sub-soil drainage per acre:—

1.	2.	3.	4.	5.	6.	7.			8.			9.		
No. of Case.	Depth of Drain.	Width of excavation at top.	Width of excavation at bottom.	Distance of Drains apart.	Length of Drain in feet.	Cost of excavation and refilling per acre.			Cost of Pipes per acre.			Total cost of sub-soil drainage per acre.		
						R.	A.	P.	R.	A.	P.	R.	A.	P.
1	3 feet.	15 inches.	3 inches.	18 feet.	2,421	20	6	10	14	8	5	34	15	3
2	"	"	"	24 "	1,815	15	4	10	10	14	3	26	3	1
3	3½ "	21 "	"	24 "	1,815	23	13	1	10	14	3	34	11	4
4	4 "	"	"	"	1,815	27	3	7	10	14	3	38	1	10
5	"	"	"	33 "	1,320	19	12	10	7	14	9	28	5	7

From the above Table I should fix about *thirty* rupees as the average

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cost per acre of Sub-soil drainage in the Terraie. The dimensions of the sectional area of the drains are taken from English examples.

Thus far I have assumed that the drainage is to be carried on by excavators in the usual manner practised in England; but, if I am not mistaken, the Terraie land is just one of those peculiarly adapted for the application of the drainage plough, as invented some years back by Messrs. Fowler and Fry of Bristol. This machine, in soils adapted for its use, is admitted to lay pipes better than they can be laid by hand, and the estimated cost of drainage by its means in England is calculated at three-fifths of that without it. Of course, as it is not adapted for all conditions, such as stony and hilly ground, we cannot calculate upon its assistance everywhere; but it is peculiarly adapted for swampy soil, free from stones, and generally level; and it is just such cases as these with which we shall have first to deal. That there are cases even in the Terraie where this useful machine cannot be employed I do not doubt, but I believe that such cases will prove to be comparatively few, and, given steam-power to work it, I do not see why we should not derive as much benefit from the use of this machine here as in the flat alluvial counties of England. Should my anticipations be well-founded and the draining plough come into universal use, considering that we should thus be rendered independent of the exorbitant Terraie rates for labor, I see no reason why our average cost for sub-soil drainage should exceed, if it attains, *twenty* rupees per acre.

I will now proceed to take into consideration the general question—"Will Sub-soil Drainage pay in the Terraie?" An English farmer, in placing such a question before himself, would naturally first consider the annual revenue derived from his undrained land. If he were to follow the opinions of such authorities as Donaldson, Johnston, Mechi, and others, he would probably reckon upon one-half more out-turn from his land when drained than before, and the calculation of how long it would thus take him to recover the money spent on drainage works would not be a very difficult one. If swamp were the only evil of which he could complain, and his land were otherwise good and well-farmed, he would probably find the whole of his money returned to him with interest in one year, as I myself and many others have done; but if his soil and other circumstances were such as we commonly find, and he farmed only moderately well, he could scarcely fail to recover the whole of his money in three years, which is no bad rate of interest even for India.

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I have tried frequently to arrive at some average value for land in the Terraie, but I am sorry to say that I can get at nothing more definite than that its paid revenue to Government varies from two annas to one rupee fourteen annas per beegah, or (if we roughly adopt English measures,) from about thirteen annas to thirteen rupees per acre. The soils upon which I propose first to operate might almost be considered valueless in their present conditions, and as, when drained, I think it might fairly be considered worth ten rupees an acre at least, it is evident that, at this rate, even Government would recover the money in three years. The profit to the tenant would certainly not be less than that accruing to Government.

ESTIMATE OF EXPENDITURE FOR THE FIRST YEAR.

		£	S.	D.	R.	A.	P.
Survey Establishment, ...					5,000	0	0
MACHINERY.	Ten horse-power Steam Engine, ...	600	0	0			
	Pumps, &c., ...	200	0	0			
	Machines for making Bricks, Pipes, &c.,... ...	600	0	0			
	Mortar-mills for grinding Cement, ...	100	0	0			
	Sawing Machines, ...	50	0	0			
	Lathe for Workshop, ...	50	0	0			
	Asphalte and Caldron, ...	50	0	0			
	Ransome's Silicate of Soda and Chloride of Calcium,	50	0	0			
	Carriage, ...	300	0	0			
	Total,	£2,000	0	0	20,000	0	0

WORKING EXPENSES.

For building Kilns, manufacturing Bricks, Pipes, &c.,	5,000	0	0
Total Rupees,	30,000	0	0

NYNEE TAL,
May, 1864.

C. S. THOMASON.

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No. XLIV.

DIMENSIONS OF ARCHED BRIDGES.

The following Formulæ, for calculating dimensions of Bridges are taken from a French Manual of Civil Engineering (Formules, tables et renseignements pratiques; Aide Memoire des Ingenieurs, Architectes, &c. PAR J. C. CLAUDEL, *Paris*, 1860.*)* N.B.—*The Constants have been converted to suit English feet.*

I.—THICKNESS OF ARCH AT CROWN.

e Thickness of Arch at Crown.

d Span.

$$e = \frac{d}{30} + 1{\cdot}1.$$

II.—THICKNESS OF ABUTMENTS.

e Thickness of Arch at Crown.

d Span.

h Height of Abutment from Spring to Foundation surface.

f Versed-sine or Rise of Arch.

E Thickness of Abutment.

H Height from Foundation to the top of the Extrados as loaded. For road bridges the surface of the loaded extrados may be assumed to be 2 feet above the crown of the extrados of the arch, and $H = h + f + e + 2$.

1.—FOR SEGMENTAL ARCHES.

$$E = (1 + {\cdot}212\, d)\sqrt{\frac{h}{H} \times \frac{d}{f+e}}$$

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2. For Semicircular Arches.

$$E = (2 + \cdot 162\, d)\sqrt{\frac{h + \frac{1}{4}d}{H} \times \frac{0{\cdot}87\, d}{\frac{1}{4}d + e}}$$

3. For Elliptical Arches.

$$E = (1{\cdot}4 + \cdot 154\, d)\sqrt{\frac{h + \cdot 54 f}{H} \times \frac{0{\cdot}84\, d}{\cdot 46 f + e}}$$

These Formulæ are based on the following assumptions:—1*st*, That in Segmental arches the joint of rupture will be at the springing; 2*nd*, That in Semicircular arches having a horizontal extrados the joint of rupture will be at an angle of 60° with the vertical, or $\frac{1}{4}\, d$ above the springing. This leaves the span between the points of rupture $\cdot 87\, d$; 3*rd*, That in Elliptical arches the joint of rupture will form an angle of [illegible]45°[illegible] with the vertical, and will be at a height of $\cdot 54\, f$ above the springing. Also that the span between the points of rupture will be $\cdot 84\, d$.

The numerator of the fraction having H for its denominator is the height from the foundation to the point of rupture.

The numerator of the second fraction is the span between the points of rupture; the denominator, the distance from the point of rupture to the extrados of the arch. It is understood that the thickness of abutment calculated from the formulæ is the *mean* thickness, which in practice may be obtained when so desired by the help of counterforts, the wing walls being reckoned as such when suitably placed.

There is one objection to the first of the above formulæ, viz., that the depth of Keystone is made independent of the Radius of Curvature at the crown.

Professor Rankine has given the following empirical rule founded on dimensions of good existing examples of bridges:—

For the Depth of the Keystone, take a mean proportional between the Radius of Curvature of the Intrados at the Crown, and a constant, whose values are,

for a single arch, ... ·12 foot;
for an arch forming one of a series, ... ·17 „

That is to say,

For a single arch, $e = \sqrt{\cdot 12\, r}$.

For an arch of a series, $e = \sqrt{\cdot 17\, r}$.

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THE ANNEXED TABLE SHEWS THE COMPARISON BETWEEN THE DIMENSIONS CALCULATED BY THESE FORMULÆ AND ACTUAL BRIDGES.

	Bridges.	Span.	Versed sine.	Height of abutment.	Thickness at Crown.			Total height.	Thickness of Abutment.		Radius of curvature at crown.	Remarks.
					Real.	Calculated by French formulæ.	Calculated by Rankine's formulæ.		Real.	Calculated by French formulæ.		
		d	f	h	e	e'	e''	H	E	E'	r	
	I. SEGMENTAL ARCHES.											
1	Various bridges in France and England,	13·1	2·3	13·1	1·8	1·5	1·3	18·9	5·9	5·8	10·45	
2		16·4	2·6	6·6	1·7	1·7	1·6	12·9	5·6	6·3	14·2	
3		25·0	2·9	14·1	2·1	1·9	2·1	20·9	11·7	11·8	28·3	
4		37·4	4·9	11·6	2·0	2·3	2·0	20·8	17·1	15·2	37·8	
5		42·7	6·1	6·6	3·0	2·5	2·6	17·2	17·1	13·9	40·4	
6		46·0	6·2	20·4	3·6	2·6	3·1	31·2	19·0	19·9	45·7	
7		52·7	5·1	12·9	3·0	2·9	3·4	22·9	32·8	28·4	70·1	
8		53·5	10·2	20·7	2·8	2·9	2·6	35·8	16·0	19·0	40·1	
9		76·8	6·4	27·7	4·8	3·7	4·5	39·8	38·7	39·7	118·4	
10		82·4	11·7	17·8	4·6	3·9	3·6	35·4	31·5	30·1	78·4	
11		86·5	13·5	16·6	3·5	4·0	3·6	36·1	32·0	29·2	76·	
12	Bridge at Turin,	147·6	18·0	...	4·9	6·02	4·88	...	...	...	160·0	Single arch.
13	Grosvenor bridge over the Dee,	200·0	42·0	...	4·0	7·8	4·1	...	...	...	140·0	Ditto.
14	Bridge of St. Maxence,	76·7	6·4	...	4·79	3·6	4·49	...	...	...	119·0	
15	Dean bridge,	90·0	30·0	...	3·00	4·1	2·88	...	...	...	48·75	

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	Bridges.	Span.	Versed sine.	Height of abutment.	Thickness at Crown.			Total height.	Thickness of Abutment.		Radius of curvature at crown.	Remarks.
					Real.	Calculated by French formulæ.	Calculated by Rankine's formulæ.		Real.	Calculated by French formulæ.		
		d	f	h	e	e'	e''	H	E	E'	r	
	II. Semicircular Arches.											
1	Various bridges,	2·0	1·0	3·0	1·1	1·2	0·41	7·2	1·6	1·7	1·0	
2		6·6	3·3	7·9	1·1	1·3	0·75	14·5	3·9	3·4	3·3	
3		6·6	3·3	6·4	1·6	1·3	0·75	13·0	3·3	3·3	3·3	
4		9·8	4·9	11·8	1·3	1·4	1·3	20·1	4·6	4·5	4·9	
5		13·1	6·5	13·1	1·6	1·5	1·5	23·2	4·9	5·3	6·5	
6		16·4	8·2	9·8	1·8	1·7	1·7	21·7	5·9	6·1	8·2	
7		24·3	12·1	6·6	2·0	1·9	2·0	22·7	6·9	7·2	12·1	
8		26·9	13·4	11·8	2·5	2·0	2·1	29·3	10·5	8·3	13.4	
9		37·1	18·5	20·7	3·9	2·4	2·5	43·7	9·8	11·0	18·5	
10		49·2	24·6	6·6	3·9	2·7	2·9	35·9	12·5	12·2	24·6	
11		65·6	32·8	3·3	...	3·3	3·3	41·4	14·8	14·7	32·8	
12	Ballockmyle Bridge,	181·0	90·5	...	4·5	7·13	3·92	...	...	...	90·5	
	III. Elliptical Arches.											
1	Various bridges,	19·7	7·5	1·3	2·0	1·8	...	12·6	5·3	5·1	unknown.	
2		39·4	14·8	10·2	3·0	2·4	...	29·4	12·3	11·1		
3		51·1	17·1	13·6	3·7	2·8	...	35·5	14·9	14·9		
4		52·2	17·4	1·3	3·7	2·8	...	28·5	11·8	12·8		
5		70·0	17·5	12·0	2·3	3·4	...	34·9	16·5	21·6		
6		79·4	26·2	2·9	3·9	3·7	...	34·8	18·4	19·6		
7		80·4	27·7	6·4	4·5	3·8	...	39·9	19·2	20·4		

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	Bridges.	Span.	Versed sine.	Height of abutment.	Thickness at Crown.			Total height.	Thickness of Abutment.		Radius of curvature at crown.	Remarks.
					Real.	Calculated by French formulæ.	Calculated by Rankine's formulæ.		Real.	Calculated by French formulæ.		
		d	f	h	e	e'	e''	H	E	E'	r	
	III. Elliptical Arches.—(*Continued.*)											
8	Various bridges,	115·2	34·4	3·2	6·4	4·9	...	44·5	28·8	28·9	un-	
9		127·9	32·0	7·5	5·3	5·4	...	46·9	35·4	35·6	known	
10	Blackfriars center arch,	100·0	40·0	...	6·7	4·43	...	...	...	...	...	
11	Ganges Canal bridges,	55·0	12·0	8·0	3·0	2·93	2·5	24·93	13·3	17·5	37·5	
12		50·0	7·0	8·0	2·25	2·77	2·8	19·77	11·3	18·6	48·1	
13		45·0	6·0	8·0	2·5	2·6	2·8	18·6	13·6	17·2	45·2	
14		40·0	5·4	9·0	2·0	2·43	2·6	18·83	11·0	15·75	39·7	
15		35·0	4·5	9·0	2·5	2·27	2·5	17·77	10·3	14·2	36·27	
16		30·0	4·0	9·0	2·25	2·1	2·3	17·1	6·25	12·3	30·1	
17		25·0	4·0	9·0	2·0	1·93	1·9	16·93	...	10·1	21·6	
18		20·0	2·67	9·0	1·5	1·77	1·9	15·43	...	8·7	20·6	
19	Markunda,	36·5	9·0	12·0	2·5	2·32	2·0	25·57	16·5	12·41	23·0	
20	Sohan,	63·0	16·0	24·0	3·0	3·2	2·9	45·2	15·0	15·13	48·0	
21	Bridge over the Severn,	150·0	35·0	...	4·5	6·1	4·39	...	...	...	160·7	Single arch.
22	Ordinary bridge over double line of Railway,	30·0	7·6	...	1·83 to 2·0	2·1	1·9	...	...	...	30·0	Ditto.
23	London bridge,	152·0	...	...	5·0	6·2	5·25	...	...	...	162·0	
24	Waterloo bridge,	120·0	32·0	...	5·0	5·1	4·37	...	...	...	112·5	

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No. XLV.

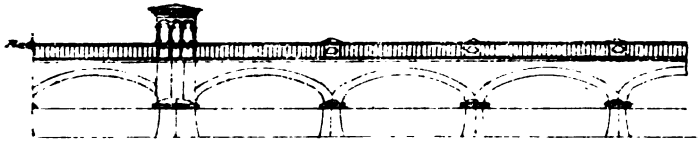
MARKUNDA BRIDGE.

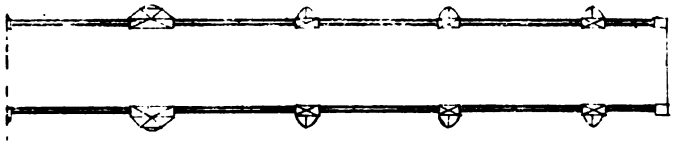
Specification and Estimate of the Bridge over the Markunda River near Umballah, now being constructed by W. PURDON, ESQ., C.E., *Exec. Engineer.*

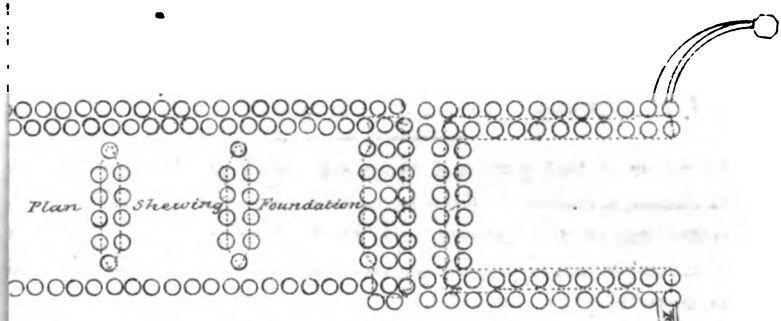
THE whole of that portion of the plains which lies between the Sutlej and Jumna, is drained by three great rivers and their tributaries. These are the Guggur, the Tangree, and the Markunda; each of these rivers has its source within one of the outer ravines of the Himalyas, which rise above the plain to the east.

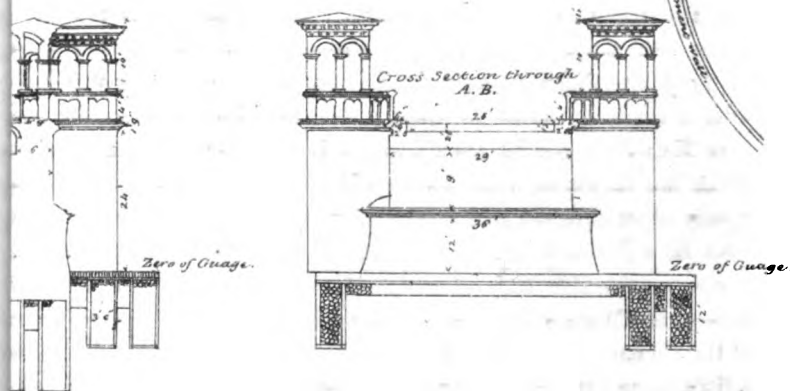
The Markunda river drains the largest area, and is in other respects also the most formidable of the three. It rises at an elevation of between four and five thousand feet above the sea, draining the heights of Tytok and Nahun; names familiar during the Goorka war of 1814; after a course of about 15 miles within the hills, it enters the plains near Kala-Am; 8 miles lower down it is joined by the Roon, a nuddee, which has its source in the higher hills, and which adds almost as large a body of water as the main stream; 7 miles further, the Khuraki nuddee joins it, and a little below Moulāna, 11 miles further, the Beguna adds a very considerable body of water—the drainage of the plain which lies between the Markunda and the Tangree rivers, 12 miles below the junction of the Beguna. The Grand Trunk road crosses 35 miles further on, and a little above Pehourah the Surssootee river joins; beyond this the united stream takes the name of the tributary. The Surssootee is much inferior in size, having its source in the plains, not more than 50 miles above its junction with the Markunda; about 25 miles below Pehourah, the united stream joins the Guggur and is lost with that river in the plain of Rajpootanah.

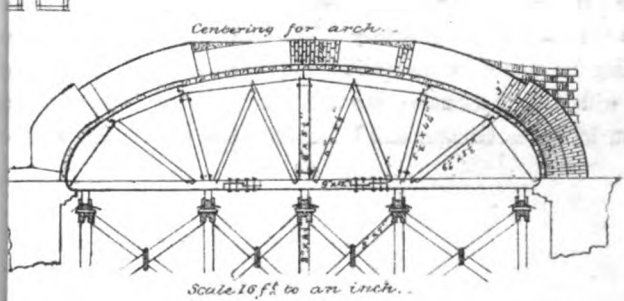
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The whole length of the Markunda is 113 miles, its course through the plains about 98 miles, and its general direction, E.S.E.

Its course through the higher hills has not been examined. Through the plains its belt of variation is, on the whole, well defined, varying in width from $\frac{1}{2}$ to $\frac{3}{4}$ of a mile, and from 4 to 8 feet in depth. This description holds good to about Hussunpore, a village about 3 miles above where the Grand Trunk Road crosses the river; below the village, and almost to the junction with the Surssootee, the banks are ill defined, the river is not self-contained, but overflows its banks, flooding the country for several miles. Having its sources in the higher hills, the rise of the Markunda is exceedingly rapid, and even where it crosses the Grand Trunk Road, it retains all the characteristics of a mountain torrent, rapid and violent; pebbles and course gravel are carried down nearly as far as Moulāna, about 25 miles below the hills. Near Kala-Am, where it first issues from the hills, some of its water is led off for irrigation, but a good deal escapes away down the loose rocky bed of the river, and even where the Grand Trunk Road crosses the river, an insignificant stream may be observed up to April, doubtless fed in part by springs in the bed of the river itself.

During the floods of the rainy season, the river has a depth of 6 to 9 feet. It offers considerable obstruction to the traffic which passes over the Grand Trunk Road, travellers being frequently delayed for many hours; even after the floods have subsided, the crossing is not unattended with risk, owing to the frequent quicksands in the bed.

From the observations and surveys made by Mr. Campbell, C.E., in 1859, he obtained the following discharge in the river during flood. The observations were made near the village of Hussunpore, about 3 miles above the site of the bridge, where the banks of the river are well defined.

Width of channel,	1,577 feet.
Area,	6,938 „
Rate of fall,	3·72 inches per minute.
Mean velocity,	5·15 „ per second.
Discharge,	35,730 cubic feet.

Mr. Campbell's investigations further ascertained that in 1845, a flood rose 18 inches above the bank of the river on which Hussunpore stands, giving a discharge of 47,838 cubic feet; nothing approaching to this has occurred since.

A design for a Bridge for this river was prepared in 1856, by Cap-

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tain Grindall, at an estimated cost of Rs. 5,13,646, and the work was actually commenced.

In 1860, Mr. Campbell submitted four alternative designs, embracing a brick bridge of arches of 80 feet span, two designs for a wire suspension bridge, and a cast-iron girder bridge of 30 feet spans, on screw tubular piles.

The Government of India, while acknowledging the care and labor expended on the subject by Mr. Campbell, preferred a modification of the original design to any of them, and gave the following specific instructions for the preparation of the new design.

The width of the Roadway to be reduced to 26 feet, the depth of the Pier Foundations to be limited to 15 feet, and that of the Curtains to 12 feet.

The bridge to be divided into five sections by Abutment Piers.

The Water-way not to exceed 1,073 running feet.

In compliance with the above instructions the accompanying design has been prepared.

The portion of the block foundations which had been partly sunk by Captain Grindall have been made use of.

The drawings are so fully detailed, that it is believed every necessary information may be obtained from them.

The estimated cost of the bridge is Rs. 3,61,180. The whole of the piers, abutments, and wings are now (July, 1864) brought up to the level of the imposts. The turning of the arches (27 in number) will be commenced after the floods have subsided.

The nature of the Foundations of the bed of the river was examined by both Captain Grindall and Mr. Campbell, but nothing but sand, or at best, a clayey silt, was met with, to a depth of 40 feet.

The total length of the bridge is 1,400 feet, the height of the roadway above the bed of the river is 24 feet, and the width of the road 26 feet.

Specification.

The Curbs for the wells to be made of Keekur, Tallee, Jamun, or other sound jungle wood, approved of by the Executive Engineer, they will be 9 inches in thickness, put together in threes, and firmly secured together by wooden treenails of seasoned Keekur wood. The masonry walls of

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the Wells are to be 9 inches in thickness, and are to be built of radiated bricks, moulded or cut to the proper form, and laid with mortar composed of two parts of soorkhee, to one part of freshly slaked stone lime, burned on the works, and well mixed together in a mortar mill in the usual manner.

All Bricks used in the work are to be soaked for at least six hours previous to their being used, and the masonry is to be kept moist, to prevent the too rapid desiccation of the mortar, until the mortar gives indications of setting. The walls of the wells are to be carried up six feet, and allowed to dry for at least ten days, when the undersinking may be commenced.

The whole of the wells of one Pier or Abutment, are to be undersunk together; when the wells have been sunk 3 or 4 feet, then the walls may be raised 6 feet more; when the wells have been sunk 8 feet, then the walls must be weighted with kucha pucka masonry, to facilitate the undersinking, as well as to prevent the walls parting from the curbs.

When the wells for the Curtain Walls have been sunk to their full depth, the excavation for the Concrete, which is to be laid between the wells of the piers, (as shewn on the drawing,) as well as for the concrete beneath the flooring, is to be commenced.

As soon as a well has been sunk to the required depth, it is to be filled at once with broken brick to the required level. In laying the concrete, 6 inches is to be laid and consolidated at a time, water from the foundation having been removed by pumping.

In Undersinking the Wells, the old system of *jhams* and divers will be dispensed with as much as possible, pumps will be used to keep down the water in the well, and ordinary excavators will be employed; the material being brought up by means of a bucket and windlass; when the material at the bottom of the well is slush, the bucket is to have a valve in its bottom so as to fill itself.

In the Piers and Abutments, the bricks will be laid in English bond, with half-inch joints, and grouted every course.

As the work advances, the hardest and best shaped bricks will be set aside for the Arches. Each Arch will be divided into several portions, by joints running completely through from soffit to back, the bricks being laid in these successive portions, alternately in rings and blocks, with joints running entirely through the arch, from soffit to the back.

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English bond will be used in the portion laid in rings, the thickness of the arch being divided into two equal rings; the blocks in which the joints run through, are not to exceed four bricks in thickness, measured on the soffit. Great care will be taken in laying the bricks which form the Keys of the Arches; thin tempered mortar or grout being used, and the joints well wedged up with hard pieces of brick; in keying in the arch, the first course on the soffit will be formed of a thickness of three bricks laid on their ends, in very thin mortar; the next course will be formed of five bricks, laid also on end, and forming continuous joints with those below them; this course will be laid in grout. By dividing the length of the course into several compartments, separated by a single row of bricks, laid in mortar, the grout may be poured into these compartments, and the bricks be set in it, and the joints then filled with pieces of brick.

The haunches of the arches will be carried up and allowed to set before bringing up the remainder of the arch. Care must be taken to load the crowns of the centres to prevent springing.

The arches will be turned on regularly framed timber Centres; these will be supported by timber struts; each point of support will be capped by a strong wooden piller plate; on this will stand a cast-iron cylinder fitted with a wooden piston. The cylinder will be 9 inches in diameter, of sheet iron, in thickness $\frac{3}{16}$ inch and 12 inches in length, open at both ends. It will have 4 half-inch holes; at half-an-inch from the lower end of the cylinder, these holes will be fitted with four wooden plugs so that they may be pulled out and inserted by the hand; each cylinder will have a solid wooden piston fitting it freely, and of the same length as the cylinder; the cylinders will be filled to $3\frac{1}{4}''$ of their length with clean sand, on which the wooden piston will rest. When it is desired to strike the centering, a man will be stationed at each cylinder; at the order being given, they will simultaneously pull out every man his four plugs; the sand will be allowed to run out until it forms a sort of semicone on the pillar plate opposite each hole, when the sand will stop running until the sand outside be cleared away; on which, it will run again from the cylinder, and so on; care must be taken that no moisture finds its way down the sides of the pistons at the cylinder.

The centres will be slightly eased immediately after keying the arch, but the centres are not to be struck until six weeks at least have elapsed after the keying in, a longer time will be allowed if convenient.

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The Mortar to be used on the work is to consist of one part of freshly burnt stone lime, and two parts soorkhee made from pieces of pucka bricks, and ground in a mortar mill in the usual manner; that used for the face joints to be ground in a hand mill.

The Concrete will consist of the following proportions:—

1 part of stone lime.

3 parts of soorkhee from pucka bricks.

6 parts of broken bricks, kunkur or stone, two-thirds of which not to be larger than a hen's egg.

The concrete to be mixed together in a little tank close to the work and thrown in from a height; no plaster will be used on any portion of the work.

ABSTRACT OF ESTIMATE.

		R.	A.	P.
c. ft. 20,11,294	Excavation in foundations, including cost of pumping, baling, &c., at Rs. 8-8 per 1000,	17,095	15	11
865	Neemchucks, complete, at Rs. 14 each,	12,110	0	0
r. ft. 12,154	Well-sinking (including kucha masonry) to 15 feet below zero of guage, at Rs. 2-7,	29,625	6	0
c. ft. 8,26,191	Masonry in foundations, wells, curtain walls, and flooring, at Rs. 25 per 100,	81,547	12	0
3,07,943	Masonry in superstructure, parapets, wings, revetments, and barrelled drain, at Rs. 22 per 100,	67,747	7	4
2,03,747	Masonry in arching and inverts, parapets, cornice, coping, towers, and roofing of do., including ornaments, and cost of centres and scaffolding, at Rs. 35 per 100,	71,311	7	2
2,43,223	Concrete in foundations, revetments, barrel drain, &c., including cost of pumping, at Rs. 13 per 100,	31,618	15	10
53,649	Metalling, at Rs. 14 per average 100,	7,510	13	9
15,64,968	Earth rammed between wing walls, &c., and in embankment north east flanks of the bridge, and in excavations to put in centerings, at Rs. 2-8 per 1000,	3,912	4	5
r. ft. 2,896	Stone curbs to roadway, at Rs. 2,	5,792	0	0
50	Piles, including driving each,	50	0	0
200	Fascines, at Rs. 12 per 100,	24	0	0
	Preliminary operations, including godowns, workmen's sheds, lime kilns, plant, contingent losses by flood, and cost of native supervision at 10 per cent.,	32,834	10	4
	Total Rupees,	3,61,180	12	9

W. PURDON, C.E.

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No. XLVI.

NOTES ON RETAINING WALLS.

(2ND ARTICLE.)

BY "DHARWAR."

SIMILAR to the above table for banks with horizontal surfaces, is the following for surcharged banks; that is, banks where the surface slopes up from the top of the wall. For the maximum case of this when the surface slope equals the natural slope of the material, the formula is $P = \frac{W h^2}{2} \cos^2 \theta$, and the breadth of a vertical rectangular wall, $b = h \cdot 578 \cos \theta \sqrt{\frac{W}{W_1}}$

The coefficients of h (K, in the table) therefore $= \cdot 578 \cos \theta \sqrt{\frac{W}{W_1}}$, and $b = K h$.

b, the breadth here obtained is also that theoretically required for bare equilibrium.

Of the elements of stability not considered in the formula, that due to the friction of the earth against the back of the wall is the most considerable.

Supposing the coefficient of this friction to be at least equal to that of earth on earth, we have the value of the force of friction $F = P \tan \theta$, and its moment $= b P \tan \theta$.

The value of $\tan \theta^\circ$ will range between the limits 1 to ·6, so that $F = P$, or ·6 P. This element of stability is therefore one of very considerable value.

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Table of Coefficients of h for Breaths of Vertical Rectangular Walls. $b = K\,h$.

Top of Bank Sloping up at Natural Slope from Top of Wall.

Ratios $\frac{W}{W_1}$	Fracts. $\frac{1}{1}$	$\frac{1}{1\cdot1}$	$\frac{1}{1\cdot2}$	$\frac{1}{1\cdot3}$	$\frac{1}{1\cdot4}$	$\frac{1}{1\cdot5}$	$\frac{1}{1\cdot6}$	$\frac{1}{1\cdot7}$	$\frac{1}{1\cdot8}$	$\frac{1}{1\cdot9}$	$\frac{1}{2}$	$\frac{1}{2\cdot1}$	$\frac{1}{2\cdot2}$	$\frac{1}{2\cdot3}$	$\frac{1}{2\cdot4}$	$\frac{1}{2\cdot5}$	Values of cos. $\theta°$ or sin. ϕ
	Decs. 1	·909	·833	·769	·714	·666	·625	·588	·555	·526	·5	·476	·455	·435	·416	·4	
Angles of Repose. $\theta°$	K, K, &c., for the above ratios.																
°																	
30		·500	·476	·456	·438	·423	·409	·395	·384	·372	·363	·353	·345	·337	·33	·323	·316	·866
31		·494	·471	·452	·434	·418	·404	·391	·380	·368	·359	·350	·342	·333	·326	·320	·313	·857
32		·489	·466	·447	·429	·414	·40	·387	·376	·365	·355	·346	·338	·33	·323	·316	·309	·848
33		·483	·461	·442	·424	·409	·395	·382	·371	·36	·351	·342	·334	·326	·319	·312	·306	·839
34		·478	·456	·437	·419	·404	·391	·378	·367	·356	·347	·338	·331	·322	·316	·309	·303	·829
35		·472	·450	·431	·414	·399	·386	·373	·362	·352	·343	·334	·327	·318	·312	·305	·299	·819
36		·467	·445	·426	·409	·395	·382	·369	·358	·348	·339	·330	·323	·315	·308	·302	·295	·809
37		·461	·439	·421	·404	·389	·377	·364	·345	·343	·334	·326	·319	·311	·304	·298	·291	·799
38		·455	·433	·415	·399	·384	·372	·359	·349	·339	·330	·321	·314	·306	·300	·294	·288	·788
39		·448	·427	·409	·393	·379	·367	·354	·344	·334	·325	·317	·310	·302	·296	·290	·284	·777
40		·442	·421	·404	·388	·374	·361	·349	·339	·329	·321	·312	·306	·298	·292	·286	·279	·766
41		·435	·415	·397	·382	·368	·356	·344	·334	·324	·316	·307	·301	·293	·287	·281	·275	·755
42		·429	·409	·391	·376	·363	·351	·339	·329	·319	·311	·303	·296	·289	·283	·277	·271	·743
43		·422	·402	·385	·370	·357	·345	·333	·324	·314	·306	·298	·292	·284	·278	·273	·267	·731
44		·415	·395	·379	·364	·351	·339	·328	·318	·309	·301	·293	·287	·280	·274	·268	·262	·719
45		·408	·389	·373	·358	·345	·334	·322	·313	·304	·296	·288	·282	·275	·269	·264	·258	·707

K, K, &c. for the above angles.

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That due to the tenacity of mortar would probably not exceed 20 lbs. on the square inch, or 2,880 lbs. per square foot, and its moment = 1,440 b^3 (or according to Barlow's article 121, where he treats a wall as if it were a beam = 500 b^3), but this effect will usually exceed the effect of the weight of the mass of the foundations which will be only $\frac{W_1 d b^2}{2}$ where d = depth of foundations and b is the breadth, neglecting spread of footings, or what will be simplest, substitute h_1 the height over foundation bed for h in expression $\frac{W h b^2}{2}$.

It seems to me from the above, and considering the means we have of decreasing the pressure of the earth by packing and consolidation, that no increase to the theoretical breadth, obtained for loose earth, by the above tables or equations, will be necessary in practice, provided only that the back of the wall be well drained and that no saturation of the earth by water be permitted. It is, however, satisfactory to practical men to have a tangible margin of strength, so that I propose the following practical additions be made to the breadth of walls.

$\frac{1}{10}$ b for well drained banks with horizontal surfaces.

$\frac{1}{8}$ b „ „ sloping surfaces.

$\frac{1}{4}$ b for walls when the material is considered treacherous, or for dams over rivers where floods have considerable velocity.

In the foregoing Tables, the wall is supposed to be vertical at back, but when it leans backwards or forwards the value of the pressure changes, as will be seen further on, according to the inclination of supporting plane to the vertical. So long as the wall reclines, the breadth obtained from the tables will give a wall having an excess of strength, and the error will be on the right side, but when the wall has a back which overhangs or leans forward, it will be necessary to add something to the strength of the wall. The amount of this extra strength will not, however, be very great, because the stability of the wall is helped by the moment of the weight of the mass AaB (*Fig* 2,) vertically over the overhanging plane, and it will be found that the stability thereby produced is, in most cases, nearly equal to the increase of pressure caused by the increase to the prism of maximum horizontal pressure, due to the inclination of the plane AB; when the surface of the bank is horizontal the rest of the mass AaB is $\frac{W h^2 \tan \beta}{2}$, and its leverage is

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$x - \frac{1}{3} h \tan \beta$; therefore, the force tending to stability $F = \frac{W h^2 \tan \beta}{2}$ $(x - \frac{h \tan \beta}{3})$; where,

β, is the angle of batter of wall at back,

x, the breadth of an approximate wall.

The breadth x will be obtained by approximations in the following manner:—

Of necessity in practice the wall will have somewhat a triangular shape, so that $x = qb$; q being a coefficient of b, as in Table No. III., page 334, depending on the form of the wall determined on.

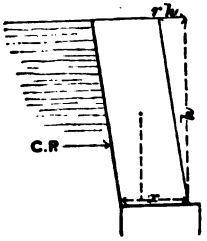
First, we obtain x for the wall, on the assumption that the back is vertical, from the value $b = \sqrt{\frac{2}{3} \frac{P}{W_1}}$; or by Table III., in page 338, and thus an approximate value for F. Next, we obtain the true value of P for a bank supported by an overhanging plane (see equations 5, 7, 9, further on,) and obtain a mean value for x when $b = \sqrt{\frac{2}{3} \frac{(P - F)}{W_1}}$ this value will probably be near enough for practice, but a closer approximation may be made by obtaining a new value for F, and thence a truer value for x.

In the case of a bank whose surface slopes up, the value of the moment of the weight of the prism AaB will change somewhat. It will be better in this case to make a geometrical approximation to the value of the leverage, as an equation for its determination would afford little practical advantage, in proportion to the difficulty of obtaining the value of x by it. The area may be obtained mathematically, and the position of the centre of gravity by construction, whence closer approximate values for x and F. An expression for the weight of AaB is in this case $\frac{W h^2}{2} \tan \beta (1 + \tan \beta \tan i)$.

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The two following cases of walls, not mentioned in the first part of this paper, are here inserted.

Fig. 7.

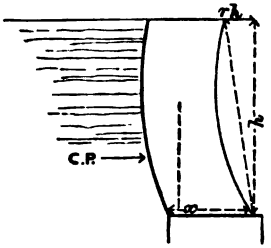


Let $r\,h$ be the total batter in each case, one being a straight batter, the other a curved. Equating the moments for the first case (*Fig.* 7,)

$\frac{W_1 h b^2}{2} = W_1\, h\, x \left(\frac{x}{2} + \frac{r h}{2}\right)$, and $b^2 = x^2 + r h x$. Whence $x = \sqrt{b^2 + \left(\frac{r h}{2}\right)^2} - \frac{r h}{2}$

and in the second case (*Fig.* 8,) supposing the curve to be parabolic, we have—

Fig. 8.



$\frac{W_1 h b^2}{2} = W_1\, h\, x \left(\frac{x}{2} + \frac{3}{8} r h\right) \therefore b^2 = x^2 + \frac{3}{4} r h x$. Whence $x = \sqrt{b^2 + \left(\frac{3}{8} r h\right)^2} - \frac{3}{8} r h$

which is also very nearly true if the curve of the force be circular, see Rankine's Civil Engineering, article 268.

The present paper lays no claim to originality as it merely aims at presenting in a condensed and practical form, the deductions of others that I find scattered up and down in the various authorities I have now the opportunity of consulting. In most authors I find a want of connected formula for the various cases of earth pressure; and often a want of any distinct enunciation of the theory from which the formulæ are obtained; I trust, therefore, I may be excused in presenting the following investigation of earth pressures, based chiefly on incomplete Notes of Lectures, delivered some years ago by Dr. Hart, L.L.D., F.T.C.D., on the subject.

In investigating the pressure of earth it is assumed that—

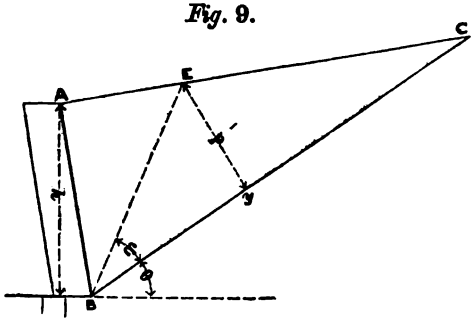
1. The earth is loose or dry.
2. Has no cohesion.
3. The plane retaining it being perfectly smooth, the friction of earth against it is neglected.
4. And that there is here equilibrium between the moments of the pressure of the bank, and those of the stability of the wall.

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Loose earth, may be considered to be a collection of particles free to move on each other, and when it is filled in behind a fixed plane, the resistance of this plane retains the mass, but if the plane be removed the particles of the earth will slip among and over each other till equilibrium is obtained; this will not be till the verticals through their centres of gravity make, with the perpendicular to a certain plane in the mass, an angle equal to the limiting angle of friction. This plane is the natural slope, and the angle, which it forms with the horizontal, is the angle of repose, or limiting angle of friction, and its tangent = coefficient of friction of earth on earth.

In *Fig.* 9, let this plane be represented by BC, the angle of repose by $\theta°$. ABC is the prism supported by the plane AB representing the back of a retaining wall. The earth below the plane BC is held in equilibrium by its internal friction, we may therefore neglect it. The mass in the prism ABC being just on the point of slipping, we may consider that the effect of friction along its surface in the direction of B is neutralized by its inclination, or that friction does not exist in the mass, as an infinitely small force will cause motion. It will not affect the reasoning therefore to consider this plane BC to be a horizontal plane, on which friction does not exist, and while it is horizontal no pressure will be exerted against AB. Let the plane BC be raised through any angle ϵ, the horizontal pressure will become by the principle of the inclined plane—

Fig. 9.



$$P = W_2 \tan \epsilon.$$

where W_2 = weight of prism ABC.

ϵ = angle of elevation of the plane BE over BC.

For the unit of breadth of the prism $W_2 = WA$.

where W = the weight of a cubic foot of the material retained.

A = the area of the triangle ABE.

Therefore $P = WA \tan \epsilon$.

There will be an elevation of this plane BE, at which the pressure becomes a maximum.

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This will be when the position of the plane BE is such that the area which it forms with a perpendicular let fall on BC, from where it cuts the surface of the bank AC, is equal to the area it forms with the surface and the plane AB; or, $A = BEy$.

To prove that such is the case by calculus. Let $A \tan \epsilon$ be sought to be a maximum, then by the principle if maxima and minima.

$$d A \tan \epsilon + A \sec^2 \epsilon \, d\epsilon = 0. \quad \text{And as } d A = -\frac{l^2}{2} d\epsilon \ (l \text{ being } By)$$

$$\therefore -\frac{l^2}{2} d\epsilon \tan \epsilon + A \sec^2 \epsilon \, d\epsilon = 0.$$

$$\text{Whence } A \sec^2 \epsilon = \frac{l^2}{2} \tan \epsilon, \text{ but } \sec^2 = \frac{1}{\cos^2}$$

$$\therefore \quad A = \frac{l^2}{2} \tan \epsilon \cos^2 \epsilon,$$

$$= \frac{l^2}{2} \sin \epsilon \cos \epsilon, \text{ but } l \sin \epsilon = p' \text{ and } l \cos \epsilon = By$$

$$\therefore \quad A = \frac{p' \times By}{2} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (1)$$

which is $A = BEy$ = area of wedge of maximum horizontal pressure. The expression for the maximum horizontal pressure of banks of loose earth is therefore

$$P = WA \tan \epsilon \quad \ldots \ldots \ldots \ldots \quad (2)$$

and as shewn above $A = \frac{p' By}{2}$ and also $\tan \epsilon = \frac{p'}{By}$

$$\therefore \quad P = \frac{W p'^2}{2} \quad \ldots \ldots \ldots \ldots \quad (3)$$

another general expression for the horizontal pressure of all cases of banks against all planes of support.

It only therefore remains to obtain values for the unknown terms A, $\tan \epsilon$ and p' in terms of the known data which are usually—

$\theta°$, the angle of repose; or, its tangent the co-efficient of friction.

h, the vertical height of the plane AB.

$i°$, the angle of slope of the surface AC of the bank.

$\beta°$, the angle of batter (from the vertical) of the plane AB.

For practical purposes it will be sufficient to consider six cases of banks of earth, and to obtain values for the general equations (2), (3), for each.

I shall also, although the expressions obtained can be shewn to be equal to one another, give separate equations for each case, deduced from both of these general equations.

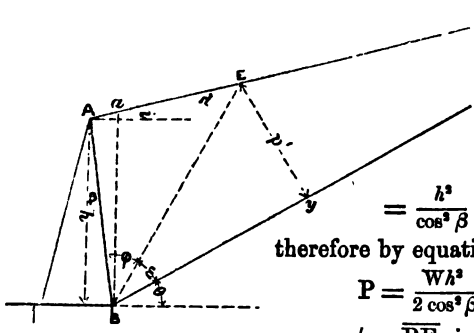
In the following formulæ—

$\phi°$, is supposed to be the angle between the plane AB and the plane BE, called the plane of maximum effect,

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λ°, is the supplement of $\phi +$ ∠ BAE.

Case I. Where the surface slopes up from the top of the wall at any inclination less than θ°, and the retaining plane AB over-hangs or reclines. *Fig.* 10.



$$A = \frac{\overline{AB}^2 \sin\phi . \sin(\phi+\lambda)}{2\sin\lambda}$$

$$= \frac{h^2}{\cos^2\beta} \cdot \frac{\sin\phi \sin(\phi+\lambda)}{2\sin\lambda} \quad \ldots \quad (4)$$

therefore by equation (2)

$$P = \frac{Wh^2}{2\cos^2\beta} \cdot \frac{\sin\phi \sin(\phi+\lambda)}{\sin\lambda} \tan\epsilon \quad (5)$$

or $p' = \overline{BE} \sin\epsilon$, and $BE = \frac{\overline{AB} \sin(\phi+\lambda)}{\sin\lambda}$

$$\therefore p' = AB \frac{\sin(\phi+\lambda)}{\sin\lambda} \sin\epsilon$$

$$\therefore p'^2 = \frac{h^2}{\cos^2\beta} \cdot \frac{\sin^2(\phi+\lambda)}{\sin^2\lambda} \sin^2\epsilon \quad \ldots \quad \ldots \quad (4a)$$

wherefore by equation (3) $P = \frac{Wh^2}{2\cos^2\beta} \cdot \frac{\sin^2(\phi+\lambda)}{\sin^2\lambda} \sin^2\epsilon \quad \ldots \quad \ldots \quad (5a)$

In this case $\phi^\circ = (\overline{90^\circ \pm \beta^\circ}) - (\theta + \epsilon)$;

$\lambda^\circ = [(\theta + \epsilon) - i]$ and ϵ is got from Neville's expression—

$$\left.\begin{aligned} &\text{Tan}\,\epsilon = \sqrt{\tan^2(\theta - i) + \tan[(90 \pm \beta) - \theta]\tan(\theta - i)} - \tan(\theta - i) \\ &\text{or (Doctor Hart's)} \\ &\text{Tan}\,\epsilon = \tan(\theta - i)\left\{\sqrt{\frac{\sin(\overline{90 \pm \beta} - i)}{\sin(\theta - i).\cos(90 \pm \beta - \theta)}}\right\} \quad \ldots \quad \ldots \end{aligned}\right\} \quad (5b)$$

This case may be looked upon as a general one, and the equations for all the other cases deduced from it by substituting particular values of ϕ, λ, β. In these angles where $\pm\beta^\circ$ is given, the positive sign is used when the plane AB over-hangs, and the negative when it reclines.

The sign of the angle i, given, is that of the most usual case of the bank surface sloping up: when the bank slopes down, the sign of i will reverse.

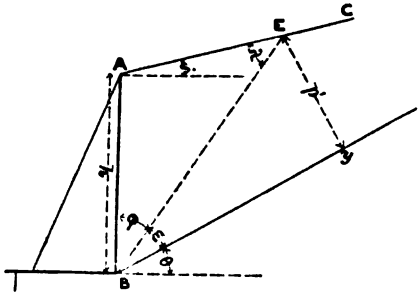
The equations (4), (4*a*), (5*b*), are also general.

I shall, however, continue to deduce the equations for each case from equations (2), (3).

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CASE II. Where the surface slopes up at any angle less than θ, and when the plane AB is vertical—

Fig. 11.



Here $A = \frac{h^2 \sin\phi \sin(\phi+\lambda)}{2 \quad \sin\lambda}$

and by equation (2)

$P = \frac{Wh^2}{2} \frac{\sin\phi \sin(\phi+\lambda)}{\sin\lambda} \tan\varepsilon$ (6)

also by equation (3)

$P = \frac{Wh^2}{2} \cdot \frac{\sin^2(\phi+\lambda),}{\sin^2\lambda} \sin^2\varepsilon$ (6*a*)

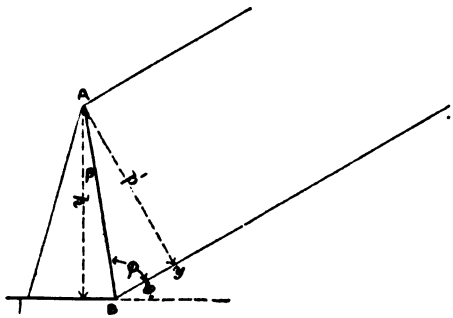
(both these equations follow from equations (5) and (5*a*) when $\frac{h}{\cos\beta} = h$)

In this case $\phi = 90 - (\theta + \varepsilon)$, $\lambda = \theta + \varepsilon - i$,

and $\tan\varepsilon, = \sqrt{\tan^2(\theta - i) + \tan(90-\theta)\tan(\theta - i)} - \tan(\theta - i)$ (6*b*)

CASE III. Where the surface slopes up at an inclination equal to the natural slope ($i = \theta$) and the retaining plane AB either overhangs or reclines.

Fig. 12.



By equation (2) $P = A \tan\varepsilon$; but (equation 1) $A = \frac{B y p'}{2}$ and $\tan\varepsilon = \frac{p'}{By}$ $\therefore$ as in equation (3), $P = \frac{w p'^2}{2}$

$p' = AB \sin\phi$

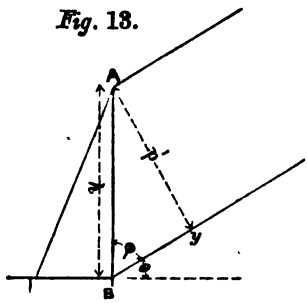
and $AB = \frac{h}{\cos\beta}$

$\therefore P = \frac{Wh^2 \sin^2\phi}{2\cos^2\beta}$ ... (7)

here $\phi = (90 \pm \beta) - \theta$.

CASE IV. Where the surface slopes up at an inclination equal to the natural slope ($i = \theta$) and the retaining plane AB is vertical.

Fig. 13.



This may be considered as a case of the above, where

$AB = \frac{h}{\cos\beta} = h$ in equation (7)

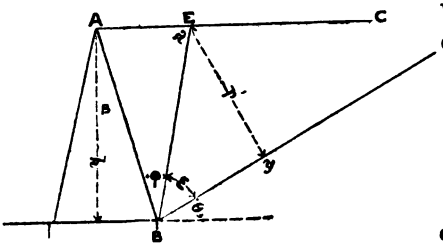
$\therefore P = \frac{Wh^2}{2} \sin^2\phi$

$= \frac{Wh^2}{2} \cos^2\theta$ ... ... (8)

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CASE V. When the surface is horizontal and the retaining plane AB either over-hangs or reclines.

Fig. 14.



This case may be considered an example of Case I., where $\lambda = \theta + \varepsilon$; then by equations (2) (4)

$$\therefore P = \frac{W h^2}{2 \cos^2 \beta} \frac{\sin \phi \sin [\phi + (\theta + \varepsilon)]}{\sin (\theta + \varepsilon)} \tan \varepsilon.$$

$$= \frac{W h^2}{2 \cos^2 \beta} \frac{\sin \phi \tan \varepsilon}{\sin (\theta + \varepsilon)} \quad \ldots (9)$$

or by equations (3) (4*a*)

$$P = \frac{W h^2}{2} \frac{\sin^2 \varepsilon}{\sin^2 (\theta + \varepsilon)} \quad \ldots (9a)$$

where $\phi = (90 \pm \beta) - (\theta + \varepsilon)$, $\lambda = \theta + \varepsilon$, and the value of

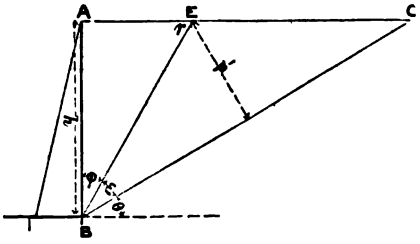
$$\tan \varepsilon = \sqrt{\tan^2 \theta + \tan (90 \pm \beta - \theta) \tan \theta} - \tan \theta \quad \ldots (9b)$$

another value for the pressure is—

$$P = \frac{W h^2}{2} [\cot (\theta + \varepsilon) \pm \tan \beta] \tan \varepsilon \quad \ldots (10)$$

CASE VI. Where the surface of bank is horizontal and the plane AB vertical.

Fig. 15.



This may be considered a special example of Case V, where $i = 0$.

$\frac{h}{\cos \beta} = h$, $\lambda = \theta + \varepsilon$; $\phi = \varepsilon$.

or in equation (2) $A = h^2 \tan \phi$

$$\left.\begin{array}{l} \therefore P = \frac{W h^2}{2} \tan^2 \varepsilon \\ \text{and in equation (3) } p' \\ = h \tan \varepsilon \\ \therefore P = \frac{W h^2}{2} \tan^2 \varepsilon \end{array}\right\} (11)$$

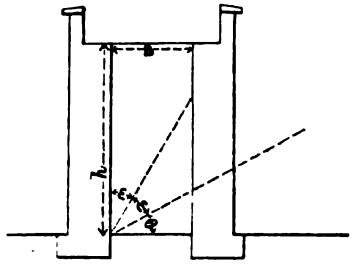
in this case $\varepsilon = \phi$, because the triangle BAE and BEy are equal and similar, and therefore, $\varepsilon = \left(\frac{90^\circ - \theta}{2}\right)$ ... ... (11*b*)

It sometimes happens that the wedge of maximum horizontal pressure, AEB, is cut off by a vertical plane between A and E, as in the case of bank retained between two walls—such as the retaining walls

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of bridge approaches—where the breadth of top of bank B between the walls is less than $h \tan \epsilon$,

Fig. 16.



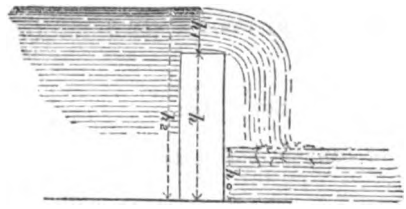
Here A becomes $h\,B - \left(\frac{B^2 \cot \epsilon}{2}\right)$

$$\therefore P = WB\left(h \tan \epsilon - \frac{B}{2}\right) \ldots (12)$$

The moment of these pressures $P\,\frac{h}{3}$ may be equated with the moments of stability of the walls against which they act, as already shewn.

When a wall is built across a stream as in the case of a weir or bundara, the pressure against it will be composed of the hydraulic pressure P, and the shock of the current P_1

Fig. 17.



First if we neglect the back water h_0. Let h be height of dam, h_1 height of flood over it. $P = 62{\cdot}5\ h\left(\frac{h}{2} + h_1\right)$, and since the depth of the centre of pressure from the surface $= \frac{2}{3}\frac{h_2^3 - h_1^3}{h_2^2 - h_1^2}$ where h_2 is the total height from base of wall to surface $= h + h_1$, and the moment

$$M_p = 62\tfrac{1}{2}\,h\left(\frac{h}{2} + h_1\right)\left(h_2 - \tfrac{2}{3}\frac{h_2^3 - h_1^3}{h_2^2 - h_1^2}\right) \ldots \ldots \ldots \ldots (13)$$

The shock also $P_1 = \frac{62{\cdot}5}{64}\,a\,V^2$, and its moment $M_{P_1} = \frac{{\cdot}976\ h^2\ V^2}{2}$ (14)

where a is the area of wall or weir, which for unit of length becomes equal to h;

V, the velocity of the stream in feet per second.

The sum of these moments tending to over-turn the wall

$$M_{(P + P_1)} = 62\tfrac{1}{2}\,h\left(\frac{h}{2} + h_1\right)\left(h_2 - \tfrac{2}{3}\frac{h_2^3 - h_1^3}{h_2^2 - h_1^2}\right) + \frac{{\cdot}976\,h^2\,V^2}{2} \quad \ldots (15)$$

When back water exists it must be taken into account as tending to the stability of the wall, and therefore to the reduction of the effect of $M_{(P + P_1)}$.

Let the height of the back water, outside the dam be h_0, then the moment of its pressure.

$$M_{P_2} = \frac{31{\cdot}25\ h_0^3}{3}$$

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and $M_{(P + P_1 - P_2)} =$

$$62\tfrac{1}{2}\, h\left(\frac{h}{2} + h_1\right)\left(h_2 - \left[\tfrac{2}{3}\,\frac{h_2^3 - h_1^3}{h_2^2 - h_1^2}\right]\right) + \cdot 488\, h^2\, V^2 - 10{\cdot}4\, h_0^3 \quad \ldots \quad (16)$$

whence by equation (15)

$$b = \sqrt{\frac{125}{W_1}\left(\frac{h}{2} + h_1\right)\left(h_2 - \tfrac{2}{3}\,\frac{h_2^3 - h_1^3}{h_2^2 - h_1^2}\right) + \frac{\cdot 976\, h\, V^2}{W_1}}$$

or equation (16)

$$b = \sqrt{\frac{125}{W_1}\left(\frac{h}{2} + h_1\right)\left(h_2 - \tfrac{2}{3}\,\frac{h_2^3 - h_1^3}{h_2^2 - h_1^2}\right) + \frac{\cdot 976\, h\, V^2}{W_1} - \frac{20{\cdot}8\, h_0^3}{W_1\, k}}$$

J. H., Dharwar.

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No. XLVII.

RANGOON CUSTOM-HOUSE AND BONDED WAREHOUSE.

Estimate of the Cost of Erecting a Custom-House and Bonded Warehouse at Rangoon, British Burmah. By Captain J. M. Williams, *Exec. Engineer.*

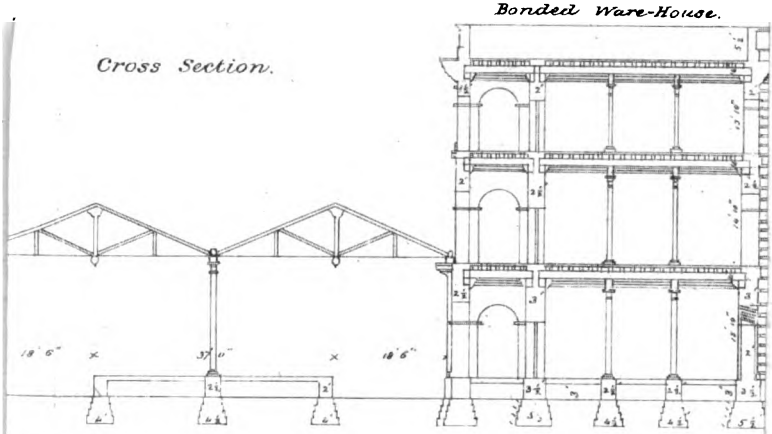
Custom-house.

c. ft.		Rs.
11,6495·5	Brick-work in mortar, at Rs. 30, per 100, . . .	34,949
s. ft.		
92,275·96	Mortar plaster, at Rs. 6, per 100, ...	5,537
92,275·96	White-washing, at Rs. 0-8, per 100, ...	461
c. ft.		
17,197·5	Brick rubbish and sand, at Rs. 4, per 100, . . .	688
5,189·25	Brick-on-edge at Rs. 25, per 100, ...	1,282
s. ft.		
6,980	Penang tile flooring, at Rs. 12, per 100, ...	838
c. ft.		
2,703·04	Teak timber in floor, at Rs. 170, per 100, ...	4,595
s. ft.		
7,365	Two layers Penang tiles, at Rs. 22, per 100, . . .	1,620
7,365	Three-inch terracing, at Rs. 5, per 100, ...	368
c. ft.		
2,027·19	Teak timber in roof, at Rs. 170, per 100, ...	3,446
s. ft.		
9,072	Three layers Penang tile, at Rs. 32, per 100, . . .	2,903
9,072	Six-inch terracing, at Rs. 8, per 100, ...	725
4,152	Doors and windows, at Rs. 1-4, per foot, ...	5,180
c. ft.		
810	Teak timber in chowket, at Rs. 180, per 100, . . .	1,458
No.		
2	Main stair cases, at Rs. 800 each, ...	1,600
2	Small do. at Rs. 500 each, ...	1,000
16	Columns, at Rs. 100 each, ...	1,600

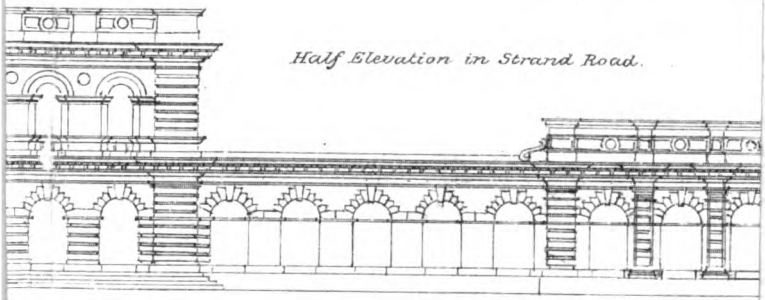
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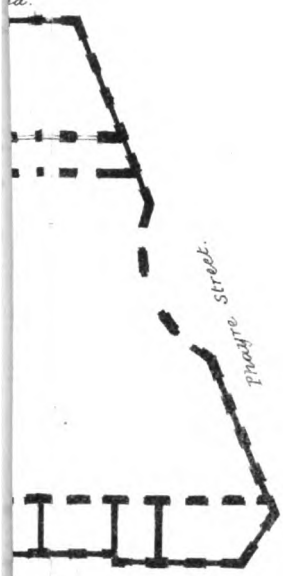
Bonded Ware-House.

Cross Section.



Half Elevation in Strand Road.





Scale, for Section an
30 feet = 1 inch

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s. ft.		Rs.
42,079·61	Painting, three coats, at Rs. 5-8, per 100, ...	2,314
	Total Rupees, ...	70,564
	Add contingencies at Rs. 5 per cent.,	3,528
	Total for Custom-house, . .	74,092

Bonded Warehouse.

c. ft.		
117,376	Brick-work in mortar, at Rs. 30, per 100, . . .	35,212
s. ft.		
87,196·13	Mortar plaster, at Rs. 6, per 100, ...	5,231
87,196·13	White-washing, at Rs. 0-8, per 100, ...	436
c. ft.		
25,009·5	Brick rubbish and sand, at Rs. 4, per 100, . . .	1,000
6,252·374	Brick-on-edge, at Rs. 25, per 100, ...	1,563
s. ft.		
8,650	Penang tile flooring, at Rs. 12, per 100, ...	1,036
c. ft.		
4,474·2	Teak timber in floor, at Rs. 170, per 100, ...	7,606
s. ft.		
8,973·5	Two layers of Penang tiles, at Rs. 22, per 100, . .	1,974
8,973·5	Three-inch terracing, at Rs. 5, per 100, ...	448
c. ft.		
4,472·2	Teak timber in roof, at Rs. 170, per 100, ...	7,606
s. ft.		
9,948	Three layers of Penang tiles, at Rs. 32, per 100, . .	3,183
9,948	Six-inch terracing, at Rs. 8, per 100, ...	797
4,196	Doors and windows, at Rs. 1-4 per foot, ...	5,245
c. ft.		
730·5	Teak timber chowket, at Rs. 180, per 100, . . .	1,314
No.		
1	Stair-case, ...	1,000
28	Nine-inch columns, iron, at Rs. 100 each, . . .	2,800
28	Six-inch do. at Rs. 75 each, ...	2,100
s. ft.		
51,435·6	Painting, three coats, at Rs. 5-8, per 100, ...	2,829
	Total Rupees, ...	81,380
	Add contingencies at Rs. 5 per cent.,	4,069
	Total for Bonded Warehouse, .	85,449

Examining Shed.

c. ft.		
85,605	Brick-work in mortar, at Rs. 30, per 100, ...	2,568
17,226	Brick rubbish in sand, at Rs. 4, per 100, ...	689
2,871	Brick-on-edge, at Rs. 25, per 100, ...	717
s. ft		
6,586	Penang tile flooring, at Rs. 12, per 100, ...	790
1,290	Mortar plaster, at Rs. 6, per 100, ...	77
1,290	White-washing, at Rs. 0-8, per 100, ...	6
15,840	Iron tiles roofing complete, including frames, at Rs. 50, per 100,	7,920

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Examining Shed (Continued.)

		Rs.
cwt. 720	Lead gutter, 6 lbs. to the foot = 38·57 cwt., at Rs. 25, .	964
No. 10	Iron columns, at Rs. 75, per 100, ...	750
c. ft. 21,114	Earthwork, at Rs. 1-8, per 100, ...	316
	Total Rupees, ...	14,797
	Add contingencies at Rs. 5 per cent,	740
	Total for Examining Shed, .	15,537

Surrounding Wall.

c. ft. 50,664	Brick-work in mortar, at Rs. 30, per 100, ...	15,199
s. ft. 43,108	Mortar plaster, at Rs. 6, per 100, ...	2,586
43,108	Color washing, at Rs. 0-8 per 100, ...	215
ft. 296·5	Panel doors, at Rs. 1-4 per foot, ...	370
593	Painting, three coats, at Rs. 5-8, per 100, ...	32
No. 2	Iron gates, at Rs. 500 each, ...	1,000
	Total Rupees, ...	19,402
	Add contingencies at Rs. 5 per cent.,	970
	Total for Surrounding Wall, .	20,372

Out Offices.

c. ft. 12,021·5	Brick-work in mortar, at Rs. 30, per 100, ...	3,606
s. ft. 8,476·5	Mortar plaster, at Rs. 6, per 100, ...	508
8,476·5	White-washing, at Rs. 0-8, per 100, ...	43
4,032	Penang pan-tile roof complete, at Rs. 38, per 100, . .	1,532
608	Panel doors, at Rs. 1-4 per foot, ...	760
c. ft. 10,203	Brick rubbish and sand, at Rs. 4. per 100, . . .	408
2,550·74	Brick-on-edge, at Rs. 25, per 100, ...	637
s. ft. 3,401	Penang tile flooring, at Rs. 12, per 100, ...	408
1,216	Painting, three coats, at Rs. 5-8, per 100, ...	67
	Total Rupees, ...	7,969
	Add contingencies at Rs. 5 per cent.,	398
	Total for Out Offices, ...	8,367
	Total for Custom-House, ...	74,092
	Total for Bonded Warehouse, . . .	85,449
	Total for Examining Shed, . . .	15,537
	Total for Surrounding Wall, . . .	20,372
	GRAND TOTAL RUPEES, .	2,03,817

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Calculations for Iron Columns for Custom-house.

Columns for Upper Story to Support Roof.

Weight of Roof.

Bearing beams	$1 \times 11' \times \frac{15 \times 10}{144} \times 46{\cdot}61 =$	534·07	
Cross do.,	$2 \times 10' \times \frac{10 \times 6}{144} \times 46{\cdot}61 =$	388·41	
Joists,	$18 \times 5\frac{1}{2} \times \frac{4 \times 4}{144} \times 46{\cdot}61 =$	512·71	1,435·19
Terracing and flat tiles	$11 \times 10 \times 65 =$		7,150·00
	Total dead weight on each column,		8,585·19 lbs.

Let W = breaking weight for long columns by Hodgkinson's formula $= 44{\cdot}34\frac{D^{3{\cdot}6} - d^{3{\cdot}6}}{L^{1{\cdot}7}}$, D being external diameter = 4 inches, d internal diameter = 3 inches; L the length = 15 feet. In this case $44{\cdot}34\frac{4^{3{\cdot}6} - 3^{3{\cdot}6}}{15^{1{\cdot}7}} = 42{\cdot}11$; also c = crushing force of iron (44 tons) × sectional area of columns = 0·7854 × $(4^2 - 3^2)$ × 44 = 241·9; then the actual breaking weight for short columns $= \frac{W\,c}{W + \frac{1}{4}c} = 45{\cdot}57$ tons, which taking the factor of safety as 4, gives the working load $= \frac{45{\cdot}57}{4}$ = 11·34 tons, or 25,401 lbs.; thus giving an excess of strength sufficient for all contingencies.

Columns or Lower Story to Support Flooring, with Weight of Columns and Roof above.

Floor.

Bearing beam	$11 \times \frac{17 \times 10}{144} \times 46{\cdot}61 =$	605·28	
Cross, do.,	$2 \times 10 \times \frac{18 \times 9}{144} \times 46{\cdot}61 =$	757·41	
Joists,	$18 \times 5\frac{1}{2} \times \frac{6 \times 4}{144} \times 46{\cdot}61 =$	769·06	2,131·75
Weight of tiles and mortar,	- - - - -		7,150·00
„ of goods	$11 \times 10 \times 400$, - - - -		44,000·00
„ of columns of upper story,	- - - -		600·00
„ of roof and each column,	- - - -		8,585·19
	Total dead weight on each column,		62,466·94 lbs.

Let W = breaking weight of long columns $= 44{\cdot}34\frac{D^{3{\cdot}6} - d^{3{\cdot}6}}{L^{1{\cdot}7}} = 284{\cdot}05$ tons, where D = external diameter = 7 inches, and d internal diameter of

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column = $5\frac{1}{2}$ inches, L = length in feet = 15; also c = crushing force of iron × sectional area of column = 44 × 0·7854 × $[7^2 - (5\frac{1}{2})^2]$ = 647·95; then crushing weight for short column = $\frac{W\,c}{W + \frac{4}{7}c}$ = 239 tons.

Taking the factor of safety as 4, this will give a safe working load of $\frac{239}{4}$ = 59·75 tons, or 133,840lbs.; which will be sufficiently strong for all contingencies.

CALCULATIONS FOR IRON COLUMNS FOR BONDED WAREHOUSE.

Columns for upper story support a roof of the same weight (8,585 lbs.) as that on Custom-house, and are of the same size, viz., 4 inches external and 3 inches internal diameter, 15 feet long, the breaking weight being 45·57 tons, with safe working load of $\frac{45{\cdot}57}{4}$ = 11·34 tons, or 25,401 lbs.

Columns for second story support a total dead weight the same as the columns of lower story of Custom-house, viz., 62,466·94 lbs.; and being of the same dimension, viz., 7 inches outside and $5\frac{1}{2}$ inches internal diameter, 15 feet long, sustain the same safe working load of 59·75 tons, or 1,33,840 lbs.

Columns for lower story support weight of first floor, weight of second story columns, and weight upon second story columns.

Weight of first floor, same as weight of second floor,	=	53,281·75
Weight of second story columns, - - -	=	950·00
Weight on „ - - - -	=	62,466·94
Total, - - -		1,16,698·69

Let W, breaking weight of long column = $44{\cdot}34\frac{D^{3{\cdot}6} - d^{3{\cdot}6}}{L^{1{\cdot}7}}$ = 720·27 tons, where D external diameter = 9 inches, and d = internal diameter = 7 inches, and L = length of column in feet = 15 feet; also c = crushing force of iron × sectional area of columns = 44 × 0·7854 × $(9^2 - 7^2)$ = 1,105·84; then actual crushing weight of short column = $\frac{W\,c}{W + \frac{4}{7}c}$ = 514 tons.

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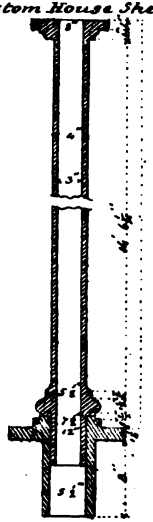
RANGOON CUSTOM HOUSE.

Detail of Iron Work.

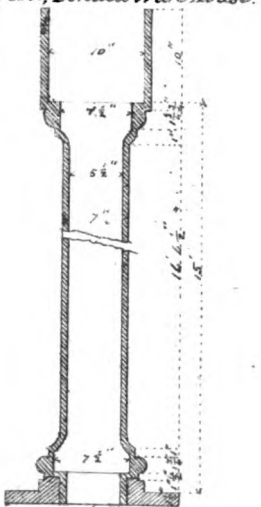
Custom House Shed.—
Elevation of half Double Truss.

Span,	37 feet.
Rise in centre,	7' 5"
Rise of Tie-rod,	11/16"
Dimension of Rafters,	3 x 3/8 x 3/8 x 1/2
Struts,	2 1/4 x 3/8 x 2 3/4 x 3/8
Diameter of King Bolt,	7/8
" Queen Bolt,	5/8
" Tie-rod,	1 1/16

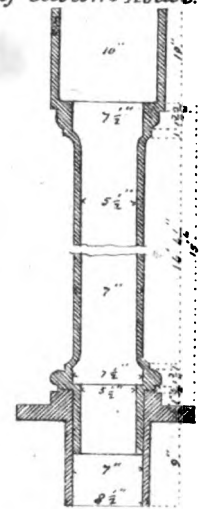
Column for Custom House Shed.



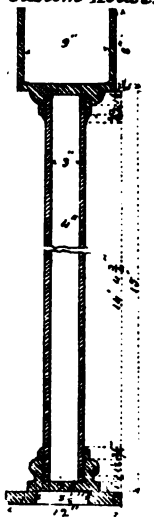
Column for 2nd floor, Bonded Ware House.

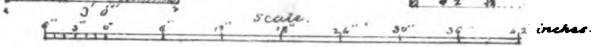


Column for Ground Floor of Custom House.



Column for Upper Floor of Custom House.





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Taking the factor of safety as 4, this gives a safe working load for the column of $\frac{514}{4} = 128{\cdot}5$ tons, or 2,87,840 lbs.; which leave an excess of strength of sufficient for all contingencies.

CALCULATIONS FOR GIRDERS AND COLUMNS FOR SHED OF CUSTOM-HOUSE.

The columns are to be 15 feet long, placed at intervals of 20 feet apart, each supporting four trusses with roof covering and one Girder of weight estimated below.

WEIGHT ON GIRDERS.

	feet.	lbs. per foot.	lbs.
Rafters,	40	8·25	330
Struts,	20	5·00	100
Purlins,	80	2·50	200
Tie-rod,	37	3·32	123
King-bolt,	6·5	2·00	13
Queen „	6·5	1·00	6·5
Ridge,	5	4·00	20
„ plate,	5	12·00	60
Tiles,	5 × 40	1·50	300
Gutter,	5	27·64	138·2

Total weight of truss and covering, = 1,290·7
Total weight on each girder 1,290·7 × 3 = 3,872·1

leaving the pressure of the wind out of consideration, as the roof is protected by the buildings.

Let W = breaking weight of Girder.
L = distance between points of support, = 20 feet.
D = whole depth, - - - - = 10 inches.
d = „ lower flange, - - = 8 „
B = breadth of „ - - = 8 „
b = thickness of web and rib, - - = 1 „

$$\text{then } W = \tfrac{8}{3}\,\frac{BD^3 - (B-b)d^3}{D\,L} = 14{\cdot}72 \text{ tons.}$$

This gives a safe working load of $\frac{14{\cdot}72}{4} = 3{\cdot}68$ tons, or 8,243 lbs., to meet a dead weight of 3,872 lbs. equally distributed at three points, thus giving an excess of strength sufficient to meet any occasional pressure from wind, &c.

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Weight on Columns.

Each column supports four trusses with roof covering, and weight of girder.

Weight of 4 trusses = 4 × 1,290·7 -	= 5,162·8
Weight of girder (estimated at), - -	1,768
	6,930·8 lbs.

Columns are 15 feet long, 4 inches external and 3 inches internal diameter, which gives by previous calculation a safe working load of 11·34 tons, or 25,401 lbs.; this being sufficiently strong to meet any occasional strain from wind, &c.

J. M. Williams.

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No. XLVIII.

SURVEYOR GENERAL'S REPORT, 1858-1861.

Abridged from the General Report on the Surveys of the Bengal Presidency, for the Seasons 1858-59, 1859-60, *and* 1860-61. By Lieut.-Col. H. L. Thuillier, R. A., *Surveyor General of India.*

General Remarks.—It is proposed, in the present Report, to treat of the whole of the Revenue Surveys now in course of execution, under the several Governments* of the Bengal Presidency, for the three seasons extending from the 1st October, 1858, the commencement of the professional season of 1858-59, to the 30th September 1861, the end of season 1860-61. I propose, also, to recapitulate and generalise the leading results attained, as detailed specifically under the head of each Survey, so as to afford a better idea of the real nature and extent of the working of the Department.

Number of Survey parties employed.—The Department has been very actively engaged and very extensive progress has been effected. The number of regular parties has been increased from 12 to 14; during the ensuing season there will be 15, besides three other small detached Establishments, making 18 in all.

Extent of work performed.—The aggregate labors of the 13 parties, employed during the period under review, are as follows, arranged according to their respective Governments:—

* Punjab, North-Western Provinces, Bengal, Lower Provinces, Oudh, Central Provinces, Sindh.

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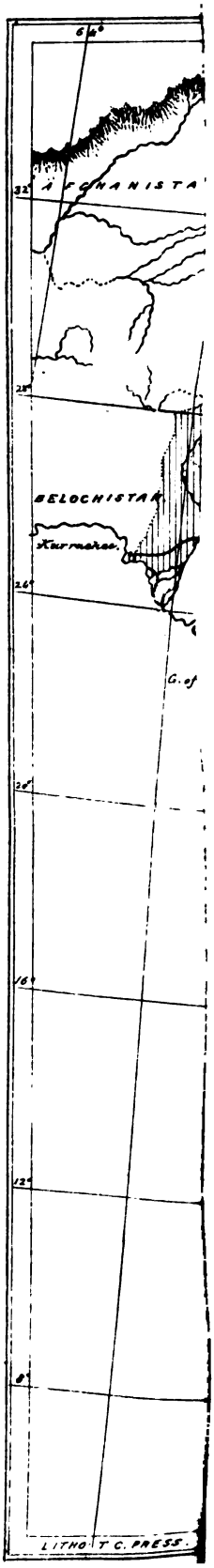
Number of parties.	Jurisdiction.	Area surveyed in square miles.	Total Cost.			Average rate per square mile.			Remarks.
			R.	A.	P.	R.	A.	P.	
1	N. W. Provinces, ...	42,90	85,615	0	0	19	14	0	Chiefly Revenue.
1	Punjab, ...	14,552	1,68,515	0	0	11	9	0	All Topographical.
1	Sind (Bombay), ...	12,975	1,60,075	0	0	12	5	0	Chiefly Topographical.
6	L. Prov. (Bengal)...	23,041	6,44,646	0	0	27	15	7	Chiefly Revenue.
2	Central Province, ...	7,862	2,48,436	0	0	31	9	7	All Revenue.
2	Oudh, ...	2,440	1,16,732	0	0	47	13	5	All Revenue.
13	Total for 3 Seasons,	65,160	14,24,019	0	0	21	14	0	

The above shews the very large area of sixty-five thousand one hundred and sixty square miles of country which has come under either the Revenue or mixed Revenue and Topographical operations by the Revenue Survey Establishments, and been completed during the three seasons. The area may be better understood, when I state that it equals about one-half of the entire British Islands, or of the Prussian Kingdom, and about a quarter of that of the whole of France. The proportion of the former description of Survey is 38,034 square miles to 27,27,126 square miles of the latter, and the mean annual average progress is 21,720 square miles. The mean average area performed by each of the 13 Establishments annually is 1,670 square miles.

Scales and description of Survey.—The area laid down on the Revenue detail system is on the scale of four inches to the mile, the limits of every village being separately defined and mapped on that scale, as well as generalised and reduced to one inch. The portion taken up topographically only, is surveyed on the one inch scale, and shows the general features of the country and all details, including territorial sub-division, up to the capability of the scale, but without the village boundaries, which are not defined or recorded, not being required at present.

Cost and Rates.—The total cost of the entire operations comes to Rs. 14,24,019, on which the general average rate per square mile is

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Rs. 21-14. The cost of the Revenue Detail Survey is Rs. 9,36,133, giving an average rate of Rs. 34-8 per square mile; and the expenses of the Topographical Operations are Rs. 4,87,886, yielding an average rate of Rs. 12-13 per square mile, the difference being nearly in the proportion of 3 to 1 in the cost of the former over the latter.

It will be observed that great diversity of rates prevails under the several jurisdictions. This is caused by various local circumstances, the peculiarity and difficulty of the country, and by the difference in the style of the operations over certain areas. The mixture of Topographical with Revenue work tends to bring down the general average.

The above results are submitted as in every way highly satisfactory and encouraging. For the very moderate cost of Rs. 21-14 per square mile, we have an excellent first Survey of an enormous area, well adapted and amply sufficient to meet all present requirements, the whole represented by maps of the most practical description and executed in approved style, on the one inch scale, besides the larger proportion of the area given on the larger scale, of four inches to the mile, in separate village sheets.

Districts completed and in progress.—The operations have been chiefly directed towards the final completion of the Punjab, the districts of Jhansee and Lullutpoor of the North-Western Provinces, with some of the Native States of Bundelcund; the Nagpoor and Jubbulpoor districts of the Central Province; the districts of Purtaubghur and Oonao of the Oudh Province; the districts of Larkhana, Jacobabad, and Mehur, and State of Khyrpoor of Sindh; with the districts of Dinagepoor, Dacca, Furreedpoor, Kooch Behar and Akyab of the Lower Provinces. The whole of the above have been finished, whilst considerable progress has been made in the several other districts still in hand.

The blanks are still unfortunately too numerous and extensive to be approximately estimated here as remaining for survey. There is still a very wide field whereon to employ the whole of the machinery at present engaged and allowed for the purpose, for very many years to come. The chief fields for employment lie in Oudh, in the enormous Central Provinces, in the Non-Regulation Lower Provinces, on the South-West Frontier, on the Eastern Frontier, including the whole

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of Assam (declared by the Government of Bengal to require a re-survey), and in Sindh.

Aggregate results for 15 *years.*—The above results, added to the area surveyed since 1846-47, the date of the revival of the Revenue Surveys, after the first Punjab War, give the following aggregate amount of work performed in the 15 seasons elapsed:—

Area surveyed in square miles.	Total cost.	Average rate per square mile.
	Rs.	R. A.
2,37,028	53,52,802	22 | 9

Topographical Surveys.—In addition to the Surveys executed by the Revenue Survey Establishments (which are connected with the Civil Department), the regular Topographical Surveys, form a very important part of the Survey of India.

The Topographical branch of the Survey Department, originally formed partially from the Staff of the Trigonometrical Branch, has been employed chiefly on the Native States, and in those extensive hilly and wild thickly-wooded parts of the British possessions which could not be treated in any other manner, and are but of small value; of which it is not necessary to have more than a good general or military map of the country, on a moderate scale, for political and administrative purposes. These Topographical Surveys are conducted entirely on a Trigonometrical basis, with minor Triangulation of the first class order, executed with a 14-inch Theodolite, the Topographical details being filled in on the one inch scale by the plane table, and the whole generalised and reduced to quarter-inch scale, by the Executive Surveyors.

Number of parties and where employed.—Four large parties* have been thus employed for some years past, under their respective Superintending Officers, and a very considerable area has been laid down by their united efforts. A fifth Party, drafted chiefly from No. 1, has likewise been organised for the ensuing season, to be employed

No. 1, Gwalior and Central India, Captain D. G. Robinson, Engineers.
No. 2, Nizam's Dominions, Circar, J. Mulheran, Esq.
No. 3, Ganjam, Orissa, and Central Provinces, Sumbulpoor, and Gurjat States, Major Saxton.
No. 4, Chota Nagpoor, Kolehan, and Chaibassa, S. W. Frontier Agency, Captain Depree.
1862-63, No. 5, Rewah, Lieutenant W. J. Murray,

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in the Rewah Rajah's Territory, through which the Allahabad and Jabbulpoor Railway passes, where it is of high importance for the Geological Survey to pursue its investigations for the discovery of coal, and this cannot be done without good Topographical Maps, which do not exist at present.

Extent of the Topographical Operations.—During the past two seasons, 1860-61 and 1861-62, an area of 16,408 square miles has been Topographically laid down, all on the one inch scale. In accordance with the practice observed, the minor triangulation is always in advance of the detail survey. The above area gives a mean average of 2,051 square miles as the annual out-turn of each party, but this scarcely represents the actual results, as the labor of the triangulation in advance forms an important part of the operations, and cannot well be reduced to a fixed area, whereon to proportion the expence. The nature of the country on which these parties are employed, is, for the most part, exceedingly unhealthy, and hostile to rapid progress.

Cost of the Topographical Operations.—Taking one year with another, and balancing the expenditure each season, on the actual amount of Topography furnished, whereby alone the Map of India can be filled up, the average cost of this description of work (above referred to) heretofore comes to Rs. 13 per square mile.

Remaining for the Topographical Surveys.—The Topographical Survey parties have been employed for several years and achieved much, but there is still a vast deal more to be accomplished, and which we cannot expect to do for a very long period. The ground already covered by these operations extends over the Nizam's Territories (including the assigned Districts), which may be said now to be approaching completion; the Hazara, Jhelum, and Rawul Pindi Districts of the Punjaub; the Goomsur, Ganjam, and Orissa Districts, and Gurjat States, brought up from the Southern Presidency; and a portion of the Chota Nagpoor Division; whilst the area remaining to occupy this branch of the Department consists of the whole of the Native States of Rajpootana, Gwalior, Central India, Bundelcund, and Rewah, on this side of India, besides the Native States of Bombay still remaining for Survey, an approximate estimate of the area of the whole of which amounts to the large figure of 319,388 square miles.

THE TRIGONOMETRICAL SURVEY.—The great foundation and basis of

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both the Topographical and the Revenue Operations is, of course, the Trigonometrical Survey, without the aid of which neither of the former can be made full use of, or proceed systematically. The progress of these interesting and valuable operations made great strides under the successful administration of my predecessor, Sir Andrew Waugh, during the long period he was at the head of the Department, for nearly the whole of which I had the privilege of acting as his Deputy, whilst superintening the Revenue Surveys. This long experience enables me to appreciate to the utmost, and to record my sense of the valuable and hearty support always rendered by that Officer's mode of conducting the Great Triangulation, to meet the necessities and requirements of the Revenue Survey, and to his forethought and great consideration for the important objects of the extension of the Geographical knowledge of India.

Present state of the Operations—The division of the duties, on the retirement of Sir Andrew Waugh, placed the superintendence of the Trigonometrical Survey under Major Walker, Bombay Engineers. That Officer, in a similar cordial spirit, as described above, has favored me with his views regarding the future extension of the Great Triangulation, and consulted my wishes as to the destination of such of his parties as may become available for fresh work. The chart of these operations exhibits the several Meridional and Longitudinal series of the Principal Triangulation already executed, covering a very considerable portion of this vast Empire, and fixing absolutely the true positions of most of the chief cities, towns, and places of importance. The Meridional operations, North of the Great Longitudinal Series between Calcutta and Kurrachee, are nearly completed, forming a gridiron between two great quadrilaterals divided by the Great Arc Series, extending from Cape Comorin to the Himalayas in longitude 78°, and checked by the six Base Lines already measured.*

Remaining to be done.—In this upper or northern section of the work there are two large blanks remaining to be filled up, one in Eastern Bengal and Assam, comprising the whole of the Lower Provinces east of the meridian of Calcutta; and the other in Rajpootana and Sindh, between the Gurhaghur Series on 73° and the Indus

* Calcutta, Sonakhoda (Darjeeling Plains), Sironj (Central India), Dehra Dhoon, Attock (Cheuh Valley), Kurrachee.

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Series. The former of these blanks requires a Series on the meridian of Dacca in 90° East Longitude; another Longitudinal one, on the Parallel of 23° North Latitude, being a continuation of the Calcutta or Great Longitudinal Series, until it meets the Eastern Frontier, passing through the Cossyah Hills, Sylhet, and Tipperah Meridional Series in 94° East Longitude now in progress, and finally the extension of the North-Eastern or Assam Longitudinal Series, from Gowhatty on the Brahmapootra River, to which point the work is already done, up the Valley of Assam, in a north-easterly direction, to the limits of the British Frontier on the borders of Thibet and Burmah. The whole of the above may be said to be of leading importance, as appertaining to the older British possessions in close proximity to the Metropolis of India, and now well covered by the Revenue Survey.

The second blank requires two small or single Series on the meridians of 69½° and 71½°, between the Great Longitudinal and the oblique Sutlej River Series, across the desert of Rajpootana and Sindh, inhospitable barren tracts, entailing heavy expense in the conduct of Trigonometrical operations, with little or nothing to fix or lay down, and of very secondary importance in a Geographical point of view. The above Triangulation will amply provide for the Topographical wants of all Northern India, down to the Parallel of 23° Latitude, and with the efforts now making by the several parties employed, may be expected to be completed in a very few years.

But there are still large tracts of country in Central and Southern India, in British Burmah, and on the East or Coromandel Coast of the Bay of Bengal, below the Parallel of 23°, which have to be provided for. The chief and largest blank is that contained between the Great Arc and the Coast Series, the triangulation of which has reached Rajamundry, and it is proposed to measure a base of verification at Vizagapatam,* the distance being nearly midway between Calcutta and Madras, during the ensuing season. This large ellipsoidal figure, comprising the whole of the late Rajah of Berar's Territory, Gondwana, the Jungle Mehals, Sirgoojah, Sumbulpoor, the Khond Country, Goomsur, &c., perhaps the most unhealthy and worst part of India, will involve the following triangulation, if the operations are to be carried out in

* Since measured, see *anti*, p. 180.—[Ed.]

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the manner proposed by the former Surveyor General, Sir George Everest, and sanctioned by the late Hon'ble Court of Directors.

Projected Principal Triangulation.—Three Meridional Series will be required; first, and of the most importance, is the meridian of 80°, passing through Jubbulpoor, Seonee, and Nagpoor, where the Revenue Surveys have already made great progress, and only await the triangulation now referred to, for the purpose of being incorporated in the Atlas. The next pressing object is the series on the meridian of 84° passing through Palamow, Sirgoojah, Oodeypoor, Sumbhulpoor, Sonepoor, and Goomsur, to meet the Coast Series a little below Ganjam; the greater part of this tract of country has been Topographically laid down, or is in course of Survey. An intermediate Series on the meridian of 82° passing through Ruttunpoor, Jeypoor, &c., may be taken up. These Series will be tied by a cross Longitudinal Series from the new Vizagapatam Base to the Beder Base in the Nizam's Territories, which will form a continuation of the Bombay Longitudinal Series.

The above will afford ample employment for many years to come. As far as can be at present foreseen, the Trigonometrical parties, as their services become available, will be put on to the work in the order I have given above, after which the remaining wants to complete the whole of India may be taken into consideration. They may be said briefly to comprise a short Series for Rangoon or British Burmah on 96½°, and the prolongation of the Eastern Frontier Series down the Coast of Arracan and the Tenasserim Provinces; also the continuation of the Coromandel Coast Series, from Madras to Cape Comorin and Ceylon. Base Lines will likewise have to be measured at Vizagapatam, Bangalore, Cape Comorin, Pegu, and Tenasserim.

Nearly the whole of the Southern Peninsula has been covered with a net-work of Triangles of different values, some of which are of an inferior order, performed nearly half a century ago, with inferior instruments, and by a less rigorous *modus operandi* than the system introduced by Colonel Everest in 1830; and eventually it may be necessary to revise some of that work, by pursuing a fresh Series on the meridian of Mangalore in 75° Longitude, through Sattara and Belgaum, with extension down the Malabar Coast, to connect at Cape Comorin; a Longitudinal section across the Peninsula in Latitude 13° is also proposed, and the measurement of another base, on the western side, may be

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ultimately found necessary. The southern section of the great Arc from Beder to Cape Comorin, and a section of the Calcutta Longitudinal Series from Sironj to Calcutta, affording, as they do, bases to so many other operations, their revision was always contemplated by the late Surveyor General, as a measure to be postponed only until the completion of such series as are indispensably requisite for the Topographical Surveys.

Special Topographical Operations of the Himalayas by the Trigonometrical Branch.—In connection with the Trigonometrical Operations, the special Topographical Survey of the Himalayas, including the whole of the protected States around Simlah, Sirmoor, Chumba, Kulu, Spiti, Lahoul, Bissalier, together with Kashmeer, Ladalk, Balti, &c., has been for some years in progress, and is still being carried on in the latter country, on the smaller scale of half a mile to the inch, by Captain Montgomerie, Engineers, the valuable and interesting Reports of whose proceedings have of late years been so much before the Government and the public, as described in the Journal of the Asiatic Society, and in my predecessor's Reports to Government. These operations, over ground of the most stupendous character, varying in altitude from 22,000 down to 5 or 6,000 feet, and within reach of snowy peaks up to 28,000, have taxed the utmost energies, skill, and resources of the picked Officers and Assistants of the Trigonometrical Department, and have obtained for them the admiration of the scientific European world.

Maps and Office Work.—From such an area as that above recorded as the result of the Revenue Surveys, it might be expected that the number of Maps and Plans produced would be very large. 199 Pergunnah or Main Circuit Maps, on the scale of one mile to the inch, have been rendered. These are all large and elaborate Maps, generally of Atlas size (some double), each containing very intricate details, involving much time and labor in their preparation. The whole of these have been supplied in duplicate, one copy being for the local Civil authority, thus making a total of 398 to represent the full labors of the Executives for the three seasons. The Village Plans, on the scale of 20 chains to the inch, amount to 31,161 in number, or with duplicates, 62,322. These latter Plans are now rendered on imperial sheets, in clusters of villages congregated together, and form a

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much better and more practical record, than by the old system of giving every village on a separate Register Form, especially when the size of the village is small. The village Plan Sheets are most valuable for all purposes of Local Engineering, in lining out Roads, Canals, Railways, and the like, giving a clearer idea of the nature of the ground, by showing a larger area at one view, and being accessible in the Local Collectorates, have afforded much satisfaction.

The area and statistical information for each village is recorded separately, on forms which are bound up with the numerical or traverse data, on which the Survey is based, and form complete Field Books; of these 58 volumes have been deposited. The observations and measurements, with computations deduced therefrom, of the Main Circuits or chief portion of the Professional work, are also recorded in 35 volumes, being bound up together on the completion of the District. In addition to the above, 39 Index Maps, scale four miles to the inch, have been received as guides to the Season's operations.

District Maps compiled.—Such an enormous amount of work coming in every season affords very considerable employment for the Head Quarter Superintending Office, in the compilation and reduction of the materials, their examination and adjustment prior to publication, as well as for the purpose of reporting on the same. It is the practice of this Office to endeavour to complete each District Map, on the reduced scale, as soon after the last Pergunnah or Main Circuit has been surveyed as possible. Each compilation is therefore carried forward, as far as the materials in hand will permit, and a preliminary Map of the District is thus prepared for the Press without any delay, and issued to the local authorities and public in this country, whilst the final Map is under preparation for despatch to England, to be incorporated in the Atlas. Two important objects are thus gained, viz., the early practical use and distribution of the survey materials in this country, where they are so urgently needed, and likewise, by the circulation of a first edition of the Map in the hands of those who know the District well, the correction of inaccurate orthography or such other items as may be susceptible of improvement, the insertion of new roads, or the addition of railways or other alterations, effected since the date of Survey, is secured.

Lithographic Branch.—In connection with the Drawing Office is

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the Lithographic Press, for the multiplication of the Maps, by transfer drawing on stone. This branch of the Department has only been in existence a few years, but it has made rapid strides with very inadequate means, and the present style of our printed impressions is equal to that produced in England. The Establishment is but small, and was fixed when the out-turn of the Surveys was one quarter what it now is. Although, therefore, it is unable to cope with the enormous progress made by the Executives as above shewn, yet it manages, under the excellent Superintendence of Mr. H. M. Smith, to turn out a vast deal of very highly creditable work, and to meet the most pressing of the wants of this large Presidency, as respects our regular Survey Maps, as well as to execute a large amount of miscellaneous desultory work sent to this Department from the various Secretariats, to illustrate the Official Reports published by the several Governments.

The following Abstract of the extent and estimated value of the Lithographic work executed, may serve to shew in a measure what has been effected by this branch of the Department during the three years, from 1st January 1859, to the 31st December 1861 :—

Description of work Lithographed.	Number of Impressions or Sheets struck off.	Cost of the Transfer Drawings.	Cost of the Printing.	Total actual Cost.	Value or selling price of Maps.	Difference to credit of the Department.
		Rs.	Rs.	Rs.	Rs.	Rs.
382 Maps and Plans,	214,397	37,077	37,077	72,958	1,13,565	40,607

The value of this appendage to the Office can scarcely be over-estimated. By the power of supervising the reproduction of the Maps of the Department, as they pass through the Press, great advantages are afforded, and the utmost accuracy ensured in the publication of the Maps. The general style and execution of the Maps now turned out has been well exemplified on the lithographed Atlas of the Degree Sheets of the Himalaya Topographical Survey, which I had the satisfaction of submitting for the inspection of the Government, and which elicited the commendations of the Government of India and of the Secretary of State. These intricate and elaborate Maps on the scale of four miles to the inch, delineating this most difficult mass of mountainous country, were executed in the style of Chromo-Lithography,

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each plate having four printings, and by a combination of Chalk Drawing for the Hills, direct on the stone, with transfer drawing for the outline, writing, and figures, a very successful result was produced, which has been much admired by scientific men generally. A copy of the same Atlas sent to the Great Exhibition of England, through the Calcutta Committee, obtained for the Department the honor of a prize medal, which I hope will be a further incentive to exertion towards effecting still greater improvements in the beautiful art of printing from the stone, and to which my anxious attention is constantly devoted.

Copper Plate Engraving.—As yet engraving on copper has not been practised in this Department, because the final Maps are under the old orders of the late Court of Directors, forwarded to the India Office, and are there incorporated into the Great Atlas of India, the sheets of which appear periodically, as before stated, and it forms the special business of the Geographer to the Secretary of State to bring out these engraved Maps; but it would in my opinion be very desirable to attempt engraving on copper here, because there are many Maps and Plans, as well as Charts, of the Trigonometrical Survey, which it is most important to retain, with a view of printing fresh editions whenever wanted. With our Lithographs, the most elaborate Map, which may have taken months to transfer to the stone, is obliged to be cleaned off, to make room for other important work, the stock and material of the Office being altogether inadequate to its growing wants. The Natives of India, moreover, are susceptible of being made excellent engravers, and this description of work, I believe, could soon be effected much cheaper than in England. I propose, therefore, with the approval of Government, to add a Copper Plate Engraving Press to the Office, and to commence to put some of our more important Maps on copper, the plates of which can be kept so conveniently, and impressions struck from them as required.

Reproduction of Maps by Photography.—The great success which has attended the reduction and reproduction of Maps by the Photographic process in England, at the Ordnance Survey Office at Southampton, under Sir Henry James, and the transmission, for the use of this Department, of two fine cameras specially selected for the purpose, with complete sets of Photographic apparatus, by the Secretary of State,

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induced me to apply for two Sappers trained in the Southampton Office, to be sent out, to assist in this work. Two Sappers, accordingly arrived from England on the 1st June last, and joined this Office, on a salary of Rs. 100 per mensem each, to cover all demands, including their Military pay and allowances as soldiers.

None of the Maps hitherto produced having been drawn with special reference to the requirements of Photography, and all being highly colored, the attention of the Sappers has been directed chiefly towards the reproduction on the same scale, of certain Maps of Districts long since surveyed, but still unpublished. Various experiments have been made and are still going on, but much remains to be done to turn the labors of the Photographers to a good practical account. The rainy season has been much against them, and the want of a proper glass house and various other necessaries, including competent superintendence for carrying on work of this description, militates against rapid success. The chromo-carbon prints transferred to zinc or stone have not been at all successful, and such manipulation, although well adapted to ancient manuscripts or old printed records, I believe is a very long way from adaptation to our wants for fine and large Maps. Photography, to be carried out successfully as a system for a large and wide-spread Department, must be prosecuted under officers who have ample time to devote to it. The Manuscript Maps, of course, must be prepared by Executives, strictly in conformity with Photographic requirements, and in this there will be no difficulty.

The Anastatic Process.—The development of the Anastatic Process for the retransfer of old Prints, Drawings, or Maps, to the stone or zinc, by immersion in solutions of strontia and nitric acid, has of late been successfully applied in England, and with the highly important advantage of preserving the original unhurt. The employment of the Anastatic Press in India is likely to afford great facilities for reproducing those Lithographed Maps which have been long out of print, and of those parts of India which cannot be as yet engraved for want of correct Surveys; much has yet to be done in India in the above way, but I hope we are in a fair way towards keeping pace with all such-like modern improvements.

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No. XLIX.

BLASTING ON THE LAHORE AND PESHAWUR ROAD.

An Account of the Blasting Operations undertaken for the removal of a portion of the Khoond Spur, on the new line of road from Lahore to Peshawur. By Lieut.* A. Taylor, R.E., *Exec. Engineer.*

Murree, July, 1852.

The old road from Attock to Peshawur, after crossing the Indus, runs for above three miles through a range of low but rocky and precipitous hills. This part of it is exceedingly narrow in many places, little over 10 feet, and some of the principal ascents are as steep as 1 in 8. It is known as the Gidar Galli pass.

The right bank of the Cabul river was selected for the new line. The only great obstruction on it was a cliff of limestone rock, near the village of Khoond, that jutted abruptly into the river. The height of this cliff above the cold weather level of the Cabul river is 145 feet. Its total length on the river face is 1,033 feet. Of this length only 285 feet presented any extraordinary difficulty; the slope of the remainder of the hill, taken at right angles to the river face, was comparatively gentle, being in some places nearly 1½ of base to 1 of height.

The following account refers merely to the plan adopted for removing the precipitous cliff of limestone rock, 285 feet in length.

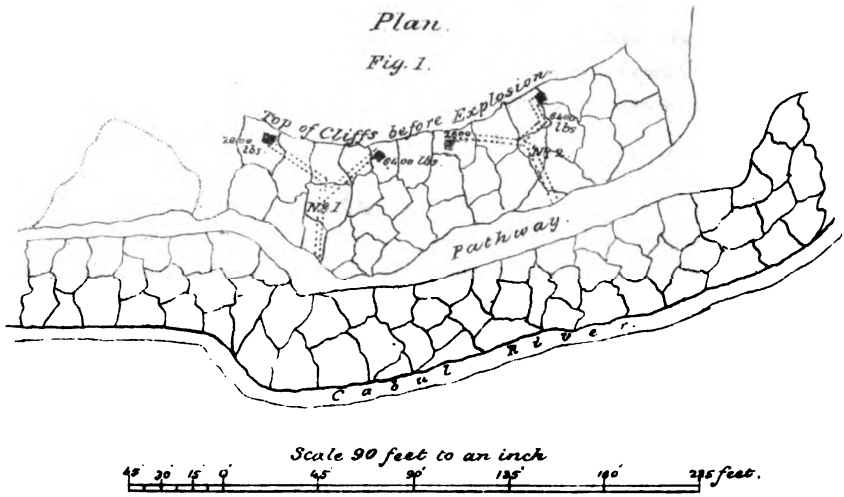
Two sets of sections are given in the accompanying sheet of drawing. The first set show the section of the hill when work was commenced, and the present section; the second set show the section of the hill before and after the explosion.

On the 3rd June, 1850, the level of the road having been approximately fixed, the first and second Companies of Sappers commenced work by

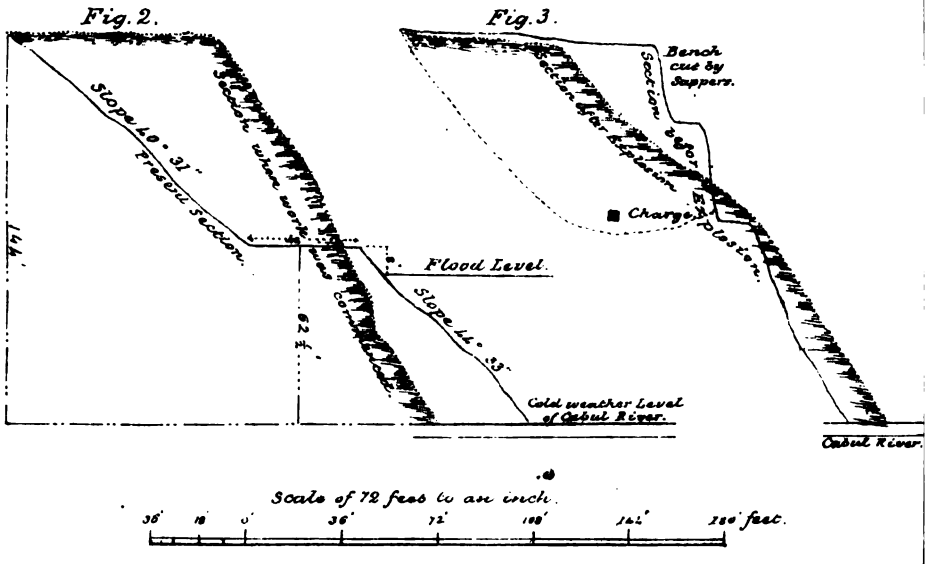
Now Lieut-Colonel and C. B.

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BLASTING ON THE LAHORE & PESHAWUR ROAD.



Sections.



LITHO: T. C. PRESS.

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opening a path round the hill on the intended level; sickness prevented me from visiting the work again till October, when I found that having finished the path by the end of August, the Officer Commanding the Sapper Companies, in the absence of a liberal supply of blasting powder, had applied his men at the top of the hill to cut it down by manual labor, assisted by small blasts of powder when the rock would not yield to ordinary tools.

Under this arrangement the execution of the work would have required an extravagant length of line, and the economy of the measure was doubtful; it was consequently determined to break up the cliff by four large charges of powder, placed as shown in the drawing. It was expected that these mines would throw a considerable portion of the upper edge of the cliff into the river, and that what remained would be so broken up as to be easily wheeled over the edge of the road without further use of powder.

By the beginning of November, 1850, the two horizontal galleries into the face of the cliff were fairly commenced. No. 2, measuring with returns, 100·5 feet in length, was completed on the 25th of January, 1851. No. 1, 97·0 feet in length, was completed on 15th March, 1851.

The loading of the mines was commenced on the 21st March, 1851, at one o'clock, P. M., the tamping was completed by eight o'clock, A. M., on the 22nd, and all four mines were exploded simultaneously during the course of the day.

The effect of the explosion was, to precipitate into the river the outer edge of the hill, (see shaded part, *Fig.* 3,) and to break up the whole of the rock included between the dotted lines in *Fig.* 3. Since the mines were fired, working parties have been employed in wheeling the *debris* into the river, and little powder has been used except on the base of the hill, at the level of the road, which was not much affected by the large quantity of powder exploded immediately above it.

Lieutenant Watson, of the Engineers, was the Senior Officer with the detachment of the Sappers employed on this work. Ill health, however, confined him to Attock through nearly the whole of the operations, and the real charge and direction of the works rested with Lieutenant Henderson, Engineers.

The following detail may be of use in future works of this nature.

To avoid any chance that might exist of injuring, by the explosion, that part of the rock on which the road was to be carried, it was consi-

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dered advisable to lodge the powder some few feet *above* the proposed level of the road; one gallery was accordingly commenced about 4 feet above the foot path, and carried in horizontally; the other was commenced at the level of the path and was carried in with a slight rise.

This care appears to have been unnecessary, as in removing the *debris*, the rock immediately below the charges was found comparatively strong and uninjured,

The *galleries* were tunnels into the solid rock; timber framing to support the roof was not found necessary.

The main galleries were 4½ feet high and 4 feet broad. The branches were smaller, 4 feet by 3½ feet. The tunnelling was effected entirely by blasting with a small jumper of 1½ inches diameter and from 3 to 4 feet in length, worked by two sepoys sitting. The easiest way of working is no doubt to make the first blast at the top of the gallery, and to remove all stone that may be loosened by it. The subsequent blasts should then be arranged as to blow through into this opening. In driving these galleries the sappers were told off into four reliefs, and the work proceeded without check, day and night.

In December, during which month the works were in full progress, each gallery was advanced 32·5 feet, being at the rate of a little more than 1 foot per working day of 24 hours. The total number of feet of gallery driven was 130; 358 lbs. of powder were expended in 176 blasts, varying in depth from 1 to 3 feet. The *cost* of driving a gallery may be estimated therefore per foot, as follows, including the cost of tools.

16 sappers in four reliefs of 4 men each, equivalent to about,

10 coolies, at @ Rs. 0-2-6, ...	Rs.	1	9	0
2·6 lbs. powder, ...	„	0	3	11
Repairs of tools, &c., ...	„	0	3	1
Total per foot of gallery, ...	„	2	0	0

Speaking generally, we found that a vertical shaft could be driven twice as fast as a horizontal gallery, the area of the section of excavation being the same in each. Two of the *chambers* were worked exactly to contain the charges. The other two were formed so as to leave a space round the powder, but we are unable of our own experience to say which is the better construction.

Loading, Tamping, and Firing.—The powder was stored in the maga-

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mine in camp in bags, made of a cotton stuff, holding each 10 lbs. These were counted as they entered the mine. The hose was 1 inch in diameter filled with coarse native powder. It was prepared in the magazine in lengths of 50 feet, an arrangement which facilitated the measuring out of the hoses to the different chambers. It was protected in the galleries by a thin wooden casing, about one-third of an inch in thickness. The powder having been carefully lodged in the chamber, the end of the hose was introduced into the centre of the pile, conducted down to the floor of the chamber, thence placed in its wooden case, and laid along one side of the gallery; a thin wall of bags filled with clay and *debris* of rock was built at the end of the gallery to isolate the powder, and the floor of the gallery was then covered with 6 to 9 inches of *debris* to protect the hose. Till this was done, work went on in the dark, afterwards lanterns were freely used. A common candle in a lantern in No. 1 gallery, not more than 40 feet from the mouth would not burn. It was very warm in the gallery, but the men working in it experienced no other inconvenience. As the want of light delayed the work considerably, a common thermantidote was applied to the mouth of the gallery. It had the desired effect, and while it continued to be worked the lantern burnt freely.

In No. 2 gallery, the candle burnt without the assistance of a thermantidote, which was probably owing to this gallery being somewhat more roomy than No. 1. The lodging of the powder was commenced at 1 P. M. on the 21st, and the tamping was completed at 7 A. M. on the 22nd, total 18 hours, being at the rate of 5½ feet per hour in each gallery. The working party was 86 sepoys, relieved three times in parties of 18, aided by 100 coolies, who worked from first to last.

The tamping having been completed, and the hoses all made of the same length, their ends were collected, attached to a piece of port fire, and covered to a depth of some inches with earth. The result was perfectly satisfactory. The hoses, about 135 feet each in length, burned so evenly, that all four mines exploded together, there being scarcely a perceptible interval between them.

Before firing the large mines, a number of smaller ones were exploded with Lines of Least Resistance of from 20 feet downward. The charges of some had been calculated at $\frac{(\text{L. L. R.})^3}{10}$, some at $\frac{(\text{L. L. R.})^3}{15}$; generally we found the charges calculated at $\frac{(\text{L. L. R.})^3}{10}$ unnecessarily violent in their

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effect, while $\frac{(L.\ L.\ R.)^3}{15}$ gave charges somewhat too weak. $\frac{(L.\ L.\ R.)^3}{10}$ was adopted for the large mines whose Lines of Least Resistance were, respectively, commencing at No. 1, 30 feet, 40 feet, 30 feet, 40 feet; and their charges 6,400 lbs., 2,800 lbs., 6,400 lbs., 2,800 lbs., total 98,400 lbs.

Powder.—The greatest part of the powder used was made by Lieut. Henderson, the materials having been procured in the neighbourhood of Attock, its average cost was 7 Rs. 8 annas per maund of 80 lbs.

The Khoond Spur is of hard closely packed limestone. The total number of cubic feet of rock removed in the cutting is about 2,000,000 of which 1,840,000 cubic feet were effectually reduced to *debris* by the large mines, being at the rate of 100 cubic feet of rock per pound of powder.

A. Taylor, Lieut., R.E.

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No. L.

ALLAHABAD SPECIFICATIONS.

(2ND ARTICLE.)

[The following extracts are taken from a very useful book of Specifications, Rates, Contracts, &c., prepared for use in the 2nd Circle, N. W. Provinces, by Capt. F. W. Peile, R.E., Superintending Engineer.]

PLASTERING.

In executing plastered and pointed work, the joints of the masonry to be raked out and cleaned.

In executing lime plaster, the joints to be stopped with mortar, and the plaster floated on in layers of such thickness as may be directed, well and slowly worked to a smooth and proper face, free from all blemishes and blisters.

Exterior lime plaster, that is, where exposed to the action of the weather, will consist of 45 parts of the best kunkur lime, 45 parts of fine soorkhee, and 10 parts stone lime. When laid on a floor or terrace roof, the plaster to be beaten till quite set and hard, and to be finished with a thin float of stone lime well rubbed in with the floating board.

Interior lime plaster, where not exposed to the weather, to consist of equal parts of kunkur lime and soorkhee.

Sand plaster to consist of equal parts of loam and sand, floated on and brought to an even surface.

All mouldings to be worked true to a template, and, if required, cow hair or chopped hemp to be added to the material to strengthen it.

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Where plaster is to be laid on in successive layers, the lower must not be allowed to dry, and the surface must be freely scored with the trowel before receiving the second coat.

In executing flat joint pointing, the joints to be stopped with mortar, consisting of equal parts of kunkur lime and soorkhee, finished off flush and clean with the face of the brick-work.

In executing tuck pointing the joints to be stopped as above, and a band of fine plaster or putty of stone-lime sieved and cleaned, to be raised over the joint with parallel edges.

Thatcher's Work.

Grassing.—The several descriptions of grass roofs are to be well and closely tied, laid in one, two, or three layers according to circumstances, and in such manner as the Executive Engineer may direct.

The quantity of grass, bamboos, and string to be used will in a measure depend on the description of each procurable in the market.

Grass bundles of the ordinary size of Gurrur grass, from 100 to 150 bundles per inch of thickness, per 100 superficial feet of roofing, will be required, and about 25 bamboos (ordinary Pillibheet) and 8½ seers string (*ôan*) to each layer of the coating.

The grassing of a roof will not be considered properly executed if it sink more than one-eighth of its thickness with the weight of a man standing on it.

Where the thickness of grassing is to exceed 8 inches when finished, it will be laid on in three layers, the first not exceeding one-third of the whole thickness may, if ordered by the Executive Engineer, be of *sarpat* or *khaseo*, or other reed or coarse grass, and it may be in the first instance laid loose on the roof and tied tightly down with battens not more than 9 inches asunder, the ties at not greater intervals than 9 inches. The second and third coats to be always of Gurrur grass made up into tatties on the ground; each of thickness sufficient to form one-third of the finished coating, the grass closely packed and tied with two battens below and two above, with ties at intervals not greater than 18 inches, each layer of tatties to be separately laid and tied on to the roof with ties at not greater intervals than 9 inches. The whole surface of the finished roof to lie evenly without rises or hollows.

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Where the thickness of grassing is to be less than 9 inches, it may be laid on in two layers, both will be of Gurrur grass laid as specified for the upper two layers above.

The eave bundles are to be of the full thickness of the grass coating evenly and tightly laid, cut off squarely and neatly, and perfectly straight.

Where the renewal of top coat has to be executed, the old top coat will be entirely removed. All hollows will be made up evenly with fresh grass laid under the battens of the lower coat, to which new ties wherever required will be given, and the top coat of new grass will then be laid on as above.

Bamboo Frames.—The bamboo work of a roof may consist of the ordinary frame, tied with *ban*, and laid over the rafters, or of a similar frame nailed to the rafters without ties, or of whole or split bamboos laid at intervals, or touching each other and nailed to the rafters.

Class I.—Will consist of medium-sized bamboos (averaging 20 feet long and 2½ inches diameter at the butt) laid longitudinally 9 inches from centre to centre, butts reversed alternately, with small bamboos (Pillibheet or Mirzapore) split in two, crossing them at intervals of 8 inches from centre to centre, and all nailed down to the roofing timbers and to each other.

Class II.—Will consist of medium bamboos split in two, and nailed down to the roofing timbers, at intervals of 5 inches from centre to centre.

Class III.—Of small bamboos whole, touching one another, and nailed down to the roofing timbers.

Class IV.—Of medium bamboos laid as in Class I, and with small bamboos split in two, one-half laid below and one above, crossing them either at right angles or diagonally at intervals of 8 inches from centre to centre, with a *ban* tie at every intersection.

Class V.—As above, but the small split bamboos laid on one side only.

Class VI.—Small bamboos laid longitudinally at 9 inches intervals, and diagonally crossed on one side with two layers of split bamboo battens, and the sides of the frame secured with split bamboos on all four edges. This sort of frame generally used to close a doorway or form a partition.

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Newly cut bamboos are not to be used, as they are liable to weevil (*goon*).

Wherever nails are used, the nail holes must invariably be drilled through the bamboos.

Bamboo Purlins, of large bamboos, averaging 27 to 30 feet long, and not less than 3½ to 4 inches diameter at the butt, may be spiked or tied down to the rafters of a building instead of sawn scantlings. Any portion of the bamboo that may be less than 2 inches diameter to be cut off and rejected. The spikes used to be not less than 2½ inches longer than the thickness of that part of the bamboo through which they have to be driven.

Where mats are laid over a bamboo frame-work, they will be laid with their edges overlapping and tied down by battens of split bamboo, so laid that in no place shall one superficial foot of matting be left without its batten.

Sirkee Ceilings.—Sirkee or reed mats will be put up as ceilings of verandahs, and in other positions; they are to be laid overlapping in such a manner that the reed only and none of the grass head may be exposed, and so tied up with thin bamboo battens and hemp string (*sootli*), that the upper mat may always entirely conceal the batten of the one below. The butts of the reeds are to be arranged in straight horizontal lines.

Fire-Ladders are of two kinds, bamboo and rope.

The bamboo ladders are intended to reach to the eaves of thatched buildings; they are from 10 to 12 feet long and 18 inches wide between the rails. The side rails, of large sound bamboos connected at top and bottom by a piece of half-inch rod iron passing through both, with a shoulder welded on to prevent the bamboos closing, and rivetted over a washer on the outside to prevent them spreading. An iron band is shrunk on to both ends of each rail. The rungs, of large bamboos split in two, lashed with tarred lashing line, at intervals of 15 inches to the side rails.

The rope ladders are fixed to the ridge, and lie on the slope of the roof to the eave. The side ropes are of closely laid 3 inches (circumference) hemp rope tarred, and the rungs are of pieces of small bamboo, 2 feet long, passed through the strands, and lashed with line to the side ropes at two feet intervals.

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The side ropes may in some cases for the sake of economy be made of *moonj*.

Tiler's Work.

Flat square tiles for floors and roofs to be 12 inches square, and 1 inch or 1½ inch thickness; made of well-tempered clay, thoroughly burnt, not vitrified, without flaws or twists, sound, of regular shape, with sharp square edges, and ringing well, to be laid with a close joint of not more than three-sixteenths of an inch in thickness, in mortar as for second class brick-work.

Where more than one course is laid, they are to break joint, and have not less than half an inch thickness of mortar between them.

Goodwyn tiles of the form shown, and laid in the manner exhibited, in (see *ante* plate XVII).

Ventilating, cylindrical and pantile roof.—Atkinson's pattern consists of two layers of tiles, the upper being Italian pantiles, laid in cement over cylindrical tiles.

(*a.*) The cylindrical tiles to be 12 inches long, 4 inches external diameter, and half inch thick, fitting one-half inch into each other, with a shoulder and socket joint; a lip, to rest on the timbering, to be raised on at half an inch from the shoulder; two holes, of half inch diameter each, to be pierced through the tile in line with the lip which is on the lower side of the tile. The tiles to be moulded of well-tempered clay, thoroughly burnt, sound, and of true shape, without taper.

(*b.*) These cylindrical tiles being laid close, with their axes up the slope of the roof, are to be covered with coarse mortar or fine concrete to a depth of one inch, and in this, while still wet, will be laid Italian pantiles.

(*c.*) The pantiles are to be 12 inches long and 12 inches wide over all, and not less than half an inch thick, moulded of well-tempered clay, and thoroughly burnt, free from twists, sound and firm, and all of uniform size and shape.

(*d.*) The mortar in which the tiles are laid is to be drawn up, so as to fill the curved roll which overlaps at the vertical joint.

(*e.*) The lower edge of each pantile to overlap 3 inches the tile below it. A lip to be raised on the under side of each tile to rest against the lower tile and prevent slipping.

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The Italian pantiles above described will sometimes be set in mortar, without the layer of cylindrical tiles. In this case the rate to include the mortar setting, which will vary in thickness according to circumstances.

Ordinary country half round and flat tiles *(nurriah* and *khaprah)* will be laid in mortar or dry, according to circumstances. The tiles to be not less than 10 inches long, made of well-tempered clay, thoroughly burnt, and sound.

Wells and Foundations.

Well-sinking.—In wells lined with brick-work steanings, the excavation will be carried down to the spring level, before the curb is laid and steaning built up.

It occasionally happens that the sinking of steaning cannot progress on account of the interposition of a bed of kunkur, or hard soil, below which a sufficient supply of water would be found. In this case, it may be necessary to underpin the curb. This is done by cutting away a portion (say one-sixth inch) of the diameter from beneath, and filling up the void carefully with masonry; then cutting and filling another section, and so on until the whole ring is complete.

But if the soil is very firm, or the curb rest on a bed of block kunkur, it would be better not to carry the steaning through, but merely to pierce the bed with a shaft of two feet less diameter than the diameter of the well.

A large supply of water may be frequently obtained by carrying the steaning to a moderate depth below spring level, and then boring a 6-inch augur hole down the centre to a depth of 20 or 25 feet further. If an iron cylinder be passed down and left in this shaft, with its top projecting three or four feet above the bottom of well to prevent its being choked, success will be certain.

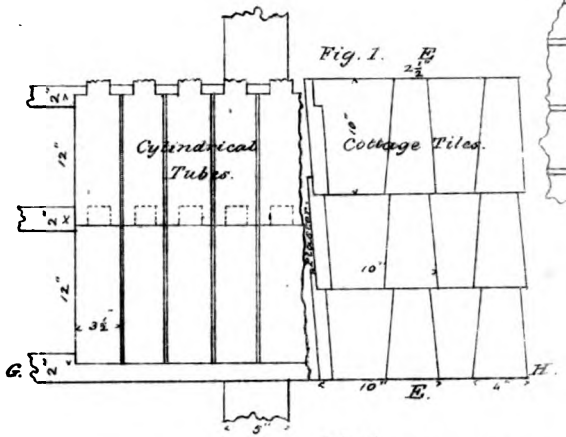
(*a.*) *Specification.*—For a well of 6 feet interior diameter and 2 feet thickness of steaning.

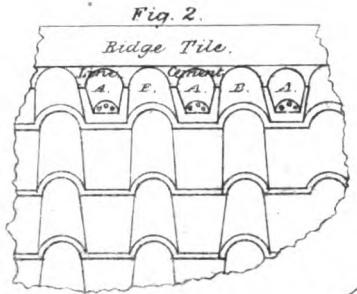
(*b.*) The excavation to be carried down to spring levels, 50 feet below the surface of the ground, 12 feet in diameter.

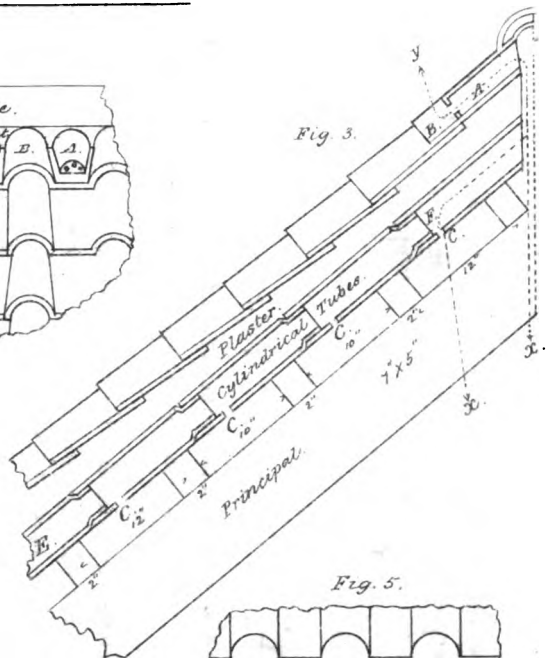
(*c.*) A stratum of sand 8 feet thick lies 10 feet below the surface,

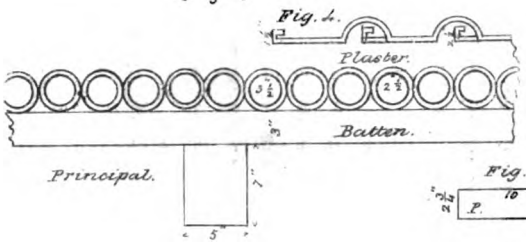
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ATKINSON'S TILED ROOFING.











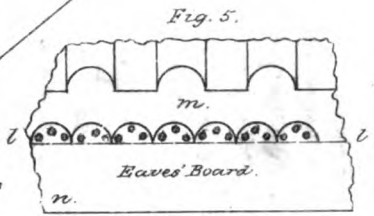


PLATE LXII.

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in order to prevent the sides falling in, the excavation will be carried through to the bottom of the sand stratum with a diameter of 20 feet.

(*d.*) If in the progress of work it be found that the sand is likely to give way, a dry brick-work steaning 1½ bricks thick will be built up to support it to the full depth of the stratum, with a clear interior diameter of 17 feet. This steaning will rest on the step left at the level where the diameter decreases to 12 feet. It will be taken up again when the well steaning has been sunk to its proper depth.

(*e.*) When the excavation has been carried to the required depth (50 feet) the sole will be brought to a true level and the curb will be laid in.

(*f.*) The curb will consist of two thicknesses of *Jamoon* wood dovetailed, secured with iron straps and bolts, and put together with wooden dowels and trenails as shown in the drawing. To be closely and neatly framed and finished in a workman-like manner. The upper thickness of 2 concentric rings, each of 6 parts and 12 inches wide, the lower of one ring 2 feet wide in six equal parts; all laid so as to break joint with one another. If timber cannot be found of width sufficient to make the lower of one ring, this will be divided as shown in the Section at A, into two rings of 15 inches, and 9 inches, respectively.

(*g.*) To the curb and bolted through its depth with nuts below will be fixed six stanchions of 1-inch bolt iron, 10 feet long, which will stand at equal distances around and in the centre of the ring of the curb. The masonry of the steaning will be built up round these, and they will be connected together at the height of 9½ feet by a ring of flat bar iron 2½ × ½, lying flat on the brick-work, through which holes will be punched to receive the ends of the bolts, and on which washers and nuts will then be securely screwed down.

(*h.*) The brick-work will be executed with the best fully burnt bricks, the headers moulded to taper 9½ inches long, 4 and 5 inches at the ends, and 2½ thick, the stretchers without taper 9½ × 4½ × 2½.

(*i.*) The bond will be as follows:—

In the first course a row of stretchers will be laid round the inside of the ring, and on the outside two concentric rings of headers, in the the second course the row of stretchers will be laid on the outside and the two concentric rings of headers to the inside. The courses will alternate in this way throughout the work.

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(*j.*) No vertical joint on the interior of the steaning to be wider than one-eighth inch, no course joint to be wider than 3/4 inch.

(*k.*) The cement below water line to be of hydraulic lime. All cement to be ground and mixed under edge stones.

When the steaning has been built to a height of 30 feet, it will be left for 30 days to dry, and the sinking will then commence.

(*l.*) When the steaning has been sunk, 10 feet of brick-work will be added to the top. It will then be sunk 10 feet further, making a total depth of 70 feet, at which it is expected that the supply of water will be sufficient. The steaning will however be carried down until four bullock motes, working continuously for 24 hours, fail to exhaust the water.

(*m.*) When sunk to this depth the soil will be carefully removed from under the curb until it has an even bearing all round. The brick-work will then be brought up to within 2 feet of the surface from which height it will be corbelled out, course by course, 2 1/2 inches in each course, to the outside for 10 courses, until the total breadth of the ring amounts to 4 feet. Four courses will then be added of this breadth, and the well will be finished off with pillars and cistern as shown in the drawing.

(*n.*) The cistern will not be built over the excavation, but will be founded on the undisturbed soil, and be connected with the well platform by a stone channel.

(*o.*) The space around the steaning will be filled in with dry rubbish below and earth above carefully rammed.

(*p.*) The brick-work below the water line on the inside will be flat joint pointed; thence to within 4 feet of the top, it will be carefully tuck pointed, the remainder with the platform, pillars, cistern, &c., will be carefully finished with the best lime plaster.

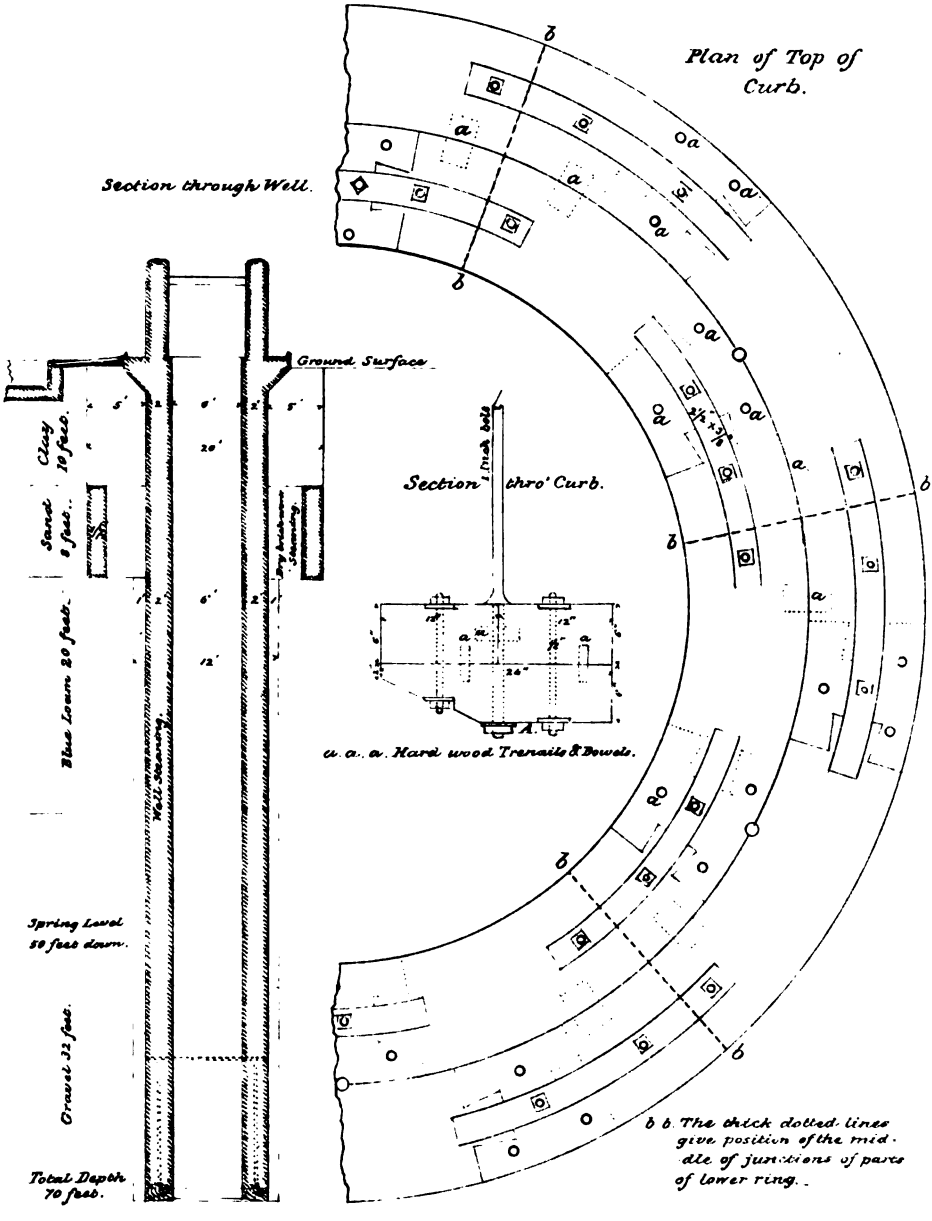
The above Specification will apply to sinking Wells for Foundations with the following additions:—

(*a.*) A plate of 3/8 inch sheet iron to be put on round the outside of the curb projecting two inches above the top, to hold the brick-work and two inches below to form a cutting edge.

(*b.*) The whole of the masonry to be flat joint, pointed on the inside, and carefully plastered on the outside, to reduce the friction in sinking.

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WELL AND CURB.



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Specification for Cofferdam for laying in the foundations of the Seotee Bridge of the Great Deccan Road (given as a guide.)

(*a.*) This bridge, which is to be of 5 openings of 40 feet span, is to be constructed across the Seotee River at Drummondgunge. The site of the bridge is fixed within very close limits by the completed road and the position of the Pass at Kutra over the lower Kymore range, which is about half a mile distant.

(*b.*) Half a mile above the site of the bridge the bed of the river consists entirely of sand-stone rock, which is considerably broken up and thrown about in masses. At site the bed, to a depth of four feet, is of sand and *budgeree*, lying on a stratum of blue loam, of density and tenacity gradually increasing with the depth. At 10 feet the soil is firm and tenacious and can be trusted. The dry weather stream is about 12 inches deep.

(*c.*) The reason for selecting cofferdam, instead of well or block foundations in this case, is the high probability of meeting with large boulder stones or slates of the sand-stone rock from up-stream, bedded at a depth below the surface, which would interfere greatly with the sinkage of the blocks, and probably altogether frustrate any attempt at obtaining a secure foundation by those means.

The nature of the substratum, moreover, while it affords facilities for the construction of a cofferdam, would cause much labor to the well-sinker.

(*d.*) The cofferdam will consist of a single line of sheet-piling driven and secured as hereafter shown for the foundation of one of the piers.

(*e.*) The timber for the piles to be of sâl wood, to be carefully selected, straight-grained, free from knots and ring shakes.

(*f.*) The gauge piles alone will be rung with an iron hoop 3 × ½ inches; these will also be shod with cast-iron shoes of the form shown in the diagram, with a square butment for the pile to rest on.

(*g.*) The sheeting piles will not be shod, but the end will be cut with an inclined edge to give the pile a drift towards the next pile. The sheeting piles will all be carefully fitted to each other before driving to ensure close contact.

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(*h.*) The wedge piles will be tapered 2 inches in a regular taper for the lower 6 feet, the sides of the upper 9 feet being left parallel.

(*i.*) The space to be inclosed is in the clear 43 × 10 feet within the sheeting. Each long side will be divided into 6 equal bays, 6 feet 5 inches long each, and each end into 2 bays of 4 feet 5 inches each, by gauge piles 9 inches square, driven 17 feet below the water line, and standing 5 feet 6 inches above it.

(*j.*) The sheet piles will all be 9 inches by 4 inches, and driven 17 feet below the water line, with their heads 1½ feet above the water line.

(*k.*) When the gauge piles are driven to their proper depth, two rows of temporary double walings, 6 inches by 4 inches, will be bolted on; the upper one to be 4 feet above the water line, and the other as low as it can be fixed, but not within four feet of the upper. The wales will be fixed to the gauge piles by ¾-inch iron bolts and nuts.

(*l.*) The sheet piles to fill up the bays are to be driven truly, and each bay keyed in with a wedge pile to make the dam water-tght.

(*m.*) When the piles are all driven, behind each gauge pile and at eight feet distance from it, on the outside, a pile 6 × 6 inches will be driven 10 feet, its head standing 1½ feet above the water line. Through mortices in the head of this and of its corresponding gauge pile, a piece of 2½ × ⅝ inches flat bar iron will be passed, through slots in which wedge keys will be driven, against iron plates laid against the piles.

(*n.*) A shore of timber 6 × 6 inches will be laid across between the heads of the pairs of gauge piles AA, on each side of the centre of the dam.

(*o.*) The excavation will then be commenced, and having cleared 5 feet, the upper row of wales will be taken off and fixed at that depth against the inside of the dam, spurred and strutted across to add to its stiffness.

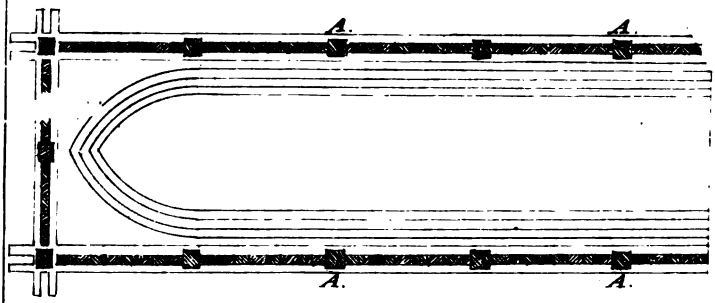
(*p.*) As the excavation proceeds the water will be baled out, and the seams between the piles will be well caulked and payed with oakum and tar.

(*q.*) Simultaneously with the interior excavation, and carried on with it to equal depths, the soil will be removed from the outside to as great a depth within a limit of 10 feet below water line as possible.

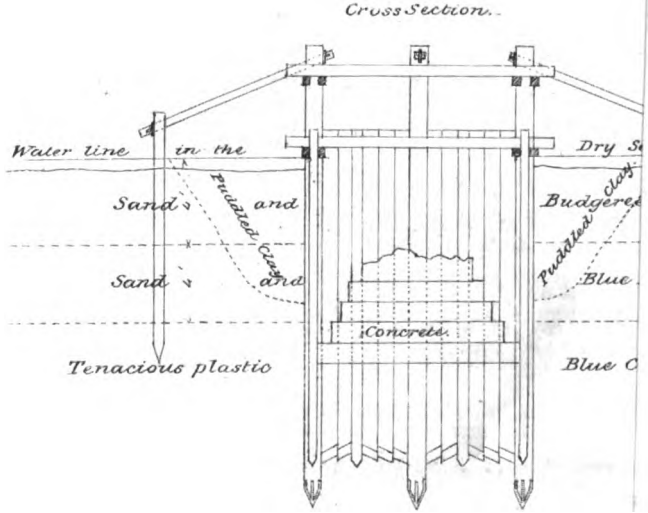
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COFFERDAM.

Ground Plan.



Cross Section.



Scale, 10 feet = 1 inch.

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This will be filled with puddled clay. It is expected that if the exterior can be thus cleared to a depth of 7 feet below water, there will be no difficulty in laying the interior of the dam nearly dry.

(*r.*) When the interior excavation has reached 9 feet below the water line, and been brought to a level, a bed of concrete 2 inches thick will be carefully laid in, the dam having been previously permitted to fill with water. The concrete will be carefully lowered in baskets, and be brought to a level on its surface. This will be allowed to lie undisturbed until thoroughly set, which should occur in 20 days when the water will be thrown out, and the construction of the foundation proceed in stone laid in cement.

(*s.*) As the masonry rises, good strong clay will be rammed round the work, so as completely to fill the space between the dam and the pier.

(*t.*) As there would be danger of disturbing the bed by drawing the piles, they will be cut off on completion of the work at 6 inches below the water line.

Concrete Works.—As a rule, the lime by itself will be slaked and saturated with water till brought to the consistency of a thick paste. The other materials will be thoroughly mixed and saturated with water by themselves, and the lime will then be added and the whole thoroughly mixed when the concrete will be laid in—not thrown into, the trench.

No more material to be mixed than can be laid on the same day.

The surface of the concrete unless under water, to be generally rammed with flat rammers and watered till cracks cease to appear.

The bed to be laid in one depth or in successive beds as may be directed by the Executive Engineer, but one bed always to be finished off throughout the surface before the second is commenced.

If laid under water, the concrete may have to be lowered in baskets, sacks or boxes.

A good concrete may be made of the following proportions :—

	Parts.
Broken stone, kunkur or vitrified brick, 1 and 2 inch gauge,	65
Soorkhee (pounded brick) or clean sharp sand, ...	21
Good pure lime, ...	14

The lime must be of the very best quality in this case. 100 cubic feet of these materials will yield only 80 cubic feet of concrete.

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Sand should be preferred to soorkhee if there be saltpetre in the soil. If the concrete be laid under water, the lime must be hydraulic.

Concrete under flags in flooring will generally have to be made with fine ballast material, and a large proportion of lime.

Khoa work in roofs will generally consist of 50 parts brick broken to one inch guage, 30 of coarse soorkhee screenings, and 20 of kunkur lime, laid on and beaten till perfectly hard and set, and kept watered until the coat of plaster is put on. Staunching to arches and walls must be similarly applied. Lime screenings are not be used as ballast in khoa work.

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Correspondence.

THE Editor acknowledges with thanks the receipt of the following papers

Bombay General Hospital—Vaulted Roofs in Sindh—On the Expansion of Masonry by Heat—On Revetment Walls—Rangoon Custom House—Umritsur Clock Tower—Steamers for the Punjab Rivers—Allahabad Jail—Irrigation and Drainage of the Terai—Formulæ for Dimensions of Arched Bridges—Mean Meer Church—Markunda Bridge—Sehore Church.

A correspondent writes from Central India:—

"I notice in the Professional Papers for May, that in your Paper on Anglo-Indian Architecture, you write that good glazed tiles are made in the Punjab and elsewhere. This is utterly unknown here, and is much wanted. I should be much obliged if you would let me know where I could get information as to the preparation of the glaze and description or sketch of kiln required."

Glazed tiles are made, and can be procured at Delhi, Lahore, Peshawur, and Moultan; the best I have seen are at the last place; the ordinary colors are white, blue, and a brownish red. At Delhi they ask for tiles of any size, 1 inch thick and from 6 to 12 inches square, 750 rupees per 1000 square feet. The tile makers are very jealous of their trade secrets, and I am sorry I can give no details of the manufacture. The glaze used is principally made of borax *(sohagah)*.

Another correspondent says:—

"I observe that in the Bengal Presidency it is considered necessary by Engineers Civil and Military, to sink wells for foundations to very considerable depths, generally this is done with a view to pass through the sandy bed and to reach the underlying clay or rock.

"In the discussion which followed the reading at the Institution of Mechanical Engineers, of a Paper on Railway Bridge Pier Foundations, published in the "Civil Engineer and Architect's Journal," for December, 1863, I observe that Mr. Strong asserts that the sand was far deeper than his foundation wells.* He bored through

* See *ante*, p. 384.

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, sand, his wells were 43 feet deep, which is the depth, as he 80 feet of nothing re generally sunk.

says, to which I for discussion the question whether these great depths are neces-

"I beg to s

sary. oundations are I believe rarely or never sunk in Madras to any consi-

"Well I have looked over the plans given in the four vols. of "Madras Engi- derable sional Papers," and can only find one instance in which the wells were sunk neer As 10 feet; generally 6 or 8 feet are considered sufficient.

so e principal object in my opinion is to take care that the wells are well bound ier across the stream and into the banks; so as to prevent any displacement of sand by currents passing between them.

"In the case of bridges, if there are not retaining walls on wells and aprons, there is no resistance to the additional velocity caused by the obstruction of the bridge; a scour is produced along the piers, &c., and the sand is displaced to very great depths, 40 feet, if I remember right, in the Jumna."

Δ

Δ's remarks are perfectly correct. The following is an extract from a letter by Col. Yule, the late Secretary to Government, on the same subject:—

"Well foundations may be used in two ways, viz., either by employing the wells as piles and sinking them till we reach a firm stratum; or, where such a stratum lies very deep, by establishing a practically impermeable barrier under the bridge, in the shape of flooring and curtain walls, to secure the foundations from scour. The last method has often been used on this side of India (without, it is believed, a serious example of failure), but it has never been so fully taken advantage of as in the Madras Presidency. There, well foundations of bridges in sandy beds of unknown depth, are not sunk more than 9 or 10 feet, often less; the wells themselves being also of very rough and crude structure. Yet they stand safely; and it is mainly owing to the cheapness of this construction that so many noble bridges have been built in Madras Presidency, over rivers such as we habitually leave unbridged, on account of the estimated cost. Indeed, the experience of Madras shows that well foundations of 6 feet in depth, on sandy river beds having a slope of 8½ feet per mile, are secure."

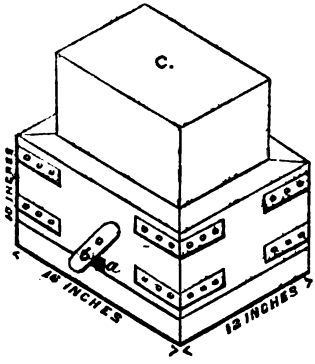
In accordance with this opinion, the foundations of the Markunda Bridge, now being constructed on the Grand Trunk Road near Umballa, (and which will be described in the next Number), are being sunk to a much less depth than is usual in Upper India, having a flooring between the piers protected by curtain walls in front and rear. The same principle is also generally applied to Canal Bridges in these Provinces. But it is to be re-

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membered—1st, That the fall in the beds of these r
than in those of Southern India, while the soil is generally greater
2nd, That it is a general practice in Madras rivers to l if not worse;
considerable distance down stream, by throwing in large the bed for a
rough stone, and that holes formed by scouring are thus s of loose
is believed for some time continuously after the construction often it
but that this superabundance of material is rarely available in idge,
3rd, That the cost of the flooring and curtain walls would oft s;
very short of the additional cost required to sink the well found extra 15 or 20 feet.—[Ed].

The following letters refer to the Mode of Striking Centres by the use of Sand, described in Nos. II and III:—

Method of Lowering Centerings, as practiced on the Great Deccan Road Bridges.—



"The centerings are struck by means of boxes containing fine dry sand. These boxes are 16″ × 12″ × 10″ outside measurement, of 2 inch planking open at top, corners dovetailed and bound with hoop iron fixed with screw nails. In each end of the box a hole, *a*, one inch square is cut near the bottom slanting upward from outside; over the hole, a stop, *b*, is fixed, turning on a pivot by means of which the hole, *a*, can be opened or closed as desired.

"A solid block of wood, *c*, 12″ × 8″ × 8″ the exact size of inside of box, is placed on the top, supported by the sand inside the box, and sunk ½ or ¾ of an inch into the box. The boxes complete are then supported either by masonry pillars or wooden strutlings, and the tops of the wooden blocks levelled by adjusting the quantity of sand in the box. The support should be the same width as the box so as to allow the sand to run out freely when the stop is opened.

"A beam 6′ × 3′, the full width of the arch is placed transversely, that is parallel to face of abutment, resting on the block of wood *c*, and on this beam the centering rests.

"All joints of the box should then be well caulked to prevent water getting in when the arch masonry is in progress, and wetting the sand.

"When the center is to be struck the stops *b*, have only to be moved uniformly to one side, which allows the sand to run out and the block *c*, together with the whole of centering being unsupported by the sand, are lowered very gradually and to such extent as may be wished, being regulated to a nicety by the stop *c*.

"I think this method preferable to that adopted by Captain Meade at the Morhur Bridge, in so far as the boxes are put in when the centering is erected, instead of

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iv ...f wood, which has to be struck out when the sand bags are first putting in a ...ation of striking out the blocks of wood, unless very carefully inserted. ...itself lower the centering a little, and the danger of the bags splitting is managed "I think ...ed."

J. MACDONALD, C. E.

To the Editor.

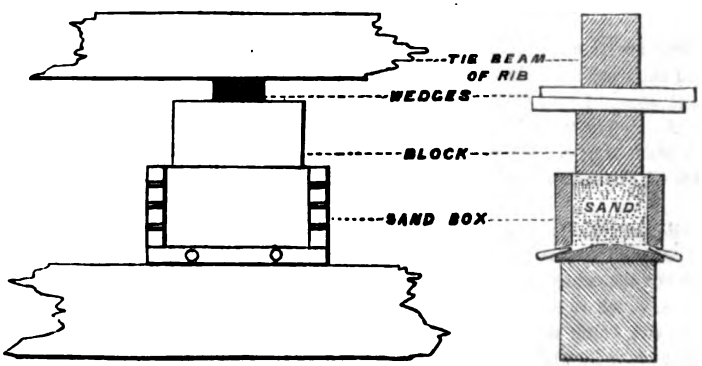
...riking Centres with sand.—The above subject having been mentioned in two of ...r Numbers, I am perhaps, rather late in offering a description of the method ...dopted on the Mirzapore district of the East Indian Railway, and which was found successful on repeated trials.

"I should not now trouble you with these remarks, but that I believe my experience may be useful to some of your readers, and may save them from trying more complicated or expensive plans, which are not adapted to the nature of sand.

"Many of the bridges on the Mirzapore district are built with ashlar arches of 60 feet span and of great weight, necessitating a very strong centering; this consisted generally of seven ribs of sàl timber, carrying for laggins a layer of the sleepers, afterwards used in the permanent way. The ribs were kept vertical by being tied together with cross braces, and were supported with four pairs of wedges under each rib in the usual way.

"The centering of our first arch was struck in the old way; a man with a sledge hammer was placed over each pair of wedges and at a given word they all struck together. From that moment the noise of the hammers rendered any further order inaudible, and the wedges came out one after the other, in no particular order, according to their tightness or the strength of the hitting. The result was most unfortunate; the heavy ribs came down singly, and in so doing broke from the cross ties, and ultimately fell over on their side and severely injured some of the hammer men.

"It was this accident which caused the adoption of sand boxes, which were made in the following way:—



The box is made of 2″ sàl plank, 18″ × 9″ × 9″ inside dimensions; the sides are dove-

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tailed into the ends and the joints all secured with 5″ screws; the box is left open. Over this box and resting on the sand is a rectangular block measuring 16″ × 8″ × 8″, so as to give half an inch play at each side and one inch ends. At each side of the bottom of the box are a couple of 1″ holes sloping upwards inwards, and closed for the time with wooden plugs loosely driven in and luted with a little moist clay.

When the arch is ready for striking, four of these boxes, (28 in all,) are placed under each rib as near as possible to the supporting wedges, the box is filled with dry sand, the block laid carefully on the sand so as to be clear of the inner edges of the box, and a pair of greased wedges with only 1″ taper are driven with a hand hammers between the block and the tie beam of the rib. The old wedges are then easily knocked out and the arch rests on the sand and is freed by drawing out the plugs.

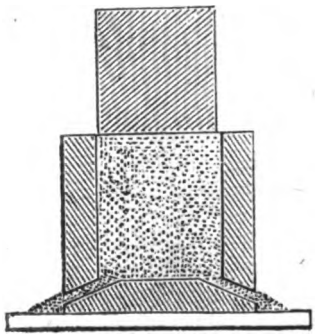
"The same set of boxes was used for I believe sixteen arches without receiving any material damage.

"This construction of sand boxes may perhaps appear too simple to be worth describing, and the only feature to which I wish to draw attention is that the surface of the sand is left uncovered for half an inch all round the edges and shows no tendency to overflow, notwithstanding the enormous weight laid on it, it being the property of sand not to transmit lateral pressures beyond a certain angle.

"The central surface of sand on which the block is laid forms such an unyielding bed that in transferring the weight of the arch and centering from the old wedges to the sand boxes, the greatest subsidence observed at the crown was never more than one-eighth of an inch.

"The play thus allowed to the block is essential to its steady descent, because as the sand is let out by the sides, its upper surface does not remain horizontal, and the block being no longer on a level bed would, if made to fit tight, most inevitably get jammed and stop or burst the box; any close fitting plug or piston will I think be found to fail on this account.

"I would suggest the following modification of the above construction as applicable to very large spans, or to any case where the arch requires to be let down slowly or the process of lowering to be stopped at any point.



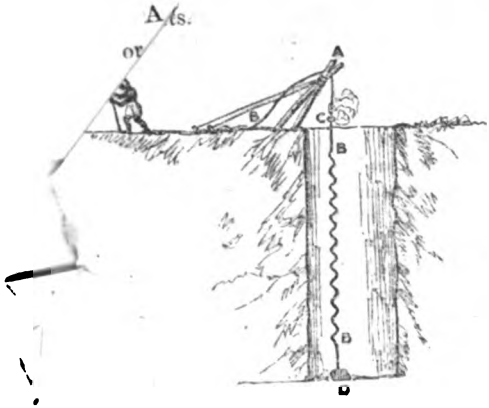
"Dispense with the plugs and let the box stand on a plank a foot wider than itself so as to form a shelf 6″ wide under the plug holes; thus the sand from the holes will stand on this plank in small cones at about 30° to the horizon, and will stop the holes as effectually as a plug. By sweeping these cones away with the hand, the sand will escape and the centering may be lowered with any degree of slowness; by letting the cones stand the process may be stopped. By the same means one part of the arch may be lowered quicker than another, which is sometimes advantageous when cracks occur in unexpected places.

C. J. SPENCER,
District Engineer, E. I. Railway.

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vi

spondent sends the following dodge for firing a charge in Wells



A A couple of bamboos tied.
B No. 8 telegraph wire twisted round a crowbar till the ring runs slowly but surely.
C A ring of the same wire ¾ inch diameter.
D Block of wood through which wire is fastened.

Round the ring twist cotton that has been soaked in a mild solution of gunpowder, set in on fire and let it run down the wire.

H. B.

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Correspondence.

THE Editor acknowledges, with thanks, the receipt of the following Papers:—Jubbulpore Railway Specifications—Roorkee Iron Roofs—Madras C. E. College—Design for a Barrack—Koorum Frontier Outpost—Oil Mills for the E. I. Railway—Sutlej Canal Report—Indus Tunnel Project—Attock Suspension Bridge—Ventilation of Barracks and Jails—Indus Silt Experiments—Purtapore Stone Quarries.

Dalhousie, 15th Sept. 1864.

TO THE EDITOR.—If you and your readers have not had too much already of "Striking Centres with Sand," I should like to add a few remarks. The centres of nearly all the arches of Bridges on the Baree Doab Canal, exceeding 20 feet in span, having been struck in that manner, some practical experience in the process has been gained.

It is strange that none of your Correspondents appear to have observed in the Civil Engineer and Architect's Journal for 1857, Vol. XX., p. 146, the extract from the abstract of Captain Fowke's Report to the President of the Board of Trade on the Paris Universal Exhibition of 1855. Captain Fowke gives M. Bouziat, the inventor's own account of the process, and to save trouble I annex a copy of the extract.

It was on seeing this extract that I adopted the process on the Baree Doab Canal.

You will observe that from not having seen M. Bouziat's description of his invention, several of your correspondents have had the trouble of experimenting on their own account, and have not yet arrived at the simple elegance of the original. For instance, as pointed out by Mr. Spencer in your No. IV., the omission of a shelf or platform on which the semi-cone of sand may form outside the hole, destroys the self-acting portion of the process, the most beautiful part of the whole invention, the gradual step by step descent of the centres held in perfect control the while, and regulated by the Engineer at his will. This arrangement is of the utmost utility, with flattish arches especially, say 50 feet span with a rise of 7·7 feet, in brick, the description of several of the arches on the Baree Doab Canal, as by lowering the haunches in advance of the crown all loading of haunches is rendered unnecessary, and the operation can be performed without the slightest crack showing.

Again, many of your correspondents appear to think it necessary to have a "box" for the sand, or a "bottom" to their cylinders. But this is not needful. An open cylinder of sheet iron is all that is required. Two or three sets of such cylinders (20

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in each set) sufficed for the whole of the bridges of Baree Doab Canal, whose arches were struck by this process in 1858-61, some 40 or 50 in number.

The only practical difficulty I know of in the matter, is the keeping the sand dry in the cylinders, especially if the arches are turned in wet weather, and if some time elapses before the centres are struck. An apron of tarpaulin securely attached all round the piston and which can be detached before striking, keeps water from getting in above, and the sand is kept dry below by its being raised above the level of the platform on the circular piece of wood described by Captain Fowke.

But if some of the sand does get a little moist, it can be raked and pushed out by the iron rod described by M. Bouziat, as the holes stand opposite one another. For this reason the sloping holes represented by Mr. Spencer are, I think, to be avoided, as also the vertical central hole advocated by Colonel Scott.

J. H. DYAS, CAPTAIN, R. E.

Extract from Abstract of Report to the President of the Board of Trade, on the Paris Universal Exhibition. By Captain Fowke, R.E. On Civil Construction—Bridges.[*]

"One of the most interesting points in connection with the construction of this bridge (Pont de l'Alma) is the method employed for striking the centres by means of cylinders filled with sand. The employment of this method does not produce the slightest change in the construction of the centering itself, as the cylinder is simply substituted for the wedges on which the centres are supported. The apparatus consists of a cylinder of wrought-iron, twelve inches in diameter and twelve inches high which is placed in a vertical position on a wooden platform, on which it is prevented from slipping by a circular piece of wood, three-fourths of an inch thick, nailed to the platform and fitting the interior diameter of the cylinder. Near the base of the cylinder at four equidistant points of its circumference, are bored holes one inch diameter, which are stopped by corks introduced from the interior of the cylinder, which is then filled to within two inches of the top with sand previously dried and passed through a fine sieve; and into the space thus left is fitted a solid piston or plunger of wood, coinciding exactly with the interior diameter of the cylinder, about ten inches high; the whole apparatus which is thus about twenty inches in height, is then introduced under the centres in lieu of wedges; and M. Bouziat, by whom this method has been invented and applied, gives the following account of the process of striking the centres:—

"'In striking centres, at a given signal the corks closing the orifices in the cylinders are withdrawn by an iron rod about a foot long and 0·31 of an inch in diameter, pointed at one of its extremities and flattened and turned up at the other. The sand then issues slowly until it has formed a little cone opposite each hole, and stops. When everything is ready the Engineer gives the order to lower from 2½ to 2 inches; then, by means of the iron rods, the men remove the cones of sand, and help its escape with the curved end in the event of its having got wet during the progress of the work, until the piston shall have descended the distance required, which will be noted by a scale attached to each piston. The workmen then allows the little cone of sand to accumulate and waits for a fresh signal, and in this way the centre descends gradually, and detaches itself uniformly from the arch without shaking it. It will be seen that being completely master of the operation, leisure is given to make all necessary observations, so as to be assured that all goes on well, or to take measures should the contrary be the case. At the Pont d' Austerlitz, commenced the 20th May, 1854, and opened for traffic on the 8th November, the centres were struck in two hours, and it might have been performed in still less time by placing a man to each of the cylinders, so as to lower all the centres simultaneously. Each arch of the bridge was supported by 36 principals, and the enormous weight of both the masonry of the arch, and the metal of the roadway, bore on the centres, they not having been removed until after the opening of the bridge to the public.'"

[*] Civil Engineer and Architect's Journal for 1867, p. 146, Vol. XX.

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GLOSSARY OF INDIAN TERMS USED IN VOL. I.

Anicut.—A weir of masonry built across the bed of a river to raise the surface level of the water for irrigation purposes. It is a Madras term.

Beegah.—A local land measure, varying much in different districts, but usually about three-fifths of an acre.

Bheestie.—A Water-carrier.

Bhoosa.—Chopped straw.

Bhuttee.—A native kiln.

Budgeree.—Calcareous gravel used for mixing with lime.

Bullah.—A young tree is so called when felled and used in the rough for roofing, piling, &c.

Bund.—An embankment.

Chokut.—The outer frame of a door or window.

Chunam.—Lime cement.

Coolie.—A laborer.

Deodar.—(*Cedrus Deodara*) a valuable wood found in the Northern Himalayahs, and used generally in the Punjab; nearly the same as the Cedar of Lebanon.

Dhenkey.—A lever worked by a man's weight, and used to draw water, pound bricks, &c.

Doab.—A tract of country between two rivers.

Ghât.—1. A mountain pass. 2. A river landing place.

Ghooting.—A kind of lime.

Grammie.—A thatcher; he also makes common scaffolding and framework.

Gunny.—A kind of coarse sacking.

Indian coinage.—12 pies or 4 pice = one anna (1½*d.*)
16 annas = one rupee (2*s.*)

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Jamah.—Vitrified brick, used for flooring, metalling, &c.

Jhum.—The peculiar tool used in well sinking (see p. 386.)

Khureef (fusl.)—The autumn crop, sugar, &c.

Kucha masonry, consists of sun-dried brick set in mud.

Kucha Pucka masonry.—Is of burnt brick set in mud.

Kunkur.—A peculiar kind of stone found in the plains of Upper India, and used for metalling roads. It is a concretionary form of olitic limestone.

Lurrie.—A small beam about 3 inches square.

Maund.—80 lbs., (28 go to a ton.)

Monsoon.—The rainy season.

Musjid.—A mosque.

Nuddee.—A water-course, full in the rains but dry during the greater part of the year.

Pergunnah.—A sub-division of a Zillah or District.

Phowrah.—A tool like a large hoe, which is the general substitute for the spade throughout India.

Pucka.—1, Cooked; burnt. 2. Full, complete; always opposed to *Kucha.*

Pucka masonry.—Is of burnt brick set in lime mortar.

Pucka Terrace Flooring or Roofing.—Is made of beaten lime over a foundation of brick.

Punkha.—A large fan hung from the ceiling and swung by manual labor to cool the air.

Rajbuha.—A minor water-course for Irrigation.

Rubbee (fusl).—The spring crop; wheat, &c.

Saul.—(*Shorea robusta*) a valuable wood found in the Himalayah forests, and used generally in the N. W. Provinces for building purposes.

Seer.—2 lbs., (40 go to a maund.)

Soorkhee.—Pounded brick, used for mixing with lime to make mortar.

Toon.—(*Cedrela Tooni*) a wood resembling mahogany, and used for similar purposes.

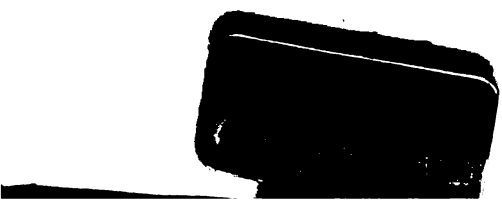
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