

The chief imports are :—cotton and woollen goods, machinery, metals, wine, spirits and malt liquors, military and naval stores, railway materials, ivory, spices, silk, sugar, tea, coffee, tobacco, horses, drugs and dyes, fruits, precious stones, books and stationery, grain, seed, oil, timber, ice, apparel and treasure. These are derived from the United Kingdom, Africa, China, Penang, Singapore, the Straits of Malacca, the Persian Gulf, Suez, Calcutta, Malabar, North America, the Arabian Gulf, Batavia and Java, Ceylon, France, the Mauritius, Aden, Cutch and Guzerat.

The chief exports are :—cotton, hides and skins, oils, saltpetre, seeds, Cashmere shawls, wool, opium, coffee, dyes, sugar, tea, grain, provisions, precious stones, beads, metals, spices, salt and fruits; and they are generally consigned to the same places whence the imports are derived.

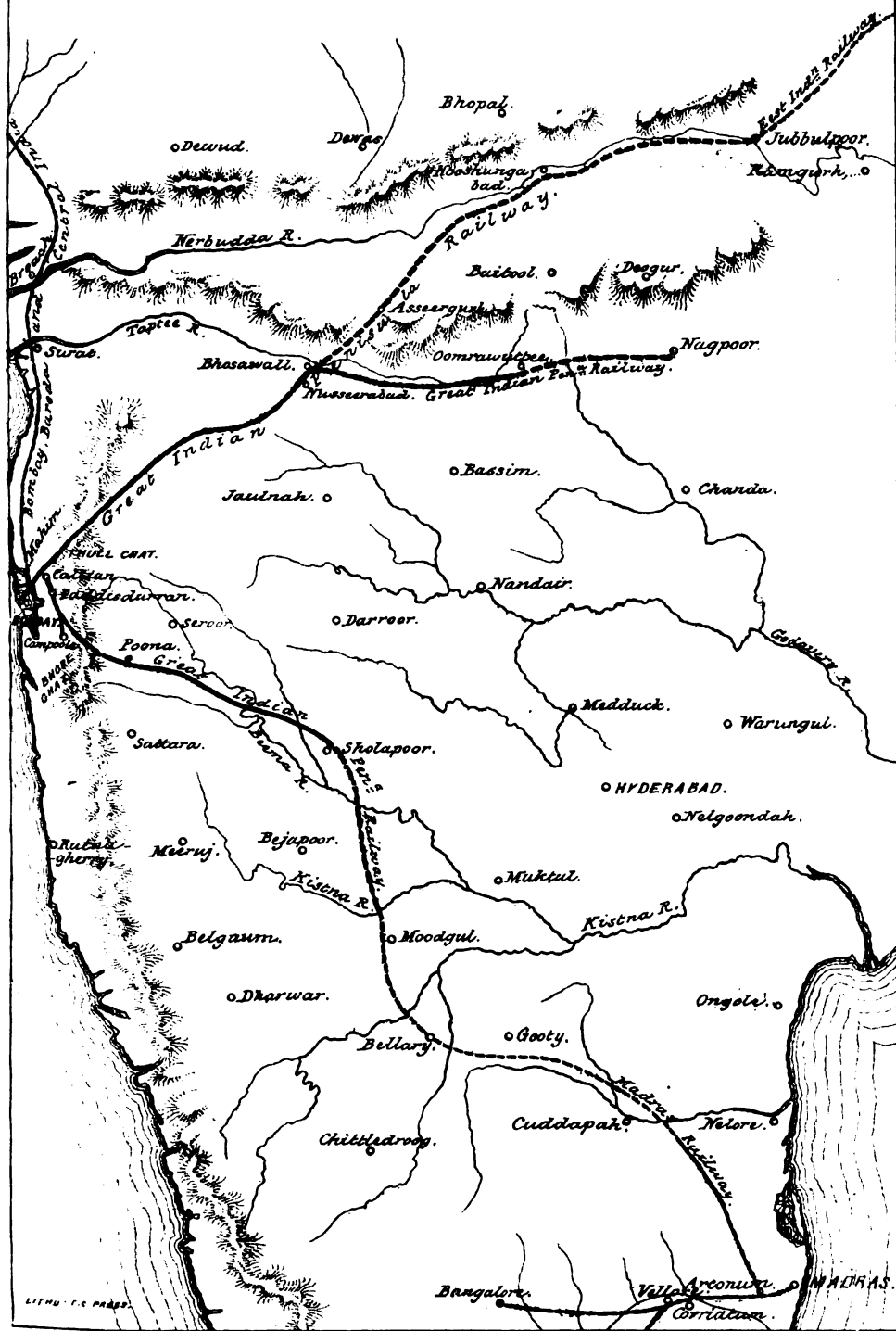
With this port and metropolis as a western terminus, the Great Indian Peninsula Railway will command a portion of the great traffic of the North-western Provinces of India; the opium fields of Malwa; the grain and seed provinces of the valley of the Nerbudda; the vast cotton fields of Berar, of the Nizam's dominions and of Sholapore; and the trans-peninsula traffic from Calcutta and Madras.

The Syhadree mountains, or as they are commonly called, the Ghauts, intercept the channel of communication for this vast and important traffic. They lie parallel to the coast, from which they are distant about 30 miles, and, in a range of about 100 miles, there are only two main roads by which wheeled traffic can cross them; the Agra road up the Thul Ghaut and the Poona and Calcutta road, up the Bhore Ghaut. The rest of the passes are rough tracks, fit only for the use of pack-bullocks.

When regarded as a means of conveyance for a rich and extensive tract of country, capable of sending to a central port like Bombay, a large amount of produce, to supply the demands of distant competing markets, the principal characteristics of the existing roads and means of transport in the Bombay Presidency are :—extreme slowness, only about twelve miles per day,—uncontrollable irregularity,—great cost of conveyance, amounting to $3\frac{1}{2}d.$ to $4\frac{1}{2}d.$ per ton, per mile,—the short duration of the favorable season for conveyance,—the limited extent of the present means of carriage,—and the damage to goods, and losses by theft and from bad weather, upon the journey.

The first section undertaken by the Great Indian Peninsula Railway Company, was that from Bombay to Callian, 33 miles, with a branch to

GREAT INDIAN PENINSULA RAILWAY.



Mahim of $1\frac{1}{2}$ miles; it was called the "Experimental Line." It was begun by Messrs. Faviell and Fowler in February, 1851, and was finished by them, in conjunction with Messrs. Wythes and Jackson, and Mr. Jamsetjee Dorabjee, a Parsee, in April 1854. The portion from Bombay to Tannah, a distance of 20 miles, was the first railway opened in India for public traffic, which event took place on the 16th of April, 1853. From Bombay to Callian, a double line of rails has been laid. Its steepest gradient is 1 in 150, and the radius of the sharpest curve is 40 chains. The Bombay terminus is at Boree Bunder, having the advantage of a quay frontage to the harbour, and although it occupies an area of 19 acres, it is already overcrowded. The site not being permanent, all the buildings are of a temporary character. The Company's dépôt for working the line is situated at Bycullah, about 2 miles from the terminus. It covers an area of $18\frac{3}{4}$ acres, and contains steam sheds, erecting and fitting shops, smithies, iron and brass foundries, saw mill, carriage-repairing and waggon-building sheds, stores, warehouses, coke shed, a timber-preserving establishment, offices, and workmens' and engine-drivers' dwelling-houses.

The principal works upon the Experimental Line are the crossing of the Sion Marsh, which is effected by an embankment; the crossing of the arm of the sea from the island of Salsette to the Concan, comprising two viaducts, the length respectively, of 111 yards and 193 yards, in the latter of which there is an opening for navigation, of 84 feet, spanned by wrought-iron plate girders; beyond this, there are two tunnels of the respective lengths of 103 yards and 115 yards. The railway is protected by post and rail fences, and prickly-pear and cactus hedges. The station buildings are of masonry. The permanent way is chiefly laid with transverse wooden sleepers, and 6 miles of it with iron pot-sleepers. The rails, which are of the double T form, weigh 84 lbs. per lineal yard, as far as Tannah; beyond which place, they weigh only 65 lbs. and 68 lbs. per yard. The lighter rails extend along the whole of the Company's main lines, except the two Ghant Inclines, on which are laid rails of 85 lbs. per yard. From Callian diverge,—the South-Eastern Extension to Poonah and Sholapore, and its proposed prolongation to the river Kristna and the Madras Railway,—and the North-Eastern Extension to Nassick and Jubbulpore, to join the East Indian Railway from Calcutta, by which a communication will also be effected with the North-Western Provinces of India.

S. E. EXTENSION.—The first section of the South-Eastern Extension is from Callian to Campoolee, at the foot of the Bhoze Ghaut mail-road. It is $37\frac{1}{2}$ miles in length, of which $30\frac{1}{2}$ miles, to the foot of the railway incline, are permanent, the remainder having been designed for temporary use, until the Ghaut Incline was opened. This portion of the railway was begun by Mr. Jamsetjee Dorabjee in 1854, and was finished in 1856. It has been constructed for a double line, but only one road has been laid. Its ruling gradient is 1 in 115 on the permanent, and 1 in 85 on the temporary, portion. The radius of its sharpest curve is 40 chains. It contains no work of any special character, but it is remarkable for the extraordinary floods and rapid torrents to which it is exposed on both sides. The bridges and culverts are built of rubble masonry, with coursed facework; and in one or two instances, cast-iron girders were made use of. The average cost of this section, exclusive of rolling stock, was only £4,500 per mile.

Bhoze Ghaut Incline.*—Four years were spent in preliminary surveys of this incline, and in laying out and preparing cross sections, to the number of about two thousand, and perhaps the most difficult that have ever been taken. Four years more have already expired since the contractor commenced operations upon it. The works were begun by Mr. Faviell in January 1856, and taken up in November 1859, by Mr. S. Tredwell, whose melancholy death within a month of his arrival in India, many members of the profession must sincerely lament. It is expected to be finished about three years hence.† It is 15 miles 68 chains in length, and the total rise is 1,831 feet. Its average gradient is 1 in 48. The steepest gradients are 1 in 37, extending in one length for 1 mile 10 chains, and 1 in 40 for 5 miles 6 chains. Short lengths of level gradients and of 1 in 330 are introduced into this incline, to facilitate the ascent of the engine. The radii of the curves upon it range from 15 chains to 80 chains, and 5 miles 33 chains are straight. It comprises twenty-five tunnels, of a total length of 3,585 yards. The longest is 437 yards; and the longest without a shaft, which is carried through a mountain of basalt, is 346 yards. There are eight viaducts of a total length of 987 yards. The two largest are 168 yards long, and respectively, 163 feet and 160 feet above the foundations. The viaducts are being built, up to the surface of the ground, of solid

* See Vol. I., p. 48.—[Ed.]

† Since completed and opened for traffic; the total cost has been £1,100,000.—[Ed.]

block-in-course masonry, and above, of block-in-course facework, strongly tied through, by header bonds of block-in-course, to the internal work of sound rubble, and with coursed rubble arches. The contract also comprises a large quantity of retaining walls. The total quantity of cutting, chiefly rock, amounts, by calculation, to 1,263,102 cubic yards. The maximum depth of cutting is 70 feet, and the greatest contents, 75,000 cubic yards of trap rock. The embankments amount to 1,849,934 cubic yards, the maximum height being 74 feet; and greatest contents are 209,000 and 263,000 cubic yards. The slopes average about $1\frac{1}{2}$ to 1. There are twenty-three bridges of various spans, from 7 feet to 30 feet, and sixty culverts from 2 feet to 6 feet wide. The rails weigh 85 lbs. per yard, and are laid with fish joints, with small cast-iron saddles under the joints, resting upon longitudinal planks, the ends of which bear upon, and are secured by fang bolts, to transverse wooden sleepers. The estimated cost of this incline is £750,000. The upper 2 miles from Khandalla to Lanowlee, with gradients of 1 in 40 and 1 in 50, were opened on the 14th of June, 1858, and have since been worked with safety and regularity.

At the eleventh mile, the incline is divided into two banks, by what is called a reversing station. This sub-division, however, was not adopted for the purpose of making two banks of the incline, but of increasing the length of the base, in order to flatten the gradient and to reach a higher level, where it encountered the great features of the Ghaut margin, near Khandalla. Without the necessary expedient of the reversing station, the practicability of changing the direction of the line would have been confined to making curves of small radius; but with the device of the reversing station, the direction was altered at a very acute angle, by means of points and crossings. In consequence of its adoption, the incline is prolonged by nearly the difference between the length of the two sides of an acute-angled triangle, and that of its base.

The peculiar difficulties upon this incline are the unfavorable nature of the hot and rainy seasons; the fatal epidemics which dismay and disperse the people employed upon it; the lofty and precipitous character of the ground, which impedes the haulage of materials and harasses all who are engaged in the operations; the extensive and sudden slips upon the mountain sides; the extreme hardness and solidity of the rocks; the scarcity of water; and the want of necessaries and comforts for the men.

The next section of the South-Eastern Extension is from Lanowlee, the summit of the Bhore Ghaut Incline, to Poonah and Sholapore, and is $205\frac{1}{4}$ miles in length. The first 42 miles were begun by Mr. Faviell in January 1856, and were finished in June 1858. The remaining $163\frac{3}{4}$ miles were commenced by Mr. J. Bray, in March 1856, and 143 miles completed on the 27th of December, 1859. Its engineering character is very similar to that of the Concan section. Its ruling gradient is 1 in 132, and the radius of its sharpest curve is 40 chains. The cuttings are in trap rock, moorum, and soil; and the embankments are chiefly composed of soil and moorum. There are twenty-two viaducts, three hundred and fifty-nine bridges, and four hundred and fifty-four culverts, all built of substantial masonry. The largest works are the viaducts over the Beema, 441 yards long and 60 feet high, consisting of twenty-eight segmental arches 40 feet in span, with a flood stream 46 feet deep, and rock foundations, the cost of which was £24,246; and that over the river Seena, 190 yards long, 54 feet high, consisting of twelve segmental arches 40 feet in span, with a flood stream 41 feet deep, and foundations partly in rock and partly on hard clay. The fences are dry rubble walls, and cast-iron posts and iron-wire rails. One peculiarity of this district is the violence and suddenness of the floods, which descend with scarcely an hour's notice, and gather into torrents on spots upon which there is no trace or warning of any stream. In the uncommenced portion of the South-Eastern Extension, from Sholapore to the junction with the Madras Line, in the Raichore district, there will be two very large viaducts over the rivers Beema and Kristna. Upon the South-Eastern Extension large quantities of cotton and country produce are now carried, and it is evident that an immense traffic must soon be accommodated. The earthwork has been executed for a single line, and the viaducts and bridges for a double line.

N. E. EXTENSION.—Returning to Callian, the first section of the North-Eastern Extension, which there diverges towards Jubbulpore and Calcutta, is from Callian to Kussarah, 26 miles, gradually climbing, by steep gradients, of which a great portion are 1 in 100, the flank of a long mountain spur, which projects from the Ghaut range, and divides the valley of the Basta on the south, from the Wyturnee on the north. This section is full of heavy work; but to obtain even such a line, demanded a long and minute study of the rugged and jungle-covered district. The works have been executed by Mr. Jamsetjee Dorabjee. The radius of the sharpest curve is

30 chains. It contains 520,493 yards of cutting, chiefly trap and basaltic rock, and 1,853,317 cubic yards of embankment. It comprises four viaducts, of which the two largest are respectively, 124 yards and 143 yards long, and 127 feet and 122 feet high; forty-four bridges from 7 feet to 30 feet in span, and one hundred and seventeen culverts. By means of this section, 849 feet of the ascent have been surmounted to the summit of the Ghaut, and thus the altitude to be overcome by the Thul Ghaut Incline is reduced to only 972 feet.

Thul Ghaut Incline.—The Thul Ghaut Incline extends from the village of Kussarah to Egutpoora, and is in course of construction by Messrs. Wythes and Jackson. It is $9\frac{1}{2}$ miles in length, and has a total ascent of 972 feet. At the end of $3\frac{3}{4}$ miles there is a reversing station, similar to that upon the Bhore Ghaut Incline, by which the base was lengthened, the gradient flattened, and the incline divided into two banks. The steepest gradient is 1 in 37, for a length of 4 miles 30 chains; and the same introduction of a level portion is adopted here as on the Bhore Ghaut. The radius of the curves ranges from 17 chains to 100 chains, and 3 miles 28 chains are straight. There are 13 tunnels, of a total length of 2,652 yards. The longest are, one of 474 yards, in black basalt, with two shafts, and another of 483 yards, without a shaft, in greenstone. There are six viaducts, of a total length of 741 yards, the largest of which are respectively, 144 and 250 yards long, and 88 feet and 182 feet high. The latter is designed for three spans of triangular iron girders measuring 150 feet, with a pair of semi-circular abutment arches, measuring 40 feet at each end. There are fifteen bridges, of which the span varies from 7 feet to 30 feet, and sixty-two culverts. The cost of the incline will be about £450,000. The preliminary surveys and studies occupied four years, and the works were commenced in October, 1857.

The next section of the North-Eastern Extension runs from the summit of the Thul Ghaut Incline, at Egutpoora, by Nassick, across the fertile valley of the Godavery, and the Indhadree range of mountains, along Khandaish to Bhosawul, the point of junction with the Oomrawuttee and Nagpore Branch. The character of this line is very similar to the corresponding section of the South-Eastern Extension, from the Bhore Ghaut to Sholapore, and the nature of the earthwork is much the same. The principal works upon it are:—a viaduct over the Godavery, 145 yards in length, consisting of nine arches 40 feet in span, with a flood stream 36 feet deep,

and foundations upon rock, excavated through sand; the Kadoo Viaduct, 242 yards in length, with fifteen arches 40 feet in span; the Munnair Viaduct, with five openings spanned by triangular iron girders, and two pairs of abutment arches; and the Wangoor Viaduct, with ten openings, also spanned by triangular iron girders. This section contains twenty viaducts, two hundred and seventy-nine bridges, and four hundred and thirty-five culverts. It was commenced by Messrs. Wythes and Jackson, in October, 1857.

The last section of the North-Eastern Extension runs from Bhosawal to Jubbulpore. It is 328 miles in length, and was contracted for by Messrs. Duckett and Stead, in January, 1859. As the operations are in a preliminary state, it is only necessary to notice the two very large viaducts over the rivers Taptee and Nerbudda. The Taptee Viaduct is 875 yards long, consisting of five openings of 138 feet and fourteen openings of 60 feet, and twenty arches 40 feet in span, with a flood stream 70 feet in depth, and foundations upon rocks. The Nerbudda Viaduct will be about 387 yards long, 100 feet high, with a flood stream 90 feet deep.

The Oomrawuttee and Nagpore Branch is about 263 miles in length. It was let to Messrs. Lee, Watson, and Aiton, who are now just commencing operations. As the line has not yet been entirely staked out, no details can, at present, be given; but its general character is known to be favorable, and the works are light. The largest works will be the viaducts over the rivers Nalgunge and Wurdah.

There is no tunnel beyond the Ghauts, upon any of the lines now under construction, comprising a length of 782 miles.

The following fundamental points are observed and carried out with the greatest practicable economy and despatch, in the completion of this system of railways. The character of the main lines is plain, substantial, and durable, and such as will provide for the regular and expeditious conveyance of a heavy and increasing traffic in goods, and the accommodation of a great number of passengers, at a moderate working cost, and at a reasonable expenditure in maintenance.

The geological nature of the country is volcanic; the hills and mountains consist of trap rock and *laterite*, a kind of ferruginous clay, so called from its frequent resemblance to brick. Granite hills protrude in the southern Mahratta country below Sholapore. The trap is of various sorts,

more or less earthy, or crystalline, and the hills have almost invariably, either a crest or axis of basalt; their surface is bare, or covered with what is called in India, *moorum*. The basalt, sometimes highly porphyritic, is nodular, rectangular, tabular, and columnar. *Moorum* is of a reddish, or gray color, and is, no doubt decomposed rock of a very earthy nature; in the cuttings, it is found both hard and soft. In the valleys, there is a great depth of vegetable soil.

As favouring engineering operations, the indestructible nature of the slopes of cuttings and embankments made of the black soil; the facility of excavating *moorum*, its firmness for slopes and embankments, and frequent suitability for ballast; the advantage of having rock foundations for the crossing of rivers and streams, and also that of making tunnels without either lining or faces; and the fine quality of the stone for building purposes and the facilities of quarrying it, are worthy of special notice. As a set-off to these advantages, there are the extreme hardness of the black basalt, which renders progress both tardy and expensive, and the precipitous altitude of the mountains, which in many cases, prevents the sinking of shafts, and thus limits the mining of tunnels to the two faces only.

Among the geological features, the existence of large quantities of *kunkur*, a variety of fresh water limestone, and the want of good brick earth, must be mentioned.

The physical geography of the districts of Western India traversed by the Great Indian Peninsula lines, may be thus briefly described. First, the plain of the Concan, elevated very little above the level of the sea; then the abrupt scarp of the Syhadree mountains, the least altitude of which above the sea, is about 2,200 feet; and beyond that, the plain of the Deccan on the South-Eastern Extension, gradually sloping down towards the eastern coast of India: whilst upon the North-Eastern Extension, the country presents the bold features of the rivers Taptee and Nerbudda, with three paralld chains of mountains called the Indhyadree, the Santpoora, and the Vyndhya ranges.

The physical character of the country is less favorable to the Railway Engineer than it might appear, in consequence of the extraordinary quantity of rain which falls upon the western coast during the monsoon, a period of four months from June to September. The line of the Ghauts is the axis of these rains, and the rivers and streams which rise in it

are either dry or stagnant, during the fine weather, and become deep and violent torrents during the monsoon. The height of known floods, where the railway crosses some of the principal rivers varies from 25 feet at the Waldhur, to about 70 feet at the Taptee, and about 90 feet at the Nerbudda. Extreme difficulty has been experienced in ascertaining the maximum heights of floods, not merely in the rivers, but in most of the numerous streams which it was necessary to cross. There is nothing upon the ground to indicate them, and the information obtained by careful and extensive inquiry has, generally, been of the most inconsistent nature. Some idea of this difficulty may be conveyed by the fact, that in the year 1837, the river Taptee, where the railway crosses it, rose 30 feet above the highest level it has since attained.

Railway Materials.—The railway materials procurable in India are—iron, coal, timber, stone, bricks, lime, gunpowder, and ballast. Indian coal and iron are very seldom seen in the Bombay market. In many parts of the Nerbudda valley, coal exists of excellent quality and in great abundance, and it lies in a favorable position for being worked. Iron ore, too, abounds, especially on the right bank of the Nerbudda. The principal mines of the district are those at Tenderkaira, near Nursingpoor, about ten miles from the Great Indian Peninsula Line. They are now worked in the rudest fashion, but the iron produced is of excellent quality. There are furnaces also at Paneghur and Gosulpoor, close to which the railway passes, and although the iron is deemed inferior to that of Tenderkaira, it is good, and forms an article of export from those towns. Valuable iron mines also exist at Poonassa and Chandghur, and there are five mines within twenty miles of Jubbulpore. Productive, however, as these may hereafter prove, it is evident that active and successful operations in the manufacture of Indian iron, or the supply of coal, depend more upon the completion of railway communications, than the railway depends upon a local supply of these materials.

The various kinds of wood procurable for railway purposes are of unusually good quality. The properties of some which have already been extensively used, are represented in the following statement, the specimens experimented upon being 7 feet in length by 2 inches square in section, a size adopted in previous experiments.

It has not been found necessary to make use of timber in the perma-

nant bridges. The following woods have been successfully converted into sleepers :—teak, blackwood, khair, errool, and red eyne.

No. of Experiments.	Names of the Woods.	Specific gravity in Ounces.	Breaking weight in Pounds.	Ultimate deflexion in Inches.	Cost per cubic Foot.
5	Northern Teak,	880	672	5'75	s. d. 5 0
3	Southern Teak,	768	1,012	6'87	6 0
2	Blackwood,	896	924	6'75	8 0
4	Khair,	1,168	966	4'00	2 6
3	Errool,	1,008	718	4'50	2 6
3	Red Eyne,	1,088	559	2'50	2 6
2	Bibla,	896	560	5'62	2 6
3	Poon,	624	425	3'62	..
3	Kullum,	656	569	6'12	2 0
3	Hedoo,	624	630	4'25	2 0
2	Jungle Teak,	656	537	3'00	2 0

The cost of a sleeper 9 feet 9 inches long, 10 inches wide, and $4\frac{1}{2}$ inches thick, has varied from 4s. to 7s. $7\frac{1}{2}$ d., and the average price has been about 6s. It was, at first, feared, that wooden sleepers could not be used in India, on account of the ravages of the white ants, but it is a curious and important fact, that although they have been very often seen, eating the sapwood of sleepers lying on the surface of the ground by the side of the railway, those laid in the ballast of the permanent road have not been injured by them.

The whole of the rolling stock, except the engines and tenders, and the first and second-class and composite carriages, is chiefly built of teak in the Company's workshops, and is strong and durable.

Excellent building stone is generally procurable, and is easily quarried. Various qualities are met with suitable either for hammer or chisel dressing, whilst the sharpness of the rough blocks and stones adapt them for strong rubble masonry. It is of the usual hard and compact nature of the trappite, or green-stone class, and when properly selected in the quarries, it is never found to be injured by exposure to the weather. The large size of the blocks has been found most useful for the foundations of machinery in the Company's shops, where sound stones, containing 44 cubic feet, have been laid. Good brick earth is rarely to be met with, and the fuel for making the bricks, which commonly consists of grain husks, is very sparingly used. Consequently, although bricks are cheap and abundant,

they are seldom of suitable quality for railway works. Moderately good bricks have been, occasionally, procured and used in arches, but to obtain them, a proportion of only 23 per cent. has been selected from the best native kilns. The price ranges from 10s. to 24s. per thousand. The former rate is for small-sized bricks of inferior quality; the latter are good bricks made of the English size. The lime is of a remarkably fine quality, and is hydraulic. In making *chunam*, or mortar, one part of lime is mixed with two parts of sand. It sets rapidly, so as to give immediate stability to the work, and continues to do so for twelve or fifteen months, until it becomes as hard as the rock itself. Saltpetre and charcoal being easily procurable in the country, gunpowder is largely manufactured. It is very strong and suitable for blasting, and costs, when made upon the spot, about £34 per ton. The ballast consists of sand, broken stones, gray moorum, and nodular basalt.

The Bombay and district markets have greatly varied, and have been sometimes found unfavourable for extensive dealings. The railway demands being unusually large, have occasionally been met by a combination of native merchants, who find it easy to establish a monopoly amongst themselves, and to work it to their profit. This movement has been defeated by a variety of expedients, such as obtaining supplies from the Government stores, procuring the articles direct from the dépôt, making them by the Company's own agency, or importing them from England. The result, however, has been a great augmentation of prices and considerable irregularity in obtaining supplies. It is one remarkable feature in Indian railway practice, that a very large, and certainly the most expensive, portion of the materials, has to be supplied from England; a circumstance which not only affects the cost, but also the progress of the works. Experience has already established the fact, that the period requisite for finishing a line for the use of public traffic in the interior of India, is not determined by the local execution of the works, but is dependent upon the delivery along the line of the permanent-way materials, station machinery, and rolling stock, which have to be procured in England, shipped to Bombay, and thence transported to the various districts of the railway.

During the year 1858-59, the shipments to Bombay of permanent-way materials, rolling stock, machinery, and miscellaneous stores, amounted to 66,937 tons, against 51,386 tons shipped in the previous year. The average sum paid in the year, for freight, was £2 0s. 9d. per ton of dead

weight, the lowest rate, 20s. per ton, having been paid in July, 1858, and the highest rate, 60s. per ton, in June, 1859; an increase of 29 per cent. upon the average rate of the previous year.

Many of the articles sent from England have been specially designed for Indian use, their main principles being strength, simplicity, and durability, with as much regard to facility of transport as those essential properties would admit.

Greaves' iron sleepers, as used by Mr. Robert Stephenson in Egypt, have been laid on portions of the Great Indian Peninsula Railway, not however, on account of any objections to the wooden sleepers procured in the country, but because of the difficulty of obtaining a sufficient and timely supply of them. A store of English iron sleepers has, therefore, been found convenient for meeting emergencies, and experience has shown that they are handy for transport, quickly and well laid by native laborers, and that they make a good and durable permanent way. A few consignments of creosoted sleepers have also been despatched to Bombay. They proved to be more expensive than Indian wooden sleepers, and were also very liable to split during exposure, between the time of landing and their being laid down. A complete apparatus has been sent out and fitted in Bombay, for dressing timber with corrosive sublimate; as the climate has proved favourable for kyanising. The Indian sleepers which have been dressed, have absorbed about $3\frac{1}{4}$ gallons of corrosive sublimate; and the cost, including haulage, has been 1s. 6d. per sleeper.

An iron goods-shed and an iron booking-office were supplied from England, in 1858. Their comparative dearness may, perhaps, be compensated for by their durability and cheapness in repairing, and they are convenient for removal; but on account of their great heat, they have been unsuccessful, notwithstanding well-devised means of ventilation. In future, any iron buildings imported from England, should consist merely of framework, the large surfaces in the sides and upon the roof being afterwards filled in with non-conducting Indian materials.

Native Labor.—Native labor, by which these works have been executed, is cheap, but very inferior to that of England. Nearly one hundred thousand men have been employed upon the Great Indian Peninsula Railway lines at the same time, and as many as forty-two thousand upon the Bho-

Ghaut Incline, which is $15\frac{1}{4}$ miles in length. This great force has not been collected without considerable trouble; it is not entirely supplied by the local districts, but is gathered from distant sources. Laborers sometimes tramp for work as in England, and on the same work may be seen men from Lucknow, Guzerat, and Sattara. The wants of the works have, however, been supplied by unusual exertions in sending messengers in all directions, and by making advances to *muccadums*, or gangers, upon a promise to join the work with bodies of men at the proper season. Country artisans and skilled laborers have their own methods of doing work, but are capable of improvement and are not averse to change their practice. For operations requiring physical strength the low-caste natives, who eat flesh and drink spirits, are the best; but for all the better kinds of workmanship, masonry, bricklaying, carpentry, for instance, the higher castes surpass them. Miners are, on the whole, the best class in the country. The natives strictly observe their caste regulations, yet will readily fall into an organisation upon particular works, to which they will faithfully adhere, and in which they are by no means devoid of interest. Although they cling closely to their gangers, they will attach themselves to those European inspectors who treat them kindly. The effective work of almost every individual laborer in India, falls far short of the result obtained in England. This is a disadvantage upon works, the dimensions, and proper mode of execution of which, limit the number of men that can be employed at one time, because the rate of progress is proportionally diminished. The fine season of eight months is favorable for Indian railway operations, but on the other hand, fatal epidemics, such as cholera and fever, often break out, and the laborers are generally of such a feeble constitution, and so badly provided with shelter and clothing, that they speedily succumb to those diseases, and the benefits of the fine weather are thereby temporarily lost. They work under the immediate control of a ganger, or *muccadam*, and the various gangs under a mistry or native foreman; and the whole under the inspection of a European overseer of works, by whom interpreters are also usually required. Not only men, but women and children, are employed upon Indian works; and thus, although the wages of the individual are small, the earnings of his family are by no means inconsiderable. The present rates of wages, per day, of the several classes of native laborers are:—

	s.	d.
Native Mistries, or Foremen of Masonry,		
Brickwork, or Carpentry,	2	6
Masons,	1	9
Bricklayers,	1	3
Carpenters,	1	6
Smiths,	2	0
Miners (a very large class),	0	9
Excavators,	0	7½
Laborers,	0	6

These rates are very low as compared with English wages, but allowing for the comparatively small effectiveness of Indian labor, the following may be safely taken as the relative cost of each kind of labor, in England and the Bombay Presidency:—

Classes of Labor.	Proportion of Work done by each.		Relative cost of Labor in in each Country.	
	England.	Bombay.	England.	Bombay.
Masons,	2½	1	1½	1
Bricklayers,	4	1	1	1
Carpenters,	3	1	1½	1
Miners,	3	1	2½	1
Excavators,	4	1	1½	1
Laborers,	8½	1	1½	1

In examining this Table, it should be borne in mind, that the comparison is between simple labor only, and that it does not represent the cost of finished work; for the economy in favor of India suffers, from the expense of obtaining the powerful aid of English appliances, from defective and clumsy methods, and from a variety of drawbacks and disadvantages peculiar to native customs. Strikes, although of rare occurrence, have occasionally taken place, and the truck system, commonly discountenanced at home, is beneficial in India.

The whole of the Great Indian Peninsula Railway has been successfully executed by contract. Speaking generally, the European contractors have as a rule, been more successful than natives, because the native tenders for the principal contracts have, usually, been either too high, or unreasonably low, so that, looking to their inexperience of such works, it has not often been thought desirable to take advantage of their agency, in the

construction of the main lines. There has, however, been one remarkable instance of the employment of native enterprise; a Parsee contractor, Mr. Jamsetjee Dorabjee, has executed four main-line contracts as satisfactorily, as expeditiously, and as cheaply, as any of the European firms, and is now about completing his fifth, which comprises some of the heaviest works on the lines.

In the other respects, native agency has been employed and encouraged, as much as possible. The Company's Engineers, Assistant Engineers, and Surveyors are generally Europeans, but one native Engineer has won his way to the office of Assistant Engineer, and has skilfully discharged its duties for three years. In the office establishment of draftsmen, accountants, and clerks, all the situations have been held by natives. As inspectors of work, natives have been chiefly employed. As district inspectors of the line, when opened, native agency is already partially adopted and is, by encouragement, gradually becoming more useful.

In the methods of executing the works two objects have to be kept in view; first, to turn those of the natives to the best account; and secondly, to introduce English appliances where it can be done with advantage. It has not always been obvious which of these measures would, under the circumstances, be the more effectual, and experience has taught that some Indian modes of doing work, which seemed barbarous and clumsy, were the cheapest and quickest means which could be employed.

Tunnels may be said to be an entirely new description of work in Western India, and the whole process, except blasting and excavation, was unknown to native workmen. In the earliest tunnels, where the top was heavy, it was found, at first, impossible to keep native miners in the heading, and the timbering was done chiefly by Europeans and one or two Parsee carpenters, and the arch was keyed in by the former alone. Native miners use the churn drill, with which they are very handy, and they have sometimes been brought to work in pairs with the hammer, and strike with dexterity. They will work hard in close contact and in the foulest atmosphere. They are careless in blasting operations, and consequently, the loss of life has been considerable; miners have been seen to fire a shot with a bamboo, and lie upon the ground while it exploded.

In building viaducts and bridges, there is a mixture of appliances and operations. In pumping foundations, English pumps only are sometimes used, but they are often aided by the native methods of the Persian wheel

and by the Mahratta *móth*, a leather bag containing about 35 gallons of water, which is lowered and lifted over a pulley by bullock power. The natives also have various hand devices for scooping or baling water from the bridge pits, all of which are occasionally resorted to. Where water has to be brought, it is carried in leather bags called *puckals*, laden in pairs on bullocks' backs. In some districts, it is thus conveyed more than two miles to the masonry.

In staging and scaffolding, it is only rarely and in very large works, that the English example has been followed, nor are crabs and derricks so often met with as might be expected. The reason for this is afforded by experience, which has taught how cheap and expeditious it sometimes is, to use the native process. The bamboo coolies, or carriers of heavy weights, will lift their loads up the roughest staging, and the masons and laborers require but little help, to find their way to the work at the top of the highest piers. The centering commonly adopted in the country, was to fill up the arch with stone and earth, and to shape the top to the form of the soffit, or at other times, to use almost a forest of jungle wood in scaffolding a rough centre. For these, centres of English construction have invariably been substituted, with, as may be conceived, immense advantage to the work.

The native sawyers always work in pairs, even in the smallest jobs. The sawing is so inferior that a great deal of adzing is requisite, and much of the work that would be planed in England, is turned out roughly with the adze in Bombay. In planing there is the same peculiarity of working in pairs; carpenters squat to their work, and it is with extreme difficulty that a few of them have been brought to stand to a bench. It is remarkable to observe how freely they call in the aid of their feet; a carpenter may be seen resting his weight upon one foot, and cleaning his axe with the sole of the other.

In making embankments, the Hindoo custom of carrying the earth in baskets upon the head, is, owing to the cheapness of land for side cuttings, found more economical than wagon roads with long "leads," and, judging by the result, it is attended with very little sacrifice of despatch. Within one month, 30,000 cubic yards have been put, by this means, into an embankment only 24 chains in length.

Smiths' and foundry work is moderately good, but the class being so small and the material being English, almost all supplies of manufactured

iron have had to be procured from England. Plate-laying was of course entirely a new operation, yet a large quantity of excellent work has been turned out by native labor under close inspection.

Among the mechanical improvements and innovations made by railway construction, may be enumerated, the use of barrows, dobbin carts, wagons and wagon roads, lorries, both wooden and iron, water pumps, crabs, moulding tables for brickmaking, stationary-engine power for sawing, pumping, and working tunnel shafts, hammer drilling, bridge centering, pile driving, timber pickling, and various kinds of iron superstructure for bridges.

The average cost of the opened portions of the line has been from about £8,000 to £9,000 per mile.

The prices of the principal kinds of work, including all the usual contract stipulations, have ranged as follows :—

		£.	s.	d.	£.	s.	d.	
Earthwork in embankment under a quarter of a mile lead,	} per cubic yard, from	0	0	6	to	0	0	7½
Cutting in earth, or moorum, ditto,		0	0	7½	"	0	0	9
Ditto in rock, ditto,	"	0	1	1	"	0	2	6
Tunnel,	"	21	10	0	"	33	0	0
Brickwork in arches,	"	0	15	0	"	1	10	0
Coursed rubble masonry in ditto,	"	1	7	0	"	1	16	0
Ashlar,	cubic foot	0	1	7½	"	0	3	0
Block in course,	cubic yard	0	16	0	"	1	15	0
Coursed rubble,	"	0	14	0	"	1	4	0
Rubble,	"	0	9	0	"	0	14	0
Woodwork (teak),	cubic foot	0	4	0	"	0	6	0
Ballast,	cubic yard	0	1	1½	"	0	1	4½
Laying permanent road,	lineal yard	0	2	0	"	0	2	10½
Post and rail fence,	"	0	1	6	"	0	2	0
Dry rubble wall,	"	0	2	6	"	0	4	0

This does not include the Ghaut Inclines, which are exceptional.

The total length of the G. I. P. Railway will be 1,114 miles, of which 508 were opened up to 1863. The estimated cost was about £10,000 per mile; and the total expenditure up to 1st May 1863, was £9,877,615.

The locomotives employed on the line have cylinders 15 inches in diameter, with a stroke of 22 inches; and four coupled wheels, each 5 feet 6 inches in diameter. Those in use upon the inclines are tank engines, having cylinders 15 inches in diameter, with stroke of 2 feet; and four wheels, each 4 feet in diameter, with skid breaks which do not pass under the wheels but are pressed upon the rails between the wheels, on each side of the engine.

No. CVI.

MASONRY GIRDER BRIDGES.

*Design for a Masonry Vaulted Girder Bridge.**To the Editor.*

DEAR SIR,—Since writing this paper, I have been informed that a similar construction has been suggested in "Ware on Vaulted Constructions," and that a few bridges have already been built in ribs, and the intervening space bridged over with slabs of stone. I do not think though that they are generally known, or that a comparison has ever been drawn between them and ordinary built bridges.

Your's truly,
F. D. M. B.

THE price of constructing vaults is much reduced by building them with solid ribs and filling in the intermediate space in a less substantial manner. Arched roofing, too, connected by tie-rods is now a common practice, making a strong and permanent flooring for factories, mills, and other large buildings. I propose to apply these two principles to masonry bridges, in the following way, which, as will be seen by the Table at the end, causes the saving of a large percentage of the cost.

The method is to build a masonry bridge as at present, but leaving out so many feet on each side of its axis (or in other words, building two arched masonry girders) and vaulting in the intervening space with a thinner arch. The springing of this cross arch will be kept in a horizontal line by building an abutment for it on the inner sides of the spandrils of the main arches, or girders.

Four designs have been worked out.

No. I. Is with the cross arch 18 inches thick at crown, and 27 inches

at the haunches; all the dimensions being calculated to stand the thrust of the cross arch. Tie-rods are added besides to stand half this horizontal thrust (Plate XXII).

No. 2. Is the same as No. 1, except that the cross arch is made 12 inches thick at crown and 18 inches at the haunches; and the other parts calculated in proportion.

No. 3. Has three main arches, with two small cross arches (12 inches thick at crown and 18 inches at haunches) connecting them. The parts being calculated sufficiently strong (as in No. 1), and tie-rods added to stand half the horizontal thrust (Plate XXIII).

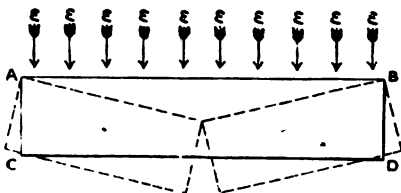
No. 4. Has the space of the cross arch carried to its utmost limit, and the whole thrust borne by the tie-rods (Plate XXIV).

These four designs are compared with an ordinary bridge of like dimensions (Plate XXV).

DESIGN, No. 1.—Span, 55 feet; height of springing above ground level, 13.14 feet; width of arch, $32\frac{1}{2}$ feet; width of roadway, $29\frac{1}{2}$ feet, arch, a segment of 60° ; thickness at crown = $3\frac{1}{2}$ bricks = $31\frac{1}{2}$ inches; thickness at haunches = $5\frac{1}{2}$ bricks = $49\frac{1}{2}$ inches; thickness of piers, 7 feet.

CALCULATIONS.

Fig. 1.



Suppose ABCD to be a plan of one of the main arches, and AC, BD, its abutments; with the cross arch *e, e*, &c. (as shown by the arrows pressing against it). The main arch could only give way

1. By breaking in the centre, like a beam.
2. By the backing being pushed off the extrados of the main arch.
3. By the backing, main arches, and piers, being forced outwards and revolving about the outside edge of the bottom of the piers.

Investigation of No. 1 (a).—ABCD (Fig. 1.) may be supposed to be a beam uniformly loaded and applicable to the formulæ $T = \frac{WL}{8D}$

where T = the thrust of compression or tension,

W = whole horizontal thrust of cross arch pressing against it.

MASONRY GIRDER BRIDGE.

Fig. I.

Elevation.

Section on A.B.

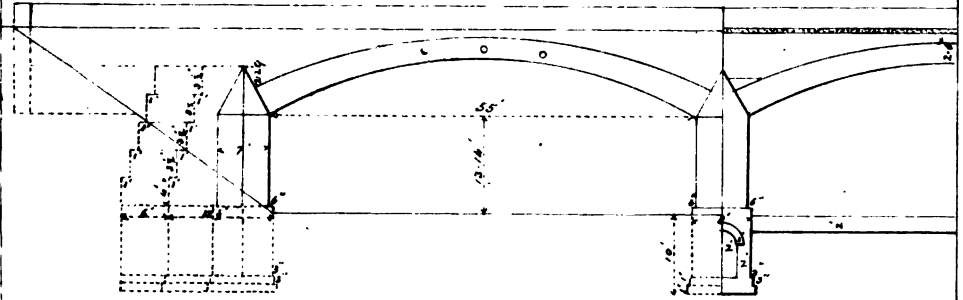


Fig. II.

PLAN.

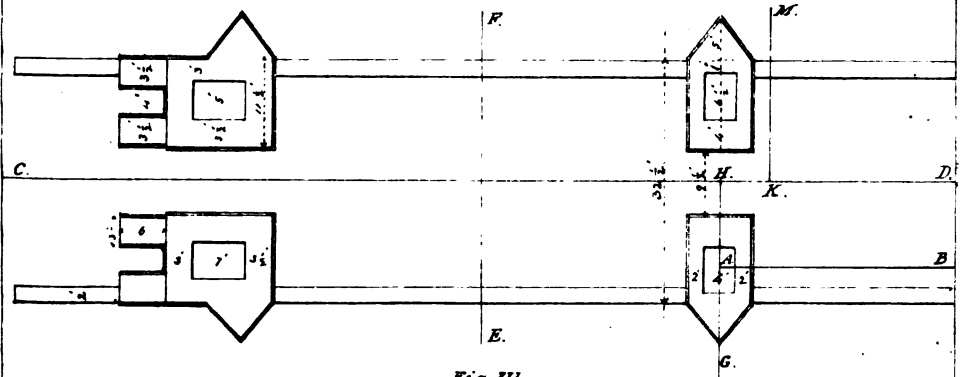


Fig. III.
Section on C.D.

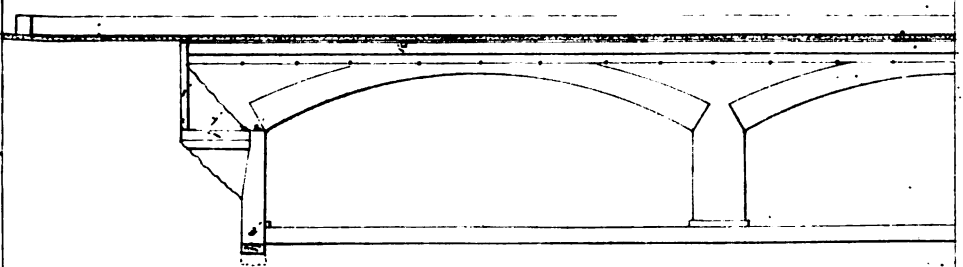


Fig. IV.
Section on E.F.

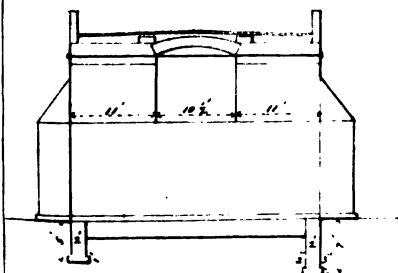
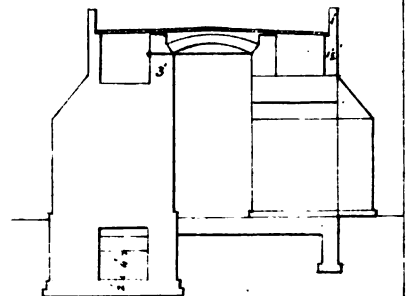


Fig. V.
Section on G.H.K.M.



Scale, 1/4" = 100 ft.

L = length W acts upon,

D = width of each main arch.

Then, if the inner half area of the key-stone of the main arch can stand half the horizontal thrust $+ T$ without crushing, and the outer half can stand half horizontal thrust $- T$ without being torn asunder, the arch will not break.

Supposing the main arches to be 11 feet wide each, the cross arch will be $10\frac{1}{2}$ feet span. Applying the figures for such an arch to the above formula—

$$T = \frac{(3280 \times 62) \times 62}{8 \times 11} = 143,299 \text{ lbs.}$$

Hence the compression on the inner half of the main arch will be

$$\frac{143299 + \frac{1}{2} (\text{horizontal thrust of main arch})}{\frac{1}{2} (\text{sectional area of key-stone in square inch})} = 182 \text{ lbs. per square inch.}$$

On the outer side, T being tension, the strain of compression will be

$$\frac{285352 - 143299}{66 \times 31.5} = 44 \text{ lbs. per square inch.}$$

$\therefore$ 11 feet width of main arch will be amply strong.

Investigation No. 1 (b).—If the arch should give way by breaking in the centre, it will revolve about the outer edge of its abutments CD (Fig 1.)

Let H = the horizontal thrust of main arch.

h = sum of horizontal thrust of cross arch acting on the main arch, then $\frac{h}{2}$ = this thrust applied at the centre,

of which $\frac{h}{4}$ is supported by each abutment.

L = span of main arch in feet.

W = width of main arch in feet.

$1000 W$ = cohesion of mortar joints (in lbs.) to resist tearing asunder. This acts with a leverage $\frac{W}{2}$ at the abutments, and $\frac{W}{4}$ at the crown (as half of this force at the crown acts on both sides).

Then taking moments about C or D ,

$$1000 \frac{W^2}{2} + 1000 \frac{W^2}{4} + \frac{H.W}{2} = \frac{h}{4} \cdot \frac{L}{2}$$

$$W = .99 \text{ feet.}$$

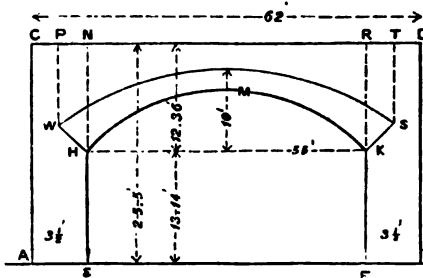
But the width of main arch is 11 feet.

Investigation of No. 2.—Taking 4000 lbs. per square foot as the

strength of good mortar to resist detrusion, and the horizontal thrust of cross arch = 3280 lbs. per foot run ;—

Then $\frac{3280}{4000} = 0.8$ feet, so that the backing will not be forced off the extrados.

Fig. 2.



Investigation of No. 3.—

The weight of the area enclosed within the rectangle ABCD (Fig. 2) may be taken as the abutments to the cross arch, when AE, FB = half width of each pier = 3½ feet.

Then the weight of this area (taking a cubic foot of masonry to weigh 100 lbs.) will be (ABCD — EHKF) × W × 100 + (moving load and parapet)* + (the roadway) = 57962 × W.

The horizontal thrust of the cross arches acting with a leverage of 21.19 feet = $3280\frac{1}{2} \times 62 \times 21.19$; and half the weight of the cross arches (with 100 lbs. per superficial foot of moving load) resting on the main arches = $1894 \times 62 = 117,428$ lbs.

Then taking moments about the outer edge of the bottom of piers, and letting W stand for the required width of main arches, and 1000 W for the cohesion of the mortar joints (as before)

$$57962 \times \frac{W^2}{2} + 500 W^2 \times \frac{7}{62} + 117428 \times W = 4309869$$

$W = 10.33$ feet = requisite width of main arches.

Hence 11 feet will be amply wide.

This width of main arches does not increase proportionally with the span of the cross arch. Thus with a cross arch $12\frac{1}{2}$ feet span, W equals 11.05 feet, and with the cross arch $14\frac{1}{2}$ feet span, W equals 11.68 feet, so that the saving of masonry would be much greater as the width of the roadway increased.

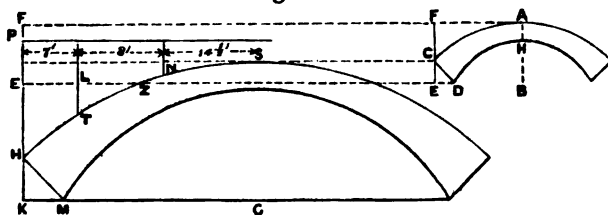
The above dimensions having been proved sufficiently strong (viz., 11

* The moving load has been taken everywhere at 100 lbs. per superficial foot.

feet width of main arches, and $10\frac{1}{2}$ feet span of cross arch) the remaining parts of the construction are as follows:—

Construction of Spandrils.—The backing of the main arch will consist of two walls built flush with its faces: the outer (or real face wall to bridge) will be $1\frac{1}{2}$ feet thick, and the thickness of the inner (or abutment wall to cross arch) will be regulated by the height between the extrados of main arch and springing of cross arch. The space between to be filled with well rammed earth, gravel, or other heavy material. The thrust of the cross arches is also lessened by tie-rods, which are calculated to sustain half the horizontal thrust.

Fig. 3.



$$KH = 3.57 \text{ feet}$$

$$HE = 4.48 \text{ ,,}$$

$$CE = 1.95 \text{ ,,}$$

$$CF = \left\{ \begin{array}{l} CP = 0.63 \\ PF = 0.33 \end{array} \right\} = \text{height of abutment wall to cross arches above the crown of main arch.}$$

$$\left. \begin{array}{l} KM = 2.06 \\ MG = 27.5 \end{array} \right\} = 29.56$$

$$AB = 2.94$$

$$BH = 1.44$$

To find the thickness of abutment wall to cross arches between E, L.

The greatest height of wall is $HP = 7$ feet, and greatest leverage of cross arch is $HE = 4.5$ feet. Let B = the required thickness.

$$\text{Then } 7 \times \frac{B^2}{2} + 500 B^2 + 1894 \times B = 3280 \times 4.5$$

$$B = 3.2 \text{ feet.}$$

As the leverage HE is continually decreasing, and tie-rods are added, 3 feet may be taken as the thickness of this wall between E, L.

Again, to find the thickness of wall between L, N, where $LT = 2$ feet;
in the same way $B = 1.86$ feet.

$\therefore$ thickness of wall between L, Z = 2 feet.

At the point N the springing point (D) of cross arch will be 4 inches below the extrados of the main arch (i. e., NZ = 4 inches).

∴ from N to S ($14\frac{1}{2}$ feet) $1\frac{1}{2}$ feet will be amply wide for this inner wall (made thicker, if necessary, at N and thinner at S).

Calculation for Tie-rods.—The safe working tension usually allowed on wrought-iron is 5 tons (11,200 lbs.) on the square inch. The total horizontal thrust of cross arches = $3280 \times 62 = 203,391$ lbs. The bars are required to bear half this thrust. Let there be eight bars.

Then

$$\frac{203391}{2 \times 8 \times 11200} = 1.134 \text{ square inches} = \text{sectional area of each bar.}$$

Hence eight bars, $1\frac{1}{4}$ inches diameter (area = 1.227 inches) will be strong enough. These will be placed, one through the centre of main arch, and the rest about $7\frac{1}{2}$ feet apart; the three centre bars passing through the main arches, and the others connecting the cross abutments.

Horizontal Thrust of Main Arches.—Total area of HNRKM (Fig. 2.) = $24.39 \times 55 - 997.04 = 344.41$

∴ Total weight borne by each abutment, including 100 lbs. per superficial foot, for moving load, = $\frac{(34441 + 5500) \times 11 + 1894 \times 55}{2} = 271,760$ lbs., and $271760 \times \cot 30^\circ = 470,703$ lbs. = horizontal thrust. Width of abutment = 11 feet = W.

Height of abutment = 19 feet (i. e., 2.29 feet above H, Fig. 3.) = H.

Let B = required breadth of abutment.

Then

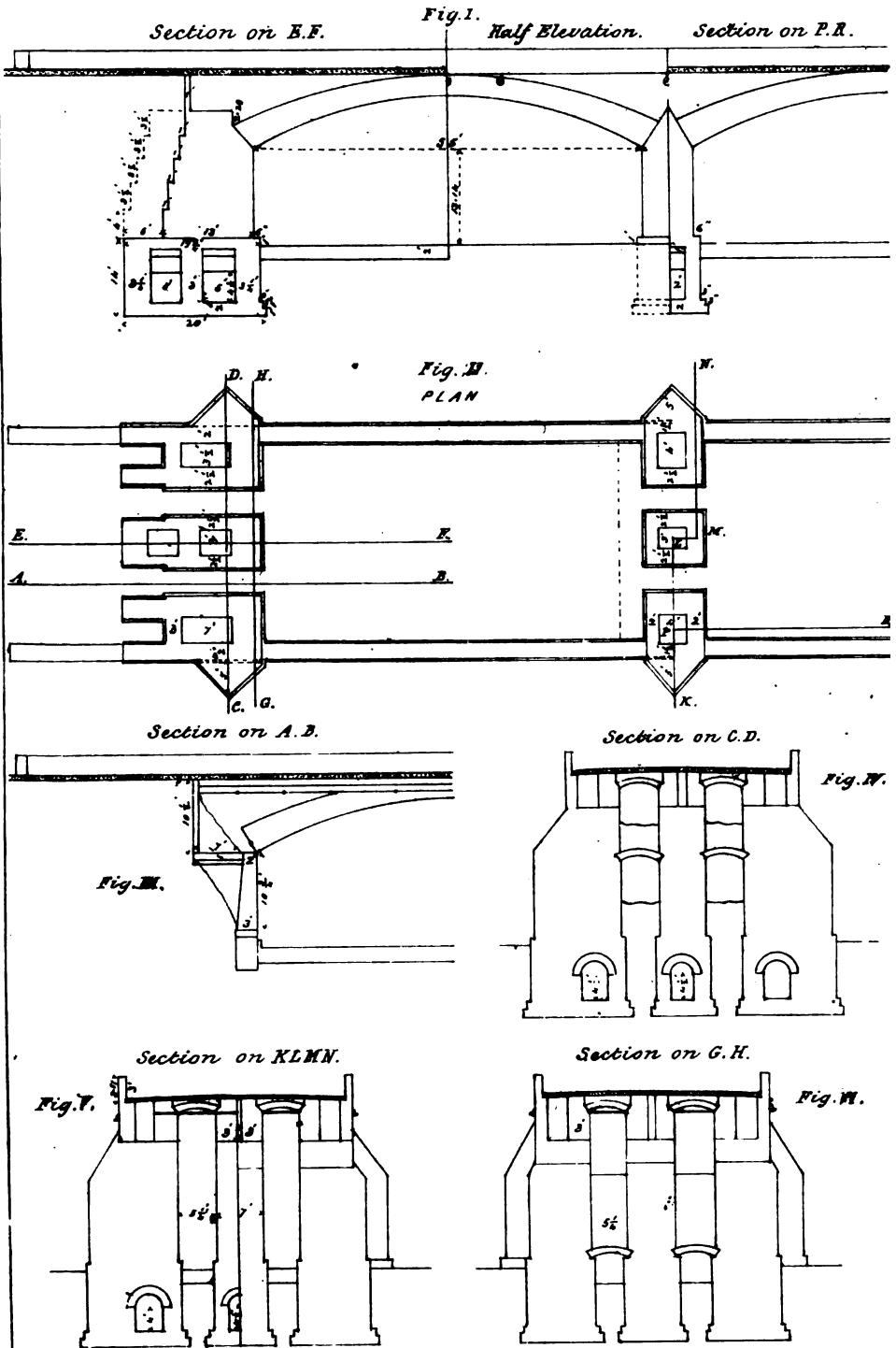
$$\frac{100.H.W.B^2}{2} + 500.W.B^2 + 271760.B \\ = 470703 \times 13.14 B = 12.94 \text{ feet.}$$

so that 13 feet broad with two buttresses 6 feet long and $3\frac{1}{2}$ feet wide, with both abutments and buttresses cut away in steps for 4 feet, will be sufficiently strong. (See Plate XXII.)

The arches between the main abutments, and resting on them, with the walls, &c., which they support (Plate XXII, Fig. III.) will also add to the stability of the abutments.

A revetment wall between the abutments, 23 feet high, to resist the pressure of the earth, would require to be 18 broad at the base, and 8 or 9 feet at the top. This would be an enormous waste of masonry; so I propose to throw an arch across, half way up between the abutments, and let

MASONRY GIRDER BRIDGE.



LITHO: T. C. PARKER.

Scale, 1" = 100 feet.

the earth lie on and under it at its natural slope (as in vaulted revetments in fortifications. Plate XXII. Fig. III.) A revetment wall (resting on an arch between the abutments) to be built to a little above water level and made strong enough to resist the pressure of the water: also a thin revetment wall resting on the inner end of the upper arch, which, having earth on both sides of it, would be subject to little or no pressure, but would prevent the roadway falling in at its junction with the cross roadway arch.

Thickness of Revetment Wall.—Supposing 10 feet of water flowing under the bridge; the revetment wall 13·14 feet high, and B = the required breadth. Then

$$10 \times 62\cdot5 \times 5 = 13\cdot14 \times \frac{B^2}{2} \times 100. \therefore B = 2\cdot14.$$

$\therefore$ 3 feet at base and 2 feet at the top will be strong enough, especially as it has a good deal of lateral support as well.

DESIGN, No. 2.—18 inches thick at the crown and 27 inches at the haunches, may be rather too strong for an arch of only $10\frac{1}{2}$ feet span. By making the cross arch 12 inches thick at the crown, and 18 inches at the springing, the dimensions of the main arch is slightly reduced. Thus—

Width of main arches 10·5 feet,

Span of cross arch 11·5 „

CF (Fig. 3) = 1·24 „

Weight of half cross arch with moving load = 1709 lbs. per foot run;
horizontal thrust of ditto = 2960 lbs. per foot run.

Width of Main Arch.—Working out the thrust of cross arches (as in page 4, except the average of cross arch = 21·84 instead of 21·19) the width of each main arch = 9·74 feet.

$\therefore$ 10·57 feet will be strong enough.

Total area of HNRKM (Fig. 2) = $24\cdot71 \times 55 - 997\cdot04 = 362\cdot01$.

$\therefore$ Total weight borne by each abutment, including 100 lbs. per superficial foot for the moving load = $\frac{(36201 + 5500) \times 10\cdot5 + 1709 \times 55}{2} =$
265,928 lbs.

Horizontal Thrust of Main Arches.—And horizontal thrust = 265928
 $\times \cot 30^\circ = 460601$ lbs.

Width of abutment = 10·5 feet = W

Height of abutment = 19 „ = H

Let B = the required breadth of abutment $\frac{100.H.W.B^2}{2} + 500 B^2 + 265928.W = 460601 \times 18.14$

$$\therefore B = 18.03 \text{ feet.}^*$$

Tie-rods.—With the exception of the change in dimensions herein given, the construction is the same as in Design, No. 1.

There are to be eight rods, as in No. 1, the dimensions of each rod will be $\frac{2960 \times 62}{2 \times 8 \times 11200} = 1.024$ square inches.

$\therefore$ diameter of each tension rod = $1\frac{1}{4}$ inch (area = 1.23 square inches).

DESIGN, No. 3.—Plate XXIII. Is to have three main arches and two cross arches.

Suppose each outer main arch $7\frac{1}{2}$ feet wide, and centre main arch 7 feet wide.

Then each cross arch will be $5\frac{1}{4}$ feet span; the thickness at crown, 12 inches; at springing 18 inches.

Rise of cross arch 0.7 feet.

CF (Fig. 3) = 0.4 feet.

Weight of half cross arch with moving load = 759 lbs. per foot run.

Horizontal thrust of ditto = 1314 lbs. per foot run.

Width of Outer Main Arches.—Then working out the thrust of cross arches (as in page 154), but taking 21.84 feet as the leverage of the cross arches instead of 21.19 feet, the width of each outer main arch will be 7.26 feet.

$\therefore$ 7.5 feet will be strong enough.

Horizontal Thrust of Outer Main Arches.—Total area of HNRKM (Fig. 2) = $23.87 \times 55 - 997.04 = 315.81$.

$\therefore$ total weight borne by each outer abutment, including moving load = $\frac{(31581 + 5500) 7.5 + 757 \times 55}{2} = 159,926$ lbs., and $159,926 \times \cot 30^\circ = 276,999$ lbs. = horizontal thrust.

Width of abutment = 7.5 feet = W

Height of abutment = 19 „ = H

* Supposing the whole weight of the cross arch to be borne by only the first 3 feet of each main arch, then the horizontal thrust of the main arches for these 3 feet will be $\frac{(36201 + 5500) 3 + 1709 \times 55 \times \cot 30^\circ}{2} = 189,746$ lbs.

Hence the pressure per square inch on the key-stone for these 3 feet would be about 167 lbs.

MASONRY GIRDER BRIDGE.

Fig. I.

Section on A.B.

Half Elevation.

Section on C.D.

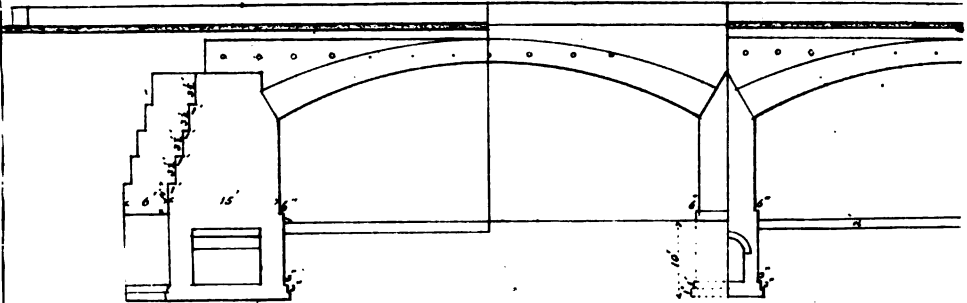


Fig. II.
PLAN

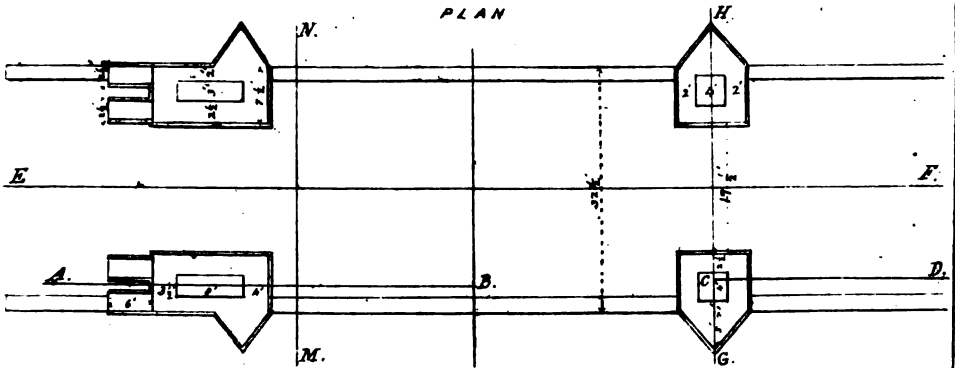


Fig. III.

Section on E.F.

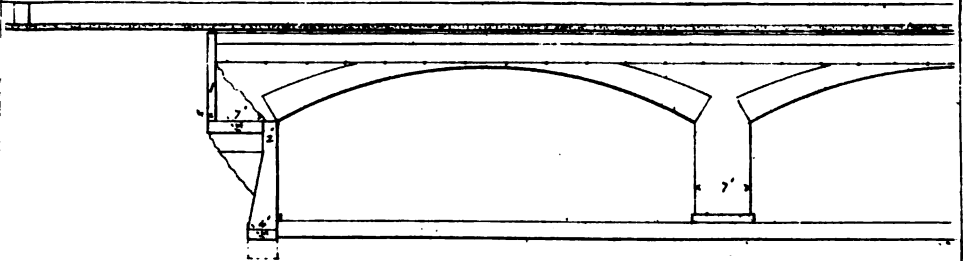


Fig. IV.

Section on M.N.

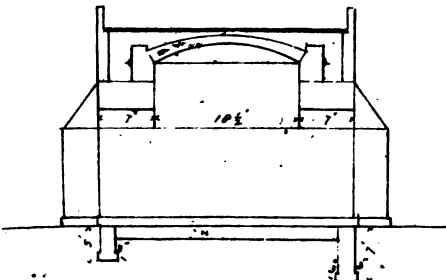
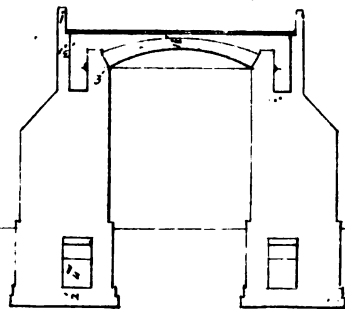


Fig. V.

Section on G.H.



LITHO: T.C. PRESS.

Scale, 1" = 100 feet.

Let B = required breadth of main side abutment.

$$\text{Then } \frac{100 \cdot H \cdot W \cdot B^3}{2} + 500 \cdot W \cdot B^3 + 159926 \cdot W \\ = 276999 \times 18 \cdot 14$$

Whence $B = 12 \cdot 37$ feet.

Again, half the weight of main centre arch =

$$\frac{(31581 + 5500) \times 7 + 757 \times 55 \times 2}{2} = 171,528 \text{ lbs., and } 171528 \times \cot 30 \\ = 297,095 \text{ lbs.} = \text{horizontal thrust.}$$

$$\text{Then } \frac{100 \times H \times W \cdot B^3}{2} + 500 \cdot W \cdot B^3 + 171528 \cdot W \\ = 297095 \times 18 \cdot 14$$

Whence $B = 12 \cdot 9$ feet.

Therefore 13 feet may be taken as the breadth of the three abutments with two counterforts to each 6 feet long, those to the side abutments being 2 feet thick, and to the centre 3 feet thick, each. The back arranged in steps (as in Plate XXIII., Fig. I.) The remaining details as laid down in Design, No. 1, or as shown in the sections, Plate XXIII.

Crushing Weight on Key-stone.—Crushing weight per square inch on key-stone of main centre arch = $\frac{\text{horizontal thrust}}{\text{sectional area in inches}} = 112 \cdot 28$ lbs. per square inch.

Tie-rods.—There are to be eight tie-rods to bear half the horizontal thrust of main arches.

$$\therefore \frac{1314 \cdot 63 \times 62}{2 \times 8 \times 11200} = 0 \cdot 4549 \text{ square inches} = \text{sectional area of each bar.}$$

$$\therefore \text{diameter of each tension rod} = \frac{1}{2} \text{ inch (area} = 0 \cdot 6 \text{ square inch).}$$

Abutment Walls to Cross Arches.—The abutment walls to the cross arches will be of same thickness as in Design, No. 1.

DESIGN, No. 4. Plate XXIV.—Is the same in construction as No. 1, except that the whole thrust of the cross arch is borne by the tie-rods; the main arch only being made strong enough not to twist or crush. The whole thrust of the cross arch being borne by the tie-rods, there will be no use in investigating whether the main arches would break in the centre as there is no outward thrust on them.

Suppose the main arches 7 feet wide.

Then span of cross arch = $18\frac{1}{2}$ feet; thickness at crown, 18 inches; at haunches, 27 inches; rise of cross arch = 2.03 feet.

CF (Fig 3) = 2.03 feet.

Weight of half cross arch with moving load, &c., 4326 lbs. per foot run.

Horizontal thrust of ditto = 7493 lbs. per foot run.

Tie-rods.—Total horizontal thrust of cross arch in 62 feet, divided amongst thirteen tie-rods, gives a sectional area of

$$\frac{7493 \times 62}{13 \times 11200} = 3.19 \text{ square inches to each rod.}$$

Diameter of each rod = 2 inches (area = 3.14 square inches).

Expansion of ties.—The expansion of wrought-iron between 30° and 212° is .0012 of its length.

∴ The greatest expansion that could take place between those extremes of temperature would be .0012 × 32.5 = .039 feet = 0.468 inches. But as the greatest extreme (supposing the ties to have been originally put up at a mean temperature) will never exceed 50°, the expansion or contraction of the bars will be unappreciable.

Horizontal Thrust.—Total area of HNRKM (Fig. 2) = 25.67 × 55 — 997.04 = 414.81 square feet.

∴ total weight of each abutment and moving load =

$$\frac{(41481 + 5500) 7 + 4326 \times 55}{2} = 283,398 \text{ lbs.}$$

and 283398 × cot 30° = 490860 lbs. = horizontal thrust.

Width of abutment = 7 feet = W

Height of abutment = 19 „ = H.

B = required breadth.

$$\text{Then } \frac{100.H.W.B^3}{2} + 500.W.B^2 + 283398 \times W = 490860 \times 13.14$$

Whence B = 14.86 feet.

Therefore 15 feet will be the breadth of the abutments (arranged in steps at the back, as in Plate XXIV.) with two counterforts to each abutment, 6 feet long and 2½ feet wide.

Crushing Weight at Key-stone.—The crushing weight at key-stone of main arch = $\frac{\text{Horizontal thrust}}{\text{Sectional area in inches}} = 184 \text{ lbs. per square inch.}$

The crushing weight of brick-work is 1,500 lbs. per square inch.

Calculations for the dimensions of an ordinary bridge of the same span, &c. Plate XXV.

MASONRY GIRDER BRIDGE.

Fig. I.
Elevation.

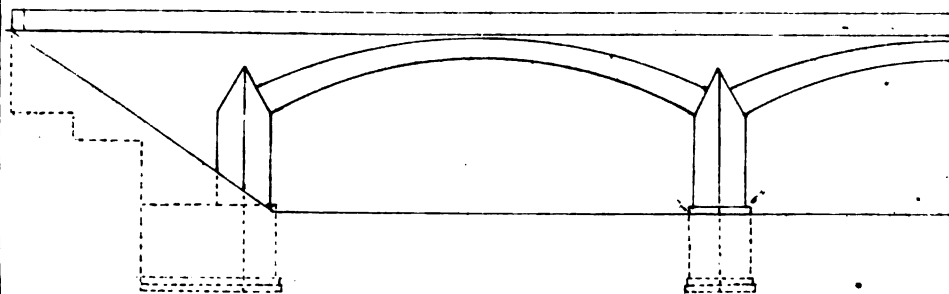


Fig. II.
PLAN.

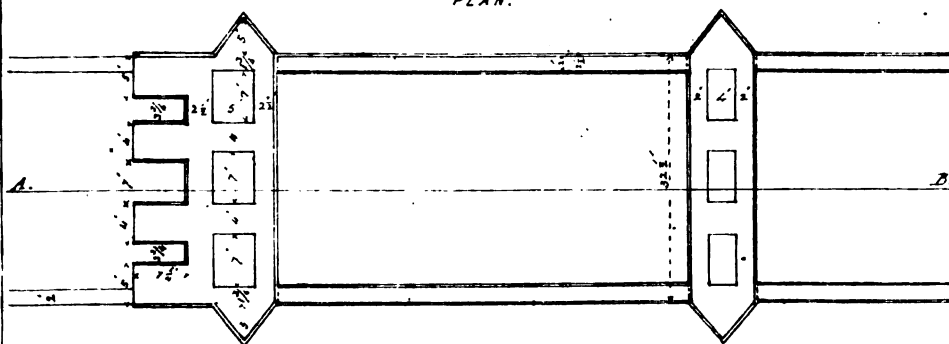
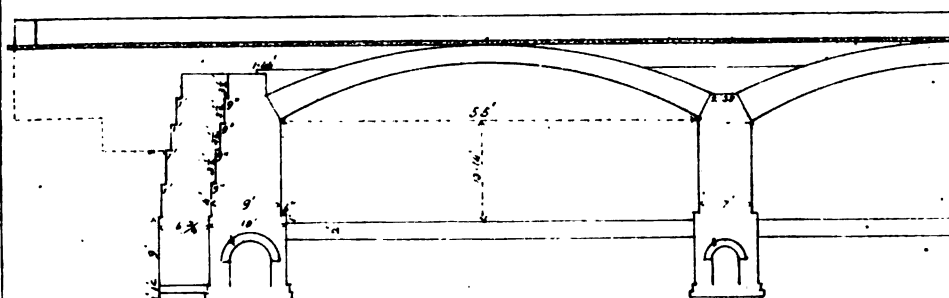


Fig. III.
Section on A.B.



Scale, 1" = 100 feet.

Total area of HNRKM (Fig. 2) = $23.64 \times 55 - 997.04 = 303.16$.

Total weight per foot borne by each abutment with moving load =
 $\frac{30316 + 5500}{2} = 17,908 \text{ lbs.}$

and $17,908 \times \cot 30^\circ = 31018 \text{ lbs.} = \text{horizontal thrust.}$

Height of abutment = 19 feet = H

B = required breadth.

Then $\frac{HB^2}{2} + 500 B^2 + 17908 \times B = 31018 \times 13.14$

B = 7.52 feet.

Let the abutments be 9 feet broad with four counterforts 7 feet long, the two inner ones 4 feet wide and two outer 5 feet wide, and reduced at the back as shown in Plate XXV., Fig. III.

The face walls to be $1\frac{1}{2}$ feet thick, and the remaining dimensions as shown in Plate XXV.

REMARKS.—In a small bridge of three bays, there is a saving of from 7 to 10 per cent; but in a large bridge requiring (say) 1,925 feet waterway, or thirty-five such bays, and having five abutment piers, the comparative cost of a bridge of ordinary construction, and of the four Designs given, would be as follows:—

	TOTAL COST OF BRIDGE.			PER CENTAGE.	
	RS.	A.	P.	Gain.	Loss.
Bridge of comparison,	1,99,255	13	8	...	...
Design, No. 1,	1,80,090	4	9	9.62	...
" " 2,	1,74,328	14	9	12.51	...
" " 3,	1,79,170	13	6	10.08	...
" " 4,	1,79,184	12	9	10.07	...

But in such a bridge the curtain walls would be of a more expensive construction, which would decrease the percentage. The foundations, on the other hand, being also more expensive, would raise the percentage, so that a saving of 10 per cent. may be taken as a fair average. The above figures show that, *ceteris paribus*, a long bridge gives a greater

percentage of saving than a short one, and in page 154, it has been shown that the wider the bridge, the cheaper (proportionally) such a construction would be. The Hexagonal Syrian Tiles (the construction of which, by Col. Fife, was published in Vol. I. of the Professional Papers on Indian Engineering) would make a capital material for the cross arches. In England small arches, up to 25 feet span have been constructed of a single ring 6 inches thick of corrugated clay pipes, and found to stand the passage of heavily laden waggons without being in the least injured.

For second class bridges, I propose building two main arches (as in Design, No. 4) with the inner face walls (called in previous Designs, abutment walls to cross arch) made thick enough to stand the pressure of the backing, and built to a level with the top of the crown of the main arches. On these walls will rest wooden beams bridging over the intervening space, and on these beams will be laid the roadway, as in ordinary iron or timber bridges. The width of the main arches will depend on the span. Such a roadway between the main arches would add so little to their weight (and consequently thrust) that the abutments would be comparatively small. The saving in the cost of such a construction would be much greater than in the above Designs, and the bridge can be made as permanent as required.

The advantages in the Designs given are—

1. There is a large saving in expense.
2. Should workmen be scarce and the stream to be bridged subject to freshets likely to carry away the centerings and destroy the unfinished superstructure; only one main arch (or less than one-third of an ordinary bridge) need be built at a time, when the damage done would be considerably less, and might often be avoided altogether.
3. The amount of material to be collected and the number of laborers would be greatly reduced. The iron work being of the simplest description can be done by ordinary native blacksmiths.
4. In deep well foundations the percentage of saving would be enormously increased.

F. D. M. B.

NOTE BY EDITOR.

I doubt whether in ordinary cases, the 10 per cent. saved would not be

Cubic contents, and cost of one Abutment.

[illegible]

Cubic contents Flooring of one Bay.

	Masonry.		
	C. ft.	R.	A. P.
Bridge of comparison,	4,428	1,107	0 0
Design, No. 1,	4,428	1,107	0 0
" No. 2,	4,428	1,107	0 0
" No. 3,	4,428	1,107	0 0
" No. 4,	4,428	1,107	0 0

Comparative Total Cost of a Bridge of three Bays.

	Total cost of foundations.			Percentage.			Total cost of super-structure (with-out flooring)			Percentage.			Total cost of Bridge including flooring.			Percentage.			Remarks.
	R.	A.	P.	Gain.	Loss.		R.	A.	P.	Gain.	Loss.		R.	A.	P.	Gain.	Loss.		
Bridge of comparison,	2,992	2	0	...	...		13,549	10	6	...	...		19,862	12	6	...	...		
Design, No. 1, ...	2,615	9	6	12-60	...		12,472	7	6	7-94	...		18,409	1	0	7-32	...		
" No. 2, ...	2,552	14	6	14 71	...		12,018	2	3	11-30	...		17,892	0	9	9-98	...		
" No. 3, ...	2,771	5	6	7-39	...		12,246	12	3	9-62	...		18,339	1	9	7-67	...		
" No. 4, ...	2,058	12	0	31-22	...		12,730	15	3	6-04	...		18,110	11	3	8-33	...		

		Ra. 32 per 100 cubic feet.	Brick-on-edge flooring,	...	...	Ra. 25 per 100 cubic feet.
<i>Rates.</i> —Heavy arch masonry, including centerings,						
Light arch masonry	do., up to 18½ span,	Ra. 27 "	Plain masonry...	...	...	Ra. 19 "
Ditto,	do., up to 16½ "	Ra. 26 "	Kunkur metalling,	...	...	Ra. 8 "
Iron bars, including nuts and workmanship,		Ra. 12 per maund.	Earthwork	...	...	Ra. 4 per 1000 cubic feet.



counterbalanced by the more complicated construction proposed. But the fourth advantage claimed, where expensive foundations are employed, appears deserving of much consideration. Supposing, for example, in a railway bridge with 100 feet spans, that the masonry piers supported on deep well foundations were so far modified, that the centre portion of the pier, instead of being continuous, were replaced by an iron girder carried on the two end portions. This cross girder would carry the two inner longitudinal girders (or two inner rails, in the case of a double line), the two outer girders being carried on the masonry ends of the piers. Such a girder would have a length (or bearing) of (say) 16 feet, a depth of 18 inches, and would have to carry a distributed load of 100 tons, for which a section of 30 square inches for either flange would be amply strong; while the cost of this short girder would be very much less than the portion of the masonry pier which it replaced, and the extra wells required for its foundation. This of course has nothing to do with the above calculations so far as arches are employed, and is simply another form of open piers, as when hollow cast-iron tubes are used, for instance. But it might be employed where iron cylinders or screw piles could not be procured; while the iron girders, if not procurable, might be replaced by timber.

No. CVII.

ROADS IN ASSAM.

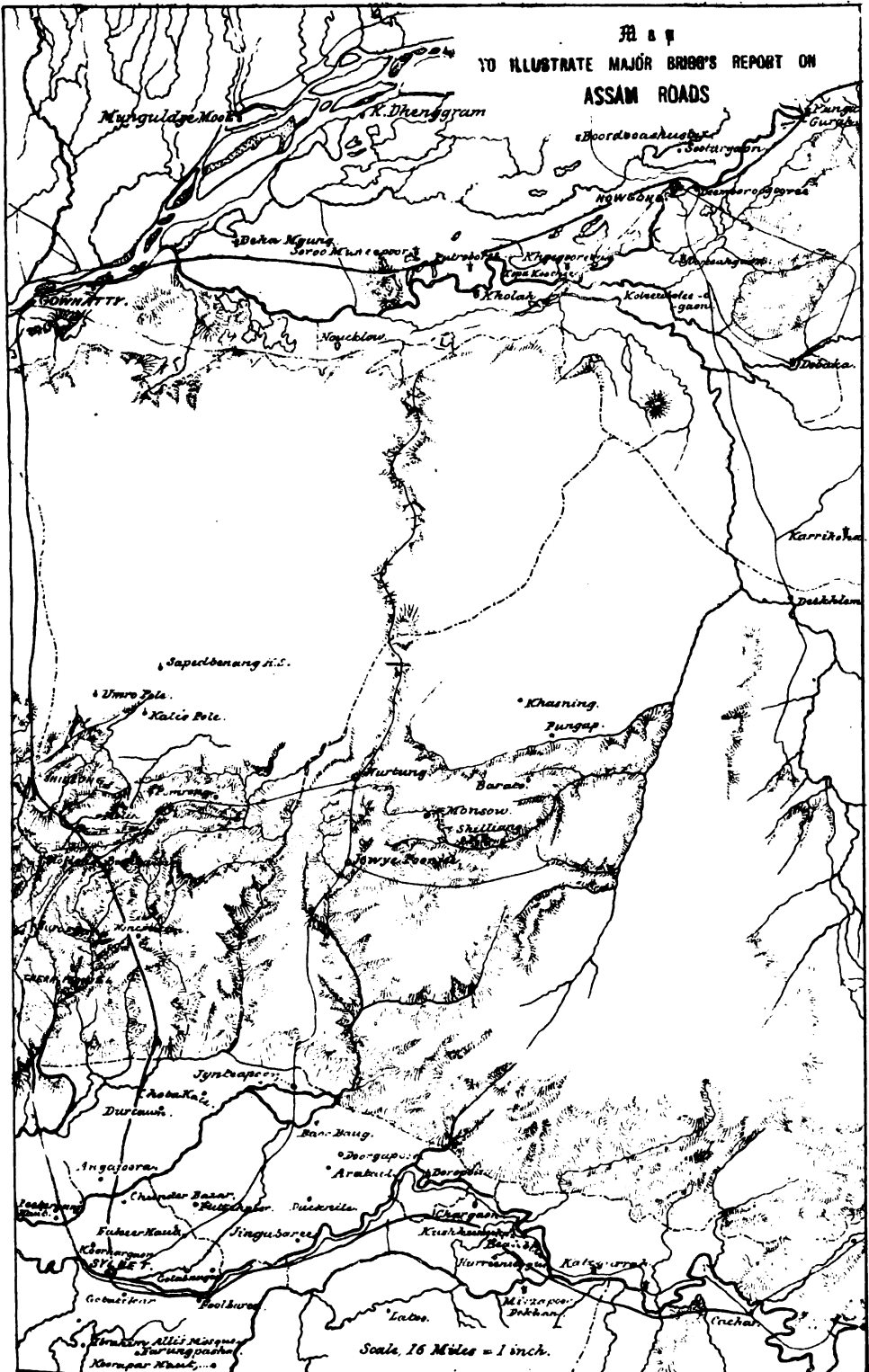
(2ND ARTICLE.)

Report on the Road from Gowhatty to the Sylhet River, by MAJOR D. BRIGGS, Superintendent of Works in Assam.—[See Map, at p. 50].

THE country lying between Gowhatty and the main axis of the Cossyah Hills, of which Shillong is the crowning height, was only known to Europeans along the Nunklow hill-path, and this was held in so bad repute from its unhealthiness, that those who ventured the journey along it did so as fast as the means at their command permitted, and considered themselves fortunate if they escaped the malarious fever which, undoubtedly, pervaded it at almost all seasons of the year. This route was wholly unadaptable to a line of road with gradients not exceeding 1 foot in 25.

Another route to the eastward was known to a few Officers, and was recommended in 1862 for adoption as the future hill road between Gowhatty and Shillong. But I found it generally so deeply imbedded in swamps and low bottoms that for this and other reasons given in my letter of the 20th November, 1862, I strongly declared against its adoption.

It seemed to me that as both of these routes were intersected by streams flowing in opposite directions from a range of hills lying between them, and that as this range abutted on the plain close to Gowhatty, I should in all probability find that a line of road might be taken close to its watershed, which would ensure a higher and healthier route, the absence of all large rivers, and probably afford a natural inclined plane sloping upwards to the great elevated plateau of the Cossyah Hills. It will be seen that in these qualities my surmises were found to be generally correct.



Although I have spoken of a range of hills lying between the two routes, it must not be supposed that this is a peculiar feature in the aspect of the country. So far from it, the whole of the space between the Cossyah Hills, properly so called, and the Valley of Lower Assam, is crowded with a mass of rounded hills apparently detached, but in reality (following the almost invariable law of physical geography) joined by low and narrow passes. The tops of these hills vary from 1,500 to 3,500 feet above the sea level, and their connecting links or passes, which become obligatory points to a road taken in the direction of the axis of any one of them, vary from 1,800 to 3,000 feet, the height increasing as the axis nears the mass of mountains from which it has been thrown off.

The appearance of these hills when viewed from the superior range of the Cossyachs is like a tumultuous but unbroken sea, no wave rising above one normal level, but no portion absolutely smooth. Where the general elevation is below 2,500 feet, the hills are covered with dense bamboo and tall grass jungle. The *sál*, *jamoon*, *gunree*, and *semel* are the common forest trees. Above that elevation bamboo generally ceases, and, except in the bottoms, the grass is of moderate height, and a pine very similar to the Scotch fir becomes the ordinary forest tree. Above 3,000 feet oak becomes common. I am inclined to associate the fever level with that of the pine.

These hills, with an exceptional wall of cliffs, or granite crags exposed by the action of water at their base, are well covered with soil, generally of a rich red quality of that kind favorable, I believe, to the growth of Tea. This depth of soil presents to the Engineer fewer natural obstacles than are generally met with in the construction of hill roads. It is also of a nature which promises to preserve its form when the section of a road 24 feet wide is cut from the hill side.

Throughout this undulating mass of hills there are but few villages. Five and six miles may be passed without the traveller seeing one, yet at almost every mile there are vestiges of former habitations, deserted, it is said, in consequence of the ravages of wild elephants. The crops of hill rice, pulse, and cotton, which are here and there met with, are all fine in quality, and the specimens of the latter were the heaviest bolls I have seen in Bengal. Unlike the distinctiveness of race and language which characterise the peoples of the mountains shutting out the Valley of Assam from the south, the population of these lower hills is of a mixture of tribes.

The Garrow, Meekir, Cacharee, and Cossyah are found here all living together, and although not so powerfully made as the true Cossyah, yet the mixed race is a fine one and marvellously superior to the lazy and effeminate people of Assam. They are quiet, good-natured, fond of home, and far more temperate than the inhabitants of the higher hills. They are great woodsmen, using the *dhou* with admirable facility, but are destitute of the means of waging war against the wild animals from which they suffer. As a rule, they have neither guns nor bows, and the art of snaring or trapping, so well understood by neighbouring tribes, is to them almost unknown. This is the more curious, that they are great admirers of flesh, and are quite without prejudice as to the kind, quality, or condition. A morsel of an elephant found dead on their hills, or a succulent puppy bought at the Bengallee *haths*, are equally prized delicacies.

Having dwelt somewhat at length on the description of the country between Gowhatty and the Cossyah Hills Proper, because it is a region hitherto unknown to Europeans, I will not give a separate description of the well known ground of the Cossyah range, but merely notice such parts as affect the line of road, when describing its course with reference to map and section.

Attached is a section of the entire line of road from the Berhampooter at Gowhatty to the Soormah at Sylhet. The heights were taken by Aneroid Barometer compared with the standard in the Surveyor-General's Office in Calcutta; and the distances, partly by actual measurement, and partly by computation of the length of base, corresponding to the observed difference of height proceeding at a known gradient. In many places the jungle was so dense that the line could not have been measured without a clearing being first effected, and that would have delayed me far longer than my other duties could permit. A map on a scale of 4 inches to the mile showing this line of road and all new roads being constructed or surveyed within the circle, is now under preparation and will be forwarded when ready. In the meanwhile the Cossyah and Jynteah Hill map will serve the purpose of this Report.

After passing through six and a half miles of the Assam Plains to the south of Gowhatty the line ascends 950 feet, at a gradient of 1 foot in 25 for four and a half miles, with a level break of half a mile. The line then descends 250 feet to the Gorbungah Valley, which lies between the last high Station and the Kukra Seel Pass. This descent is easily effected at

a gradient of 1 foot in 40. But when the ultimate point to be reached was still upwards, this descent is, of course, contrary to the true principles on which hill roads should be laid out, as the Engineer has no right to impose on the traveller the double ascent of so many hundred feet. The choice lay between winding for six miles up and down a lateral valley, or introducing the easy gradient of 1 in 40 for a mile and a half down and a mile and a half up to the Kukra Seel Pass, and the latter course was preferred. For the same reason the abnormal descents at the 22nd mile, the 36th mile, and the 49th mile, became necessary to avoid an increase of distance of some eighteen miles.

After a short descent of 1 in 33 from the Kukra Seel Pass the line proceeds at a very easy gradient through long flat valleys to the Oomur Nuddee. On either side are hills covered with the unrivalled forest growth of Assam, and here it is that the soil is of so excellent a quality for the growth of tea. The line crosses several small streams, tributaries of the Oomur, which is crossed at a spot easily bridged, where its crystal stream dashes over a ledge of rocks; and this site has been selected for the first Inspection Bungalow. The valley is well stocked with magnificent sal trees, and being at a general elevation of more than a thousand feet, is always comparatively cool.

Between the Oomur and the Amtenah streams, a rise of 150 feet at 1 foot in 33, and a corresponding descent is necessary to cross a small intervening range on which cotton and hill rice are cultivated. The Amtenah will require a bridge of 70 feet span, the largest on the whole line of road until the Sylhet Plain is reached.

From the Amtenah the line recovers the watershed by ascending for three miles, at a gradient of 1 in 33, to the obligatory Pass above Punkir village. It passes through rich red soil covered with forest presenting no difficulties. Here it meets the head of a long flat valley which extends down to the old Nunklow road near Nowgong, and which some twenty years ago was covered with cultivation. The annoyance the villagers met with from wild elephants caused its abandonment; but now, in consequence of the large clearings the road will require, its re-cultivation is confidently looked for. Crossing the head of this valley to a series of obligatory points on the watershed line, it passes along them at easy gradients and level spaces until it strikes the Oomloor river near its source close to the village of Palliar. Here, at 2,200 feet above the sea level, the first

pinces are met with, and from this the natural growth changes from dense bamboo jungle and lofty grass to comparatively low grass, and an entire absence of bamboo and other plants characteristic of the Assam jungles. Two miles beyond Palliar, at an elevation of 2,500 feet, we are building the second Inspection Bungalow from Gowhatty, and I believe the spot will prove generally healthy and above the limit of the fever stratum.

Having reached 3,000 feet we are obliged to descend at 1 foot in 60 and 1 in 100 to the next obligatory point on the watershed, (elevation 2,772 feet) from which we run up easily to the crossing of the Putran stream, the eastern tributary of the great Borpanee river which flows under Nunklow. It will require a bridge of 65 feet. The descent is through beautiful glades, bounded by grassy knolls, on which magnificent red barked pine trees cluster in groups, more pleasing to the eye than art could ever have devised. If this mass of swelling uplands proves as healthy as the appearance of the few inhabitants promises, and as my native predilections in favor of the healthful atmosphere of the pine suggests, another wide field in the waste garden of Assam lies ready to repay the industry of the English settler.

The ascent from the Putran stream to the first terrace of the Cossyah Hills Proper, forms the longest incline on the road, at a gradient nearly approaching 4 feet in 100, which Government was pleased to fix at my suggestion as the maximum. The incline varies from 1 in 33 to 1 in 25 and is twelve miles in length. To have eased the gradient would have added to the length of the road, which I thought objectionable. These twelve miles lie through a magnificent forest of pines, many of which attain great size. Although there are some stiff rocky banks to be cut into for the full section of the road, yet, except at one spot, there is no continuous line of cliffs. The exception is where the line cuts a wall of granite about 200 feet in length, at 40 feet from its top. In two places narrow spurs will be cut down 30 feet, and at the top of the pass there will be 20 feet taken off its height. Here, at an elevation of 5,222 feet, the third Inspection Bungalow will be built. The two already adverted to are being built in the ordinary Assam style of thatched roof on posts, with bamboo mat walls and flooring, costing about Rs. 250 each; but such will not do at this elevation. Good rubble stone walls, chimnies, and planked flooring are required; and it is hoped that Government will sanction Rs. 1,500 for each Bungalow in the Cossyah Hills, as it is

impossible for the Road Officers to live in tents during the greater part of the year without losing their health; and, as a matter of mere economy, it is cheaper to provide weather-tight accommodation than to have them frequently unfitted for duty through sickness.

After reaching the top of the Pass, which I will call that of Nongrim-chitla, (for the village of that name is within $2\frac{1}{2}$ miles,) we enter upon a country of long flat valleys and bare ridges, grim and sterile in appearance during winter, from the almost total absence of trees, but during spring and summer spread with a richly tinted carpet of wild flowers and berries. Where, too, the soil is best, hundreds of acres of potatoes show its richness by their luxuriant growth, and prove the fitness of the climate for European crops. The cattle also, by their size and sleekness, evince the nutritious property of the natural grasses, and suggest speculation as to the weight and quality of the beef they might produce if stall-fed in winter with the turnip, which the potato land would undoubtedly supply.

The flat valley country extends, with only one interruption, for ten miles in the direction of the line of road, and widens out to great breadth in the neighbourhood of the village of Marpana, stretching up on the broad flank of Dinghai, which rolls up its massive out-line in the eastern horizon to a height only 370 feet less than Shillong. The one interruption alluded to is the second terrace of the Cossyah upper plateau, the rise from 5,200 feet to 5,600 feet. Except in temperature there is no difference between the two, therefore I have described them as one. This rise is arranged at a gradient of 1 foot in 27 along the face of a hill presenting no special difficulties.

Under the village of Marpana, the road shoots through a chasm formed by the river of that name, and this will constitute one of the most picturesque parts of the line. The river rushes from one flat valley to the next, through a narrow opening between two ranges of cliffs, so narrow that it is not seen until the gorge is entered. From the cliff on the left bank the road will be cut, crossing the river where it turns sharply to the east by a bridge of about 50 feet span. It then gently descends at 1 foot in 33 to a highly cultivated valley, which it first touches, and then slips over a low pass into another fine valley leading to the Kuksee Nullah.

The Kuksee, lovely as a Devon brook in its clear deep pools and sparkling runs, its mossy banks glowing with wild flowers and the bright straw-

berry, with here and there a rugged rock to force its calmer beauties into stronger contrast, bounds the last of the open valleys north of the "Wailing Waters," the rock-bound and terrible Oomeeam. Through oak copse, birch, and rhododendron, the road gradually ascends to a pass 200 feet above the Kuksee, from which pass it winds down to the Oomeeam, crossing the river just before it is thrown into an abyss more than 1,000 feet in depth. In the ascent, a chasm of 60 feet has to be bridged, and in the descent about one quarter of a mile of very compact slate has to be cut through; otherwise no extraordinary difficulties occur.

From the Oomeeam, the line ascends at first at a gradient of 1 foot in 30 along the very precipitous hill-side which slopes down to the river. Here the excavations will be heavy for about one mile, but the rock is not compact, and will offer no great impediment to the work-people. Near the village of Marbeesoo the line joins the present road from Moflong to Shillong, about three miles distant from the western boundary of the station. At this point, after crossing a tributary of the Oomeeam, a fertile valley is followed up to the west flank of the Shillong mountain, the gradient being 1 in 55 and the distance four miles.

Having described the line as far as Shillong, I will state what work has already been done between it and Gowhatty, the cost, and our immediate requirements; but in doing so here, I beg to be understood as not in any way depreciating the project for the extension of the line of road to the Sylhet Plain. Without this extension the project would be but a half measure, and its great political and social advantages would remain undeveloped. Besides, I state the opinion of the Civil Authorities when I say, that without a cart road to Sylhet it will be impossible to keep Shillong supplied with ordinary provisions.

As I write, it is just a year since I commenced exploring the country to the south of Gowhatty, and we now have the road (with the exception of a break of about ten miles) open for ponies or laden mules. Those ten miles will, I expect, be completed by the time the Report is in the hands of the Lieutenant-Governor. There are narrow places where little could be done without blasting, and although long since applied for, neither tools nor powder have been sent from Calcutta.

We have suffered from the want of Officers and subordinates generally, while the want of labor has, of course, been a great source of trouble and

anxiety. It is not solely the result of a paucity of inhabitants in the country; a good deal is due to the want of Assistants and fit subordinates, because had they been available, work could have been commenced at many different places, drawing labor from the neighbourhood which could not be induced to move to more distant parts of the line.

The entire outlay up to the present date has been Rs. 14,655, and upwards of seventy miles are open to a minimum of 5 feet in width. This sum includes all expenses in surveying and laying out the first trial lines; in carefully surveying for Estimates thirty miles of finished bridle road; in a mile and a half of very heavy earthwork in the Gowhatty Plain, where the road passes through inundated ground; in building temporary timber and bamboo bridges over every stream; in clearing jungle for 50 feet on each side of road for twenty-five miles; in building one Inspection Bungalow and commencing another; in building numerous sheds for tools and hutting coolies; and in carrying out provisions for them, and establishments generally.

Upon the whole road the average cost has been close upon Rs. 200 per mile, which includes balances in hands of disbursers and contractors.

Considerable interruption to progress has been occasioned by the necessity of sending out from Gowhatty all requisite stores, provisions, and tools; carriage for such draws a number of laborers from road work, and disgusts many more who object to be made porters of. I am now in treaty for the purchase of some mules, which will, I trust, be a source of relief to all parties.

We are establishing shops for grain near all the Inspection Bungalows, so that, I trust, ere long the road may be travelled without inconvenience or hardship.

I will now describe the line I have selected for the descent from Shillong to the Sylhet Plain, which, for reasons stated, differs somewhat from the line I examined in 1862. The highest point reached by the road at Shillong is by aneroid 6,088 feet above sea level. The Sylhet Plain is by the same instrument 52 feet. The base required for such descent at a continued gradient of 3 feet in 100 is thirty-six miles nearly. The intervening valley of the Bogopanee and the necessity of keeping as near as possible to the watershed line, to avoid a mass of difficulties which the well-known precipitous walls lining the southern face of the Cossyah range

presents, obliged me to increase this base to fifty-three miles. But this is no drawback to the excellence of the line, because an unbroken ascent of 8 feet in a 100 for so great a distance would have been very severe upon draught cattle, and the selected line in no place proceeds very much out of its true direction.

The difficulty was to find a base of sufficient length which did not run us into the great natural bastions of sandstone above-mentioned, and which would not necessitate zig-zags, those most objectionable make-shifts for avoiding difficulties in hill roads. This was the objection I found to the line explored in 1862, when I came to lay it out.

I first of all examined two lines running through Cherra Poonjee, (which station I should have liked to have brought on to the line of road,) one to the westward by Chelah, the other, taking the line projected by Lieutenant Yule (now Colonel Yule, C.B.) in 1842, for the incline from the coal mines to the plain. Both I found led through very difficult ground, and would have entailed many zig-zags. Besides, Cherra stands immediately overlooking the plains at a height of 4,400 feet above them; such a difference of level would have required a base of at least twenty-two miles, whereas the distance by footpath is not above eight. This would not only have been a highly unpopular feature in the road, but would in reality have considerably increased the distance from Shillong to the plains, as the country between Shillong and Cherra undulates too steeply for a cart road upon the line of the present path, and this would have necessitated several inclines quite out of the true direction, thereby considerably lengthening the distance beyond what it is at present.

I then tried the line which I explored in 1862 through Lailankhote, descending from the gorge by the stream which flows southward towards Ponduah, but this led through such ground that for miles I could not obtain even footing. To explore the line for a hill road when the glens and ridges are covered with jungle, and to lay it out at a restricted gradient, are two such different operations that it is almost impossible to estimate by mere exploration either distances or difficulties.

I lastly tried a line through Lailankhote down the long spur passing Nonkredem, the residence of the Rajah of Khyrim, and abutting on the Sylhet Plain at Lukhet. Here I found a possible base line through a country generally favorable (with the exception of four miles near Nonkredem), reaching the plain within twenty miles of the station of Sylhet.

In my letter above quoted I suggested that the southern terminus of the road should be at Chattuck, because that was the highest point on the Soormah that steamers could reach at all seasons of the year; but it has since been pointed out to me that Chattuck is no base from which supplies for Shillong could be drawn, and that unless easy communication is established with Sylhet, there will be great risk of the troops and residents at Shillong being hard-pressed for provisions. Again, it has occurred to me that, as Shillong is looked to as the great sanatorium for the hundreds of European Planters who will ere long overspread Cachar and Sylhet, it is but right, provided there is no fatal objection, that the southern approach to it should be from a central point, such as the town of Sylhet.

In my letter of the 9th December 1862, I was led into error as to the probable distance from Gowhatty to Chattuck, which I stated as about 104 miles. The almost impenetrable mass of jungle which covered a portion of the hills between the Cossyah range and Gowhatty prevented my seeing much of the sinuosity of their contour, and my endeavors to reduce the general gradient to a rate not exceeding 1 in 30 have considerably added to the distance, which will now be, from Gowhatty to Sylhet, 154 miles. The distance by the old mountain road *via* Cherra Poonjee is 142 miles. Considering that the first is to be a cart road with no gradient exceeding 1 in 25, and the second was laid out without reference to gradients at all, except that at which a pony could climb, the result is more favorable than that ordinarily obtained in hill roads.

I will now examine, in detail, the line adopted from Shillong to Sylhet, of which about four miles in the valley of the Bogapanee is open to 18 feet in width, and the rest only laid out.

Leaving the western shoulder of Shillong at 6,088 feet, the descent of 600 feet to the torrent of the Bogapanee is effected at a gradient of 1 foot in 33 for four miles, and nearly level for two. The hills are bare and covered with short grass. The geological formation presents few difficulties. This is the chief iron region of the Cossyah Hills, and large quantities are continually being taken to Lukhet to barter for grain and the produce of the plains. The projected road will assist this traffic greatly.

The erection of a stone bridge over the Bogapanee with timber platform was commenced last year, but a very great rise in the river swept away the centre pier before it was half built up, and a fresh project, avoiding any intermediate pier, is now under preparation. Four miles further down this

river, an iron suspension bridge was built about 1844, but was swept away by an extraordinary rise in the river six years afterwards. I believe that an entirely stone bridge of one opening of 90 feet span will prove the best structure for this very troublesome torrent.

After a mile and a half of ascent through huge boulders of granite the road reaches Lailankhote, where it crosses the Cherra Poonjee and Jowai road. The ascent is easy, and with proper blasting tools, the formation of the roadway will not be difficult. From the Lailankhote plateau commences the steady descent to the Sylhet Plain, unbroken, except by a few level portions, and it is between Lailankhote and Nonkredem where the only real difficulties of the line are met with. The hill sides are there very steep, and the rock line near the surface. It is, according to Oldham, of the metamorphic series, and is decidedly difficult to work.

The first difficulties are caused by a sudden break or wall in the spur of 460 feet in depth. This obliges us to cut the road out of the steep hill side facing the east, which is exceedingly rocky and precipitous. There is no other available line, and so we must face it. After reaching the bottom of this wall at an obligatory point called Roloo, we skirt a peculiarly isolated hill and pass on the watershed line, following it to Nonkredem. In several places it is nothing but rock forming narrow sharp ridges, at present broad enough only for a very bad mountain path. These sharp ridges will have to be cut down until a sufficiency of width is obtained for the road. As stated in my letter above quoted, it is scarcely possible to have all this rock excavation effected without the assistance of a Company of Sappers, or at least a body of men accustomed to blasting operations. We have taught a few men here and there; but I can testify, from long experience in such operations, that a mass of excavation in rock can only be successfully accomplished by the concentration of a considerable force worked in a systematic manner.

After passing Nonkredem we return to the sandstone formation, affording easy ground for a hill road passing over grass slopes broken here and there with oak woods. On the opposite hill, Cherra Poonjee can be easily seen, but between it and the line lies a tremendous chasm, eight miles in width and 4,000 feet in depth.

The same easy ground extends the whole way down till within 1,000 feet above the Sylhet Plains. Occasionally rocks are met with, but no extensive cliffs. The hill sides are generally pretty clear of jungle, and

nothing could be more favorable for a line of hill road. At Tunginath, 4,400 feet above the sea level, the coal seams described by Mr. Oldham* are passed. The distance to them by road from the plains will be probably twenty-five miles.

At 1,000 feet above the plains commence dense plantations of areca, jack, and orange trees, for which the south face of the Cossyah and Jyn-teah Hills is famous. They grow on very little depth of soil and over rough rocky ground. The road will be expensive throughout these five miles of descent, but not more than ordinarily so in hill road work. There will be a good deal to pay for compensation for damage done to the plantations, probably about Rs. 3,000 per mile, or Rs. 15,000 in all.

It may be well here, where my description of the hill portion of the road ceases, to state what my opinions are now as to the mileage cost of a 24 feet road across from plain to plain. Assuming as the rates for excavation, Rs. 5 per 1,000 in soil; Rs. 8 in stony ground, reducible with pick-axe and crowbar; Rs. 15 in rock and slate, where frequent blasting will be necessary; I estimate that there will be—

56	miles of the first.
67	" " second.
7	" " third.

The section of the first class will give about 2,64,000 cubic feet per mile. The section of the second about 6,33,000 per mile. The section of the third about 12,67,000 per mile. From this we have—

	Number of miles.		Cubic feet per mile.		Rate per 1,000.		Cost.
First class, ...	56	×	2,64,000	×	Rs. 5	=	Rs. 73,920
Second class, ..	67	×	6,33,000	×	" 8	=	" 3,39,288
Third class, ...	7	×	12,67,000	×	" 15	=	" 1,15,000
400 masonry culverts, at Rs. 5,000 each	...	...	...	...	...	=	" 2,00,000

(Stone everywhere procurable.)

750 running feet of stone and iron bridge, at 120 per foot, " 90,000

Probable cost of road within the hills, Rs. 8,18,208

To this has to be added twenty miles of road in Sylhet Plain,

at Rs. 4,000 per mile, " 80,000

And 700 feet of masonry and iron bridges, provided the Peine
and Gwine rivers are bridged, at Rs. 120 per running foot, " 84,000

Probable total cost of road, Rs. 9,82,208
or about Rs. 6,000 per mile.

* See Oldham's *Geology of Khasia Hills*, p. 66.

About one-half the road may hereafter require to be metalled.

I have only now to describe the portion of the line in the Sylhet Plain. It is not generally more than 50 feet above the level of the sea, and is consequently liable to inundation from the backing up of the rivers during the rainy season. This is more especially the case immediately under the hills, where the elevation is still less than on the banks of the large rivers that intersect the valley, the Soormah and Kooaheerah. These, by the deposit of silt are being gradually raised above the normal level.

In any case, then, a road communicating between the hills and any town on these rivers, must pass through a certain portion of low country. The direct line from Nya Haut, where the Shillong Road will reach the plain, to Sylhet, will pass through about four miles of inundated country on either side of the Peine river. After doing so, it reaches a highly cultivated rice country passing near Durgam and Angajoor to the Salooke Ghaut on the Gwine or Ghinga Khall. From the Ghaut a very heavy bunded road exists to Sylhet, six and a half miles distant. It is also bridged, but from the employment of bad material the bridges are falling into decay. I propose having both the road and bridges put into better order. They have not hitherto been under charge of the Department of Public Works. The Peine and Gwine rivers will each require bridges of 800 feet in length, divided into bays of 60 feet. Wrought-iron girders upon screw piles will be most suitable.

In concluding this Report, I may state that from what I now know of the Cossyaha, I believe that this great work might be constructed within three years. Bringing into easy communication Assam and Sylhet, whilst at the same time it opens out a sanatorium for each, and extends the area of rich culturable land to the European settler, it affords the best security against future Jynteah outbreaks, and appears in all its bearings to be a most desirable undertaking.

D. B.

No. CVIII.

PRESBYTERIAN CHURCH—ALLAHABAD.

THE architecture of this building is of the simplest early English with very little ornament, effect being mainly sought by contrast of material and workmanship employed.

The mass of the masonry is of brickwork, pointed on the exterior and plastered interiorly, but all the openings, buttresses and quoins, have stone dressings; and the copings, cornices and pinnacles, are also of stone.

The building consists of a nave and side aisles; the interior walls on either side being pierced by large Gothic arches with deep mouldings springing from stone columns, each of which consists of four cylindrical columns clustered into one.

The principal entrance is through a doorway entirely of stone, with deep mouldings and detached columns in the side jambs, under a carriage porch of coursed rubble stone, the exterior having the face pitched, and the interior dressed to a fairly smooth surface.

There is an entrance at either side into the body of the Church, through a high Gothic doorway, with attached columns of stone in the side jambs, and towards the south end of the Church further from the main entrance on either side, a small porch is attached; one of which forms a vestry, the other an entrance.

The Church ranges north and south. The main entrance is to the north, and the southern end is occupied by a large window of three lights, the jambs and mullions of which are all of stone.

There is a circular window of stone tracery high in the northern gable.

The floor is flagged with stone slabs 18 inches square, alternately white and red in color; the roof covering is of corrugated galvanized iron laid on and bolted to purlins fixed to the principals of the trusses.

The pitch is high, the vertical angle 80° . The trusses of sál wood; hammer and collar beam, the exposed portion being worked into deep mouldings and varnished.

A ceiling of American pine planking, tongued and beaded, and varnished, is laid under the principals and collar beams of the trusses. The contrast of color between the dark sál wood and light colored pine produces a pleasant effect.

The hammer trusses run down and terminate on corbels of stone, somewhat similar in form to the large columns of the nave.

The doors and windows are all of teak wood varnished. Chandeliers, wall and pulpit lights of appropriate design in bronze, have been procured from London.

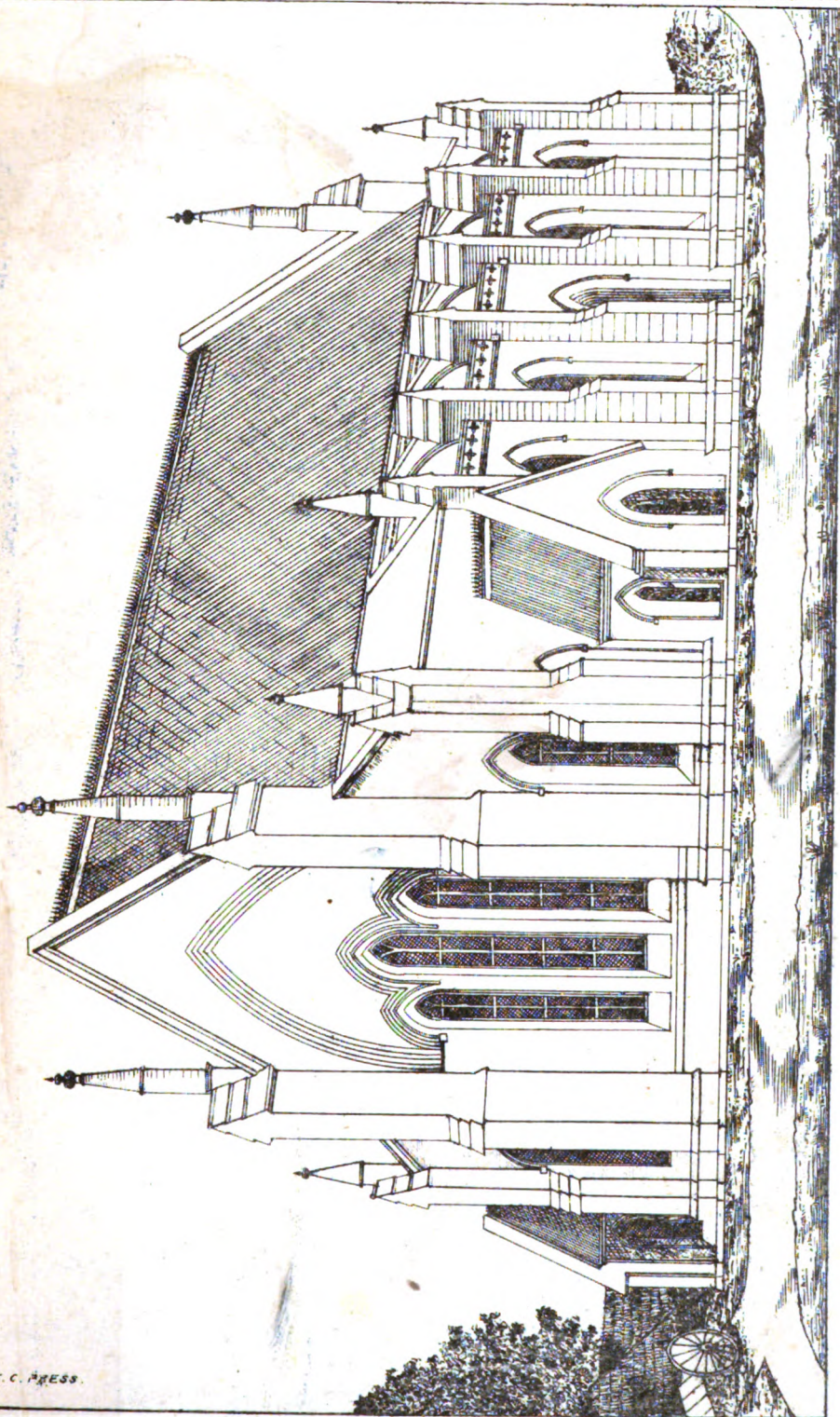
The sittings, when complete, will consist of arm chairs of a simple pattern, ranged within book rails of teak wood, with heavy standard ends to form pews.

The cost has been defrayed in about equal proportions by the Government and the congregation, who hope hereafter to raise funds sufficient to add a tower and spire.

F. W. P.

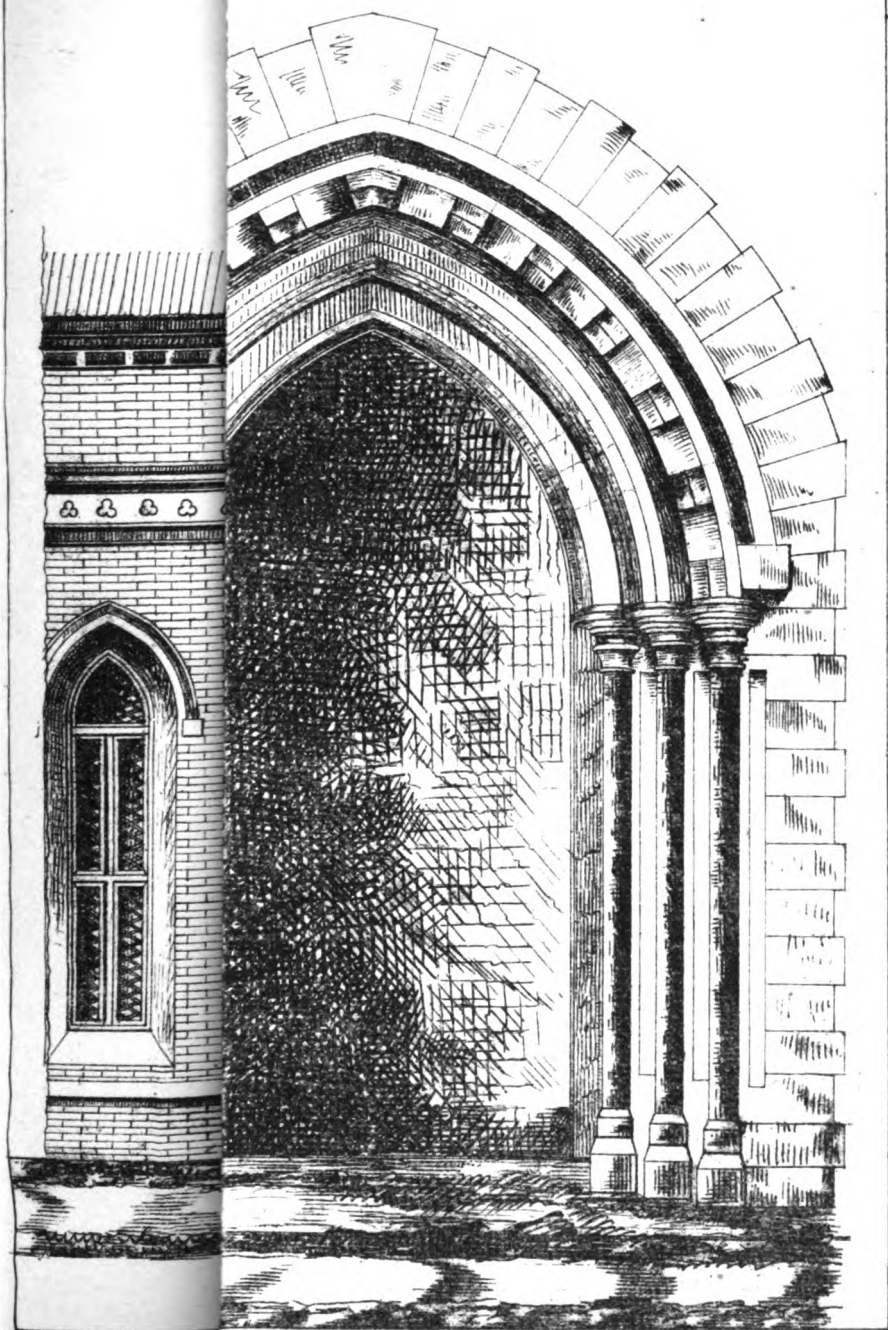
[This Church was built by Capt. D. Limond, R.E., from the designs of Capt. Peile, R.E., Superintending Engineer.—Ed.]

PRESBYTERIAN CHURCH—ALLAHABAD.

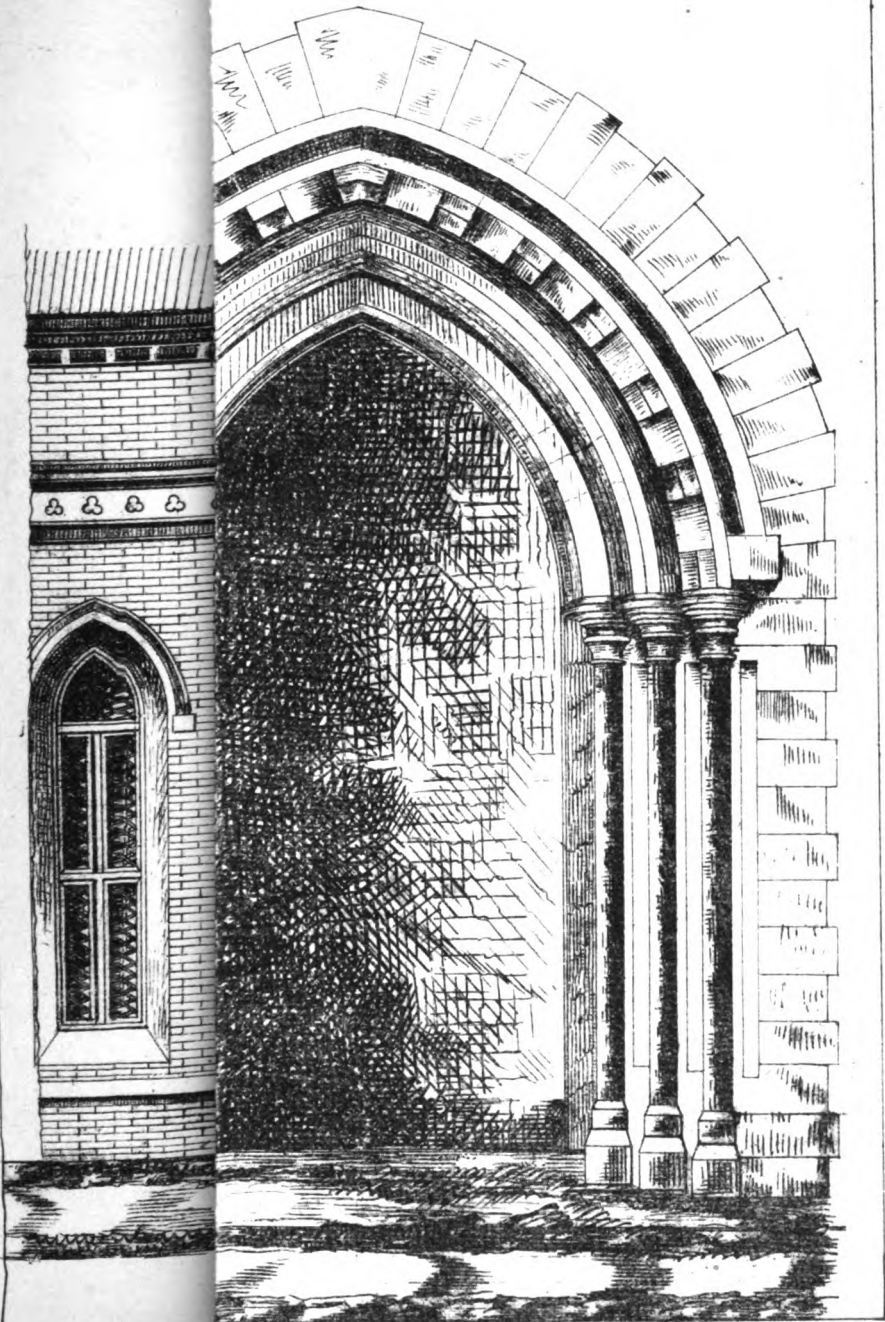


LITHO. T. C. PRESS.

Principal Entrance



Principal Entrance



No. CIX.

RAILWAYS IN WAR.

In whatever degree existing Railways may affect the operations and movements of troops in future warfare, it is undoubtedly extremely important that an army occupying a civilized country should contain amongst its numbers, a small body of men conversant at least with the elementary principles of Railway construction. For, by being familiar with the duty of each part in any structure, we know where to attack it in order to destroy or disable the same according to the exigencies of the case.

In the present paper it is proposed to consider as briefly as possible, in what manner and by what means, a line of Railway may in time of war be dismantled, in order to impede or arrest the enemy's trains; and on the other hand, how the damage done by the enemy may be most expeditiously remedied with available resources. The following remarks, although intended for a Railway constructed with rails supported at intervals in chairs on wooden cross sleepers, (such as the London and N. W. Railway) will be found applicable with modification, to lines with various superstructures of any gauge.

To proceed then at once to consider the different ways in which such a line of communication may be destroyed or rather broken in the field, so as to interrupt the passage of trains, it is proposed to class them under seven heads, the selection from which will depend on existing circumstances. The passage of trains may be interrupted :—

1. By removal of keys and widening of gauge.
2. By displacement of rails with or without destruction of chairs.
3. By displacement of rails and destruction of sleepers.
4. By abduction of rails, chairs, and spikes, with destruction of sleepers.

5. By blowing in the sides of deep cuttings.
6. By the demolition of some permanent structure such as a bridge or viaduct.
7. By blowing in tunnels.

In the first process about a quarter of a mile of line could be disabled by 20 men provided with suitable hammers in half an hour, and the keys burnt or otherwise made away with. The effect would be, that any train travelling along the line would leave the track and considerable damage ensue, unless the driver perceived the alteration of gauge and pulled up in time, which is extremely unlikely; and even in that case, although there would be no more damage than the loss of keys, considerable delay would be the result.

Process No. 2 would require more time, trouble, and additional tools, for should the rails be fished, wrenches as well as heavy hammers,* will be requisite. With these tools, the rails may be abstracted (leaving the chairs on the sleepers) and buried, thrown into a river if convenient, or concealed by other means, as probably it will only be desirous to break up a short length this way. Twenty expert men could certainly complete it in half an hour or less, exclusive of the time employed in making away with the metals.

Process No. 3 will require additional tools, in the shape of shovels and picks for the removal of the ballast, in order to displace the sleepers. It would seldom if ever be advisable to remove the chairs from the sleepers, as the operation is too laborious; for the spikes having rusted, hold with remarkable pertinacity in sound wood, and it is only by continued blows from a heavy hammer that they can be extracted.

By process No. 4, the whole of the permanent way is removed and concealed or destroyed; it must be only on peculiar occasions that this is expedient, as the trouble and time expended would not receive adequate compensation from this entire demolition of permanent way.

By process No. 5, an obstruction in the shape of earth is merely placed on the road and little or no material damage done to the Railway, but a delay occasioned in proportion to the quantity thrown down and the means available for its removal.

The amount of destruction caused by process No. 6, must be regulated

* Ordinary plate-layer's hammer.

according to circumstances. The bridge may be entirely demolished, or only one arch; or one pier of a viaduct blown down.

When process No. 7 is resorted to, the point of attack must be well chosen; it will vary with the length of the tunnel, and the nature of the rock, (in a geological sense,) through which it passes. Long tunnels through hard solid rocks, such as require no lining, will be best attacked at the shafts by blasting from the top, or by other means of filling in. Short tunnels with masonry lining may be advantageously attacked at the crown or both haunches.

Whenever it is determined to interrupt the passage of trains, of course the desired end should be sought for, with the least trouble, expense, and permanent damage. As expressed by General Sir J. Burgoyne, "in damaging a railway to impede the progress and available means of an enemy's army, the object will of course be to do as little injury to a great convenience of the country as is consistent with the primary consideration of crippling the military resources of the enemy for the time." As this paper aims merely at practical facts it will not be out of place to enumerate the tools necessary in the foregoing operations, which may be classed under two heads A and B.

A, including Nos. 1, 2, 3, and 4, are all attacks on the permanent way.

B, including Nos. 5, 6, and 7, are all attacks on permanent structures.

In order to decide upon the number and proportion of tools, it is necessary to take some number of men as a standard unit, or detachment complete, of which there may be any number with an army; and for this purpose it is proposed that a detachment should consist of 22 men, exclusive of non-commissioned officers. For operations under the head A, the detachment will require

8 Picks and shovels for opening up the ballast.

4 Screw spanners to take off fishes.

15 Heavy hammers to force the sleepers from the chairs, and having one end small for keys.

4 Handspikes.

The above numbers are chosen in order that every man may be employed from the first on the most complete demolition. Thus, to commence work, we have eight men with picks and the same number with shovels to remove the ballast, four men with spanners to take off the fishes, and two men with hammers to displace the keys. As previously men-

tioned, the separation of sleepers and chairs is extremely laborious, and therefore when necessary, the simplest and best way would be to form stacks and burn the sleepers, when the chairs might be afterwards collected.

In operations under the head B, such tools would be required as have hitherto been in use for the demolition of ordinary bridges, &c., on common roads; and as in these, there is nothing new to the Military Engineer, no further comment is here called for on this portion of the subject.

Having thus briefly noticed the several ways in which the Railway may be most readily dismantled, it behoves us to consider the more difficult work of *reconstruction*, and in so doing it will be convenient to preserve the order above adopted, and to suppose that the line has been disabled in one of the manners already described, by process 1, 2, 3, &c., and to note in each case the method peculiar to itself.

When the keys have been made away with, we should naturally replace them by new ones; these may be rough pieces of wood, dressed in proportion to the time and means available.

But should it be impossible to make new keys, from want of timber or any other cause, a sufficient number may be obtained from the *entire* portion of the line, by abstracting one from the centre of each rail (but not both from the same sleeper). It would be well as a precaution to wedge up the rail, where keys were absent, by stones or anything at hand, but this is not absolutely necessary provided that there are not two consecutive keyless chairs.

Of course it will be necessary to limit the speed of passing trains, over these portions in proportion to the want of perfection in the repair.

Should the line have been dismantled by any other process under the head A, the mode of reconstruction will be explained for all, if we take the worst case, in which the whole of the permanent way has disappeared, and show by what means it may be renewed.

Here we have a break in the Railway where nothing remains but the formation level and ballast, and it is necessary to construct a way across this for the passage of trains.

Now, it is very evident that this cannot be done without materials, and thus assuming that there is no depôt within reach, the important question is, where are they to come from? Doubtless on a double line one track can be renewed at the expense of the other, and by this means a through

communication made. This will cause little delay to the traffic (unless the break is several miles long) when the train can be shunted on to its own line at the point where both are perfect. Every train must be brought to a stand before advancing on the single portion, and not allowed to cross unless a pilot is on the engine, as is the custom with ordinary passenger, or other trains when from some cause or other one line has been disabled and is undergoing repairs.

But in the case of a single line, it will be necessary to obtain the required materials from the most convenient sidings, being careful only to carry away what is absolutely wanting.

It would save considerable labor if each pair of rails could be transported with sleepers, chairs and keys, *en masse*, only unfixing the fishes, where used; but whether this could be done must depend on the available power and carriage.

The weight of one set complete, or element (*ut ita dicam*) would be, approximately, slightly under two tons (varying with every Railway) which might be raised, carried for a short distance, and placed in position, by 30 men. When this is done, the ballast must receive an additional amount of previous care. In all cases the services of the regular plate-layers and navvies employed on the line should, if possible, be obtained.

R. A. S.

No. CX.

THE BOMBAY REVENUE SURVEY.

On the Principles and Practice of the Bombay Revenue Survey, by
LIEUT.-COL. A. COWPER, R.E.

A PERIOD of nearly 30 years has elapsed since the Government of Bombay resolved upon instituting a Revenue Survey for the Presidency, and for this purpose two Engineer Officers, Lieuts. Wingate and Nash, were selected to conduct the professional part of the survey, which was considered at first as an experiment; and Mr. Goldsmid, a civilian, was associated with them to aid in the Revenue portion. Owing to the decease of Lieut. Nash, which occurred some years after his first appointment, the task of carrying out these surveys devolved upon Lieut. (now Major) Wingate and Mr. Goldsmid. By the joint labors of these two public officers, the experiment was brought to a successful issue, and the gradual extension of the operations over the entire presidency, and the facilities experienced by the department and its officers generally, may be considered as greatly due to the talents and influence of Mr. Goldsmid, who was afterwards Secretary to Government, and was always ready in that important post to aid the survey with his cordial and hearty support. To Major Wingate is justly due the careful elaboration of the original design of the survey, into the admirable administration which has proved so efficacious for the revival of agriculture in the Presidency, and the reports submitted by that officer for the introduction of the revised survey into the different districts, are amongst the most valuable of the Records of Government, and illustrate the ability with which the principles of the system have been carried into

effect. The operations have now extended themselves over nearly the whole of the Bombay Presidency, embracing an area as large at least as Great Britain and Ireland. They form the basis of the Revenue administration for the realization of all taxes connected with the land, and these form by far the most important branch of the Bombay Revenue.

The districts composing the Presidency, consist for the most part of portions of the great Empire of the Mahrattas, who in their turn had conquered them from different native rulers. The previous history of these districts for several centuries had been one of anarchy and mis-rule, with but very few periods of good and prosperous Government. Under the most favorable circumstances, a native dynasty is too prone to consult its own immediate requirements and rarely looks beyond one generation, and the prosperity produced by any individual ruler who is an exception to this view, is not fated, in consequence, to be of any long continuance.

A graphic description of the condition of these provinces in the early part of this century, will be found detailed in the first two volumes of the Duke of Wellington's Despatches. The great Captain had campaigned over the entire country from the Tomgabuddra to the Nerbudda river, and was minutely acquainted with its state. On the 23rd July, 1803, he writes to the Governor General—"The whole of the Mahratta territory is unsettled and in ruins. Holkar's armies consumed the produce of last year, and owing to their plunder and extortion, entire districts were depopulated, and the habitations of the people destroyed. The consequence is that every man is a plunderer and a thief, and no man who can find anything to seize or to steal will cultivate the land for his subsistence:" and fourteen years of Mahratta rule elapsed after this before the introduction of the British Government.

The bases of the Revenue management in each Province, so far as can now be ascertained, were probably the Surveys instituted by the more capable and enlightened of the native rulers. These embraced an actual measurement and classification of the land, and an assessment fixed with reference to both; the processes were necessarily of a rough nature, but the standard of assessment being pitched very low, any inequality in the land-tax was not severely felt. The scheme of these original surveys varied in each province; in some the land measure was the standard or invariable element; in others the rate of assessment was constant, and the area of the land to which it was applied, varied with the class and productions of the

soil. With each successive conquest the taxes originally levied on these settlements were increased, and fresh taxes imposed; but amongst these the Mahratta conquest stands out pre-eminent for the number and variety of the new cesses that their rapacious ingenuity enabled them to impose. The Mahrattas were our immediate predecessors, and on the establishment of the British Government, the revenue management of each district was found to be in a state of confusion; few, if any authentic records being forthcoming as a guide for our revenue officers to settle the country on. The land was as a rule greatly over-cessed in the aggregate, and the character of the component imposts were in many instances of a most pernicious nature. Under the whole however was the *ryotwar* system; the individual cultivator had under all rules been considered as the tenant of the soil, with Government as the landlord, and could not be ousted from his holding so long as he paid the land and other taxes, which were placed either upon his entire holding or upon the fields or produce contained in it.

The question therefore of introducing a uniform system of revenue management throughout the provinces, where this tenure, the *ryotwar*, prevailed, soon became one of paramount necessity in order to equalize and reduce the taxes on land, and to abolish or absorb those that were of an objectionable nature.

The efforts that were made by several of our earlier administrators to afford relief to the exhausted districts under their control by means of rough surveys, reduction of assessment, and other expedients, were productive of great benefit in their several localities, and pointed the way towards a more general measure.

The first and main object in setting on foot a *ryotwar* system of survey, was to determine the size of the plots of ground or fields, to form the unit or basis of the survey, and on which the cess should be placed. It is evident that no object can be attained by fixing this area at less than can be cultivated by *ryots* of the most limited means. The smallest amount of stock that can be cultivated with, is one pair of bullocks; with one bullock only, a *ryot* cannot cultivate at all, and he must either borrow another bullock or throw up his land. The *minimum* area to be measured separately and to be constituted a "Number," as it is called, was fixed therefore by the new survey at what two bullocks could plough. In determining the *maximum* area to be measured by the survey and constituted a separate "Number," it is manifest that this must not exceed the means

of the generality of the ryots to cultivate, so that they may be easily made the subject of sale and transfer. Cultivators possessing two pairs of bullocks were found on enquiry to form the most numerous class of small farmers, and the *maximum* area was consequently fixed at what four bullocks could plough.

It was finally determined therefore to fix the size of Revenue Survey Numbers at from what one pair of bullocks could plough up to double that size. On an examination of the internal distribution of the village lands with a view to adjust them to this size, they were found to consist of recognized sub-divisions known as *thuls*, *tickas*, *daghs*, &c. These were generally found to be too large for our purpose, being held for the most part by several individuals. The external limits of these were usually permanent, but the interior limits were constantly changing among the occupants through the operation of sales, transfer, and inheritance, and were found to be broken up in many instances into very minute portions. For adapting the above rule for the measurements of these plots or fields to "Survey Numbers," it was resolved to interfere as little as possible with the existing limits of fields or occupancies; and the following rules for the division of land were finally sanctioned for this purpose:—

1st. The size of Revenue Survey Numbers, will as a rule be from what a single pair of bullocks can plough up to double this quantity.

2nd. Tracts of land incapable of, or unsuitable for, cultivation, may be divided into as large portions as may be convenient.

3rd. Land held on different tenures must be measured separately and not included on the same Number.

4th. Different kinds of culture—as dry crop, rice, garden, &c., when in conformity with the usage of the districts—should as far as practicable be measured into separate Numbers.

5th. Every holding* falling within the limits prescribed by Rule 1, should be constituted a Survey Number.

6th. Every holding in excess of this area, should be divided into two or more Numbers, so as to bring the area of each within the rule.

7th. When a holding is of less area than is laid down in Rule 1, and there are other similar holdings contiguous to it, on the same tenure, so

* By "holding" is meant any field, estate or coparcenery, contained within a continuous line of boundary and in the possession of one person or coparcenery.

many of them may be clubbed together as may be requisite to form a Number, but no more.

8th. When a holding of less area than that required by Rule 1, does not adjoin another similarly circumstanced, it should be made a separate Number.

If therefore it be assumed that one pair of bullocks are able to plough

20	acres of light dry crop soil,
15	" medium "
12	" heavy "
4	" rice land "

then the plot of land forming the standard unit or "*Revenue Survey Number*," would be of a size between this amount and its double. By the survey operations the lands of a village are thus cut up into plots of ground of a nearly uniform size; and on the map, the limits of these are defined by continuous black lines, so that something of a gridiron appearance is presented, similar to the skeleton triangulation of a trigonometrical survey.

In order to preserve these Numbers intact for revenue purposes after they had been once constituted by the survey, and to prevent their being split up into portions too minute to afford subsistence to the cultivators, it was decided, supplementary to Rule 7 above, that when two or more occupants were included in the same number, and any one of these relinquished his share or died without heirs, the portion must be taken up by one of the other cultivators; or failing that, by some one else. In the event of there being no one ready to cultivate the waste portion, the whole Number must be relinquished. All sales, transfers, &c., of Government land, were directed to be of portions recognized in the Revenue records, which would as a rule be whole Survey Numbers. In agreeing to cultivate waste land, the ryots are required also to take up entire numbers, excepting where the annual assessment exceeds Rs. 20, when the names of two ryots are permitted to be entered.

These arrangements effectually secured the internal integrity of each Survey Number; and the next question that presented itself was—How to ensure the preservation of their external limits or boundaries? Without some external marks easily recognized and of a permanent character, these Numbers would not retain their original form, and after the lapse of a few years the areas would have so altered as to render the assessment unequal and perhaps render a fresh measurement necessary. A continuous

ridge or mound of earth encompassing the entire number, is doubtless the best boundary, but it would be too expensive in practice, and a system of detached earthen mounds, two at each of the four corners of the number and one at convenient intervals, say every ten chains along the sides, with stones sunk at the bends, was found on trial to be a sufficient demarcation of the limits of numbers, and this is therefore the system which has been adopted throughout the Bombay Presidency.

All disputes about tenures, occupancy, limits of fields, and other purely Revenue matters, have to be adjusted by the Civil Authorities, whose aid is called in when requisite for that purpose, either by the measurer or by the European Assistant himself. But when these disputes occur between villages concerning their mutual boundaries, they will be found sometimes very troublesome to adjust, more especially when the rights of alienees are affected. Many of these disputes are of long standing, some even tracing so far back as hundreds of years, and concern large tracts of land; several will be found to have been the scene of faction fights, and even in some instances, to have been attended with bloodshed. The existence of these disputes in any number, if not settled at the time of the survey, delays the completion of the records of the villages that are affected by the dispute, and their classification and settlement has to be put off till these can be finished. The Survey operations may in this manner be seriously compromised unless early attention be given to these disputes; and when once settled, no time has to be lost in erecting the boundary marks to prevent their being re-opened.

In the actual settlement of these disputes, the Assistant will soon find that an accurate map of the land in question is an indispensable preliminary to an investigation of the villagers' claims. The disputed land therefore should be surveyed in presence of both parties, and all topographical features and permanent marks noted, such as water-sheds, nullahs, cartroads, and also temples, tanks, wells, fruit trees, trijunction stones or pillars, cultivated land, &c. This latter class of objects is very useful in establishing the right of usufruct or occupancy, and a search amongst the records produced by the villagers will generally confirm the possession to one of the parties. The dispute may thus be generally narrowed to merely the waste land; and failing proof of this, it may be divided into equal parts between the villages, or else some permanent natural boundary, such as a water-course, water-shed, or cartroad, if conveniently located, may be fixed upon as the mutual limit. Disputes between Government villages can be

decided by the Survey Assistant without much trouble ; but when one of the parties is an alienee, it is advisable to take his written agreement to constitute the Assistant the umpire in the dispute, and to abide by his decision without appeal.

To prevent any after misunderstanding, the exact line of boundary, as finally agreed on, should be traversed in, and permanently marked off by means of masonry pillars. These should be of the same size, and at as long distances apart, as is compatible with being well in sight, the one from the other ; all intervening bends and earthen marks being fixed by means of off-sets taken with the cross-staff. These distances are marked in figures on the map, which is made up in duplicate, and signed on oath as correct by the professional measurer ; the duplicates are countersigned by the Assistant, and the alienee or his accredited agent, and one copy is retained by each party. It is then nearly impossible that these disputes can be re-opened, and the exact boundary fixed by the Survey can always at any future time be recovered.

The above gives a brief description of the principles on which the Measuring branch of a Survey is conducted. In the actual field operations the European Assistant has usually some twenty Measurers, and three learners of measuring, under him. His duties are to supervise and *test* the work of these men, he making no original surveys himself. It is usual to give the entire of one *talooka* or *mahal* to one establishment, and on receipt of the list of villages therein, at the close of the monsoon, the Assistant appoints measurers to contiguous villages at one end or corner of the district allotted him ; and as these are finished, moves on the men gradually towards the other or opposite corner, by surveying the villages *en route* in succession ; and by this arrangement, the Assistant can always, without shifting his camp often, be within easy reach of his measurers, and able to pay them those sudden and unexpected visits so necessary to the preservation of the discipline and efficiency of a native establishment. As a general rule, the best measurers should be appointed to the largest villages or towns, more especially those which have much garden or rice land, and so down by gradation ; the fresh hands being put to the smallest villages of 3 and 400 acres. It is not advisable to appoint more than one measurer to one village, as if two or three measurers be appointed, the daily duty of attending the measurers in the field, dragging the chain, holding bandrols, erecting boundary marks, &c., would be too onerous for the village officers and inhabitants. If, however, under any peculiar circum-

stances it becomes necessary to appoint two measurers to a village, it should be divided into two portions, having a road or large nullah as the boundary; this should be carefully traversed in with a theodolite, and the same tracing being given to both, the work of the two is kept perfectly distinct, and the maps made up by the two measurers can be easily joined together. Villages are rarely of such size that they cannot be done single handed by one good measurer in a season, and it is better to appoint trustworthy measurers to the larger villages at the commencement of the working season, even if they are at some distance from the Assistant's camp, rather than wait until the work has arrived in their vicinity, and there appoint two or three measurers thereto.

The survey made by the European Assistant is as above stated, not an original survey, but a test of the Measurers work, and is of the utmost importance; as from its agreement or otherwise within a certain small percentage of the work of the measurer, the entire measurements of the latter are either accepted or rejected. This test should be constant and recurring; and, if the measurers have been appointed to villages in a proper manner, the Assistant's camp can be pitched at some village centrically situated with reference to these, and no difficulty will be experienced in taking a proper number of tests of any village that may be finished during the season. After some amount of practice, when the Assistant can plot his work with a considerable amount of accuracy, he should not allow the measurer to exceed 1 per cent. in error in all numbers above six acres, if not a very irregular figure; 2 per cent. may be allowed if under six acres; but an error of 3 per cent. ought never to occur, except in very small garden or rice Numbers.

The only part of the measuring operations remaining to be noticed, are the arrangements of the native measurer. The chain with which the areas of numbers are ascertained is 33 feet in length, exactly half the length of Gunter's chain, and is divided into 16 links, called *annas*, of 2 feet $\frac{3}{4}$ inch each. Forty of these square chains make an acre, and a square chain is equal to 4 poles, or $\frac{1}{16}$ th of an acre, and is called a "*goonta*," the areas being calculated in acres and "*goontas*." The measurer is provided with a wooden staff or gauge 8 feet 3 inches in length, for the purpose of constantly testing his chain; he is supplied also with a pair of compasses and a diagonal scale showing chains and annas. His map is constructed to a scale of 8 or 16 inches to the mile, according to the average size of the Survey Numbers, whether large or small.

In the example herewith given of a measurer's map, is shown the method of the division of land into Revenue Survey Numbers, the method of setting up the boundary marks in the field, and the plotting of the map itself on the base lines. This latter should invariably be effected by the principle of the triangle and not the right angle, for which the measurer is supplied with no instruments. The areas in the measurer's map are intended merely as a guide for the terminating points of other lines, and should be described faintly with the steel compasses. The diagonal with off-sets, is as a rule, the system adopted in the field measurement. The measurer devotes one day every week or every fortnight to an inspection of boundary marks, and sees to the payment of the laborers who have erected them.

After the measurers have obtained some experience in mapping, there is found to be no difficulty in piecing together these Survey Numbers, one next another, so as to form an entire map of a village. A great assistance is however given to the correct protraction of the map, by means of lines ranged from one boundary of the village to the opposite one, and all the first Survey Numbers are measured along this; in measuring the subsequent ones, it is as well to return to the base line numbers, every now and then, so as to keep up a constant check on the accuracy of the protraction. For a village of 1000 acres, one base line will be found to be sufficient, if properly selected in a locality free from jungle and other obstacles, and two base lines will be enough for a village up to 2,000 acres. These base lines are connected with one another by means of a triangle, as shown in the example: they should never depend upon a right angle taken with the cross-staff for their relative positions.

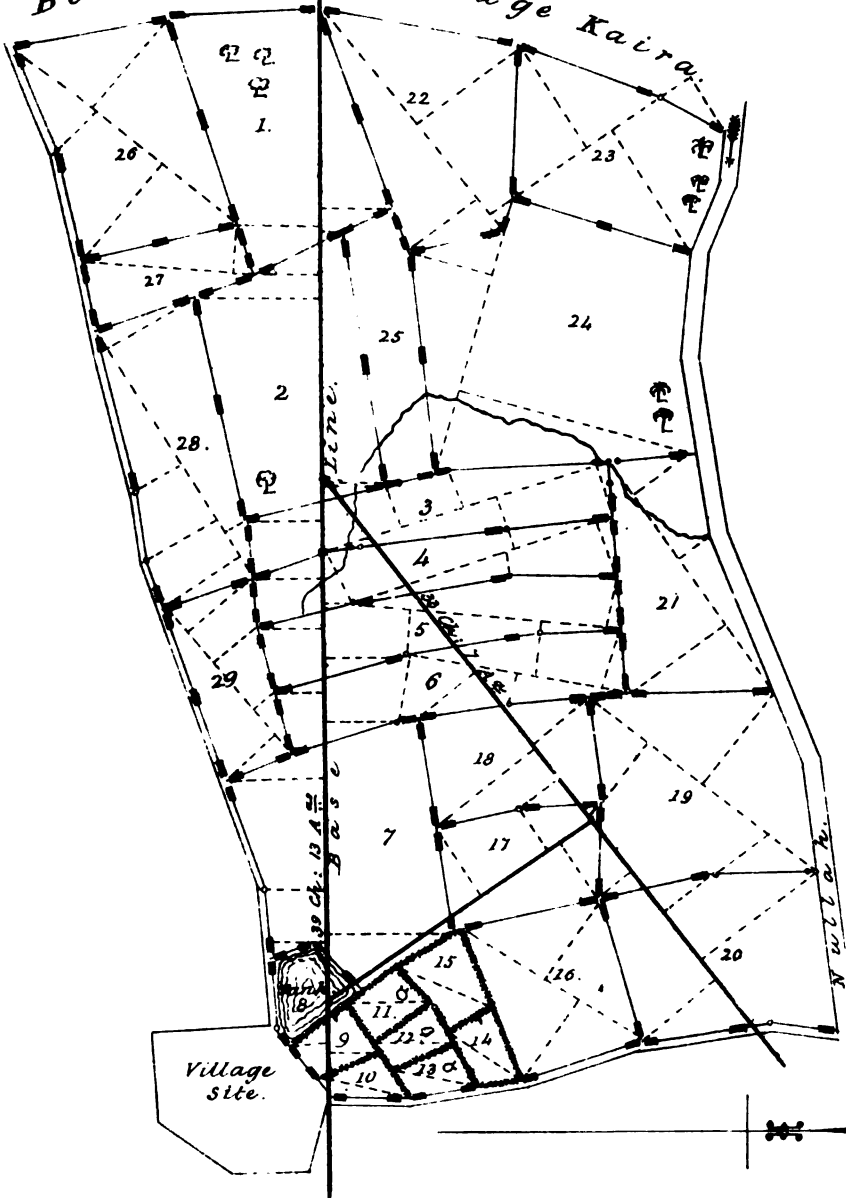
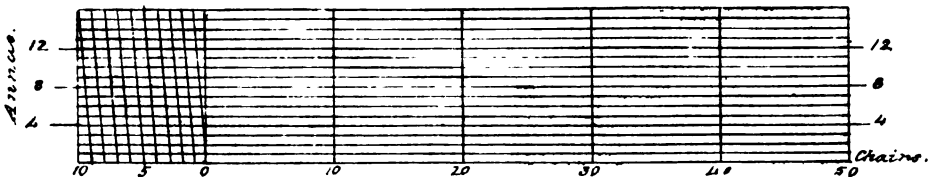
These maps are now protracted by the measurers with sufficient accuracy to be pieced together, and form *talook* maps for revenue and topographical purposes.

All the Measurer's observations in the field are finally entered and abstracted into his fair field-book. These books are lithographed and supplied to the measurers, by which means a great deal of their valuable time is saved. It is calculated that the cost to the state of each working day of a good measurer in the fair season, is from Rs. 4 to 5, and it is a judicious economy to give him every assistance possible, so as to enable his time to be entirely devoted to his measurements in the field, and book work at his lodgings.

All the work that has been done in the fair season, has to be revised in the rains; the corrected results are tabulated in convenient forms, and

BOMBAY REVENUE SURVEY.

Boundary of Village Kaira.



Forty of these square Chains make an acre, and a square Chain is equal to 4 poles, or $\frac{1}{160}$ of an acre, and is called a "Goonda"; the areas being calculated in Acres & Goondas.

two fair copies made of the village maps for the Classing Department, which is the next operation of the survey. It becomes nearly impossible to pursue field operations after the first fall of rain in June, and all the establishment return to head-quarters by the 15th of that month. As a rule those villages that have been measured by the worst measurers should be checked by the best. One of the most important of these operations, and the most troublesome, is the multiplication of the lengths and breadths of the internal figures, triangles and trapezoids, into which each survey number has been broken up by the chaining operations of the measurer. This used formerly to be done by actual calculation, but the product is now obtained from multiplication tables made up as far as 40 chains by 40 chains, and lithographed for the purpose. These tables were for a long time a great desideratum on the surveys, and their introduction has effected as much good on the Bombay side as Boileau's Traverse Tables did in Bengal and the North Western Provinces, for the traverse system of survey in force there. One-quarter of a leaf of these tables is shown here, embracing the multiplication of all intermediate quantities from 28 to 29 chains by 36 to 37 chains. If, for example, we want the multiplication of 28 chains 13 annas by 36 chains 11 annas, the result 1057-0-15 is obtained at once from the tables without the trouble of working out a long sum in duodecimals.

When these tables were being lithographed, the proof sheets were carefully tested and collated with a copy of the tables made up by hand, and after being struck off, a trifling reward was offered to any one who would discover errors in the results. They may be considered now as arithmetically accurate. These tables, together with the assessment tables, which will be described afterwards, have so greatly facilitated the very onerous calculations that had formerly to be done by hand, that a considerably greater amount of work can now be got through by the men in the fair season, as they finish their work earlier in the monsoon, so as to enable them to pass a longer time in the district.

By the use of these tables each measurer is able to work much more accurately, and the value of the bad computers is raised to nearly a level with that of the good. As an additional precaution against error, the entire area of each number is tested by means of the talc square on the map, so that it is next to impossible that any serious error in area can remain undetected. All these processes gone through in the rains, are tested to the extent of 10 per cent. by the Assistant himself, and the registers and

documents embodying the results are sent at the close of the recess to the Superintendent's office for distribution to the Classing branch, in which the relative value of the soil and water in each of these Survey Numbers has then to be determined.

All the records of the survey are kept in the vernacular language of the province in which the operations are progressing. The notation is the same as the European or the Arabic system; and the finished digits or numerals should preferably be used, and not the original traces or strokes, which represented numbers in the first instance, and from which the present digits have been formed.

MAHRATTA.	1	2	3	4	5	6	7	8	9
Strokes or traces,	—	=	≡	⊥	⊥—	⊥=	⊥≡	⊥⊥	⊥⊥—
Finished digits,	१	२	३	४	५	६	७	८	९

The construction of the first three numerals from the original strokes, is readily understood, but the process of transition in the remaining numbers, four to nine, is not so clear; but if the original strokes be written with rapidity, a character will be produced closely corresponding with the form of the finished digit.

Natives are very prone to employ these original strokes, and more especially to represent fractions and subordinate denominations by these signs, but they can be so easily altered, by adding fresh strokes, that a great facility is given by their use to the falsification of the records, and their employment should consequently be interdicted. To illustrate this point, of we take the number 5, as formed by one perpendicular and one horizontal stroke, it is evident that by adding one or more strokes of one or both these sorts, it can be altered without fear of detection into any other number whatever, except exact multiples of 4. The completed numeral should therefore be used throughout all the survey operations, as not being capable of easy alteration, and readily detected if tampered with.

The Classification should now be considered; and it is found that the chief circumstances affecting the value of land within the limits of the same village are—natural productive capability—distance from site of village, as affecting facilities for cultivation and manuring—and, in the case of garden or rice land, the supply of water for irrigation. If rules cannot be laid down for all these points with arithmetical accuracy, still as near an approach as possible should be made thereto, as our results will then be

	11			12			13			14			15		
0	1032	12	0	1035	0	0	1037	4	0	1039	8	0	1041	12	0
0	1034	8	11	1036	12	12	1039	0	13	1041	4	14	1043	8	15
4	1036	5	6	1038	9	8	1040	13	10	1043	1	12	1045	5	14
4	1038	2	1	1040	6	4	1042	10	7	1044	14	10	1047	2	13
8	1039	14	12	1042	3	0	1044	7	4	1046	11	8	1048	15	12
2	1041	11	7	1043	15	12	1046	4	1	1048	8	6	1050	12	11
2	1043	8	2	1045	12	8	1048	0	14	1050	5	4	1052	9	10
6	1045	4	13	1047	9	4	1049	13	11	1052	2	2	1054	6	9
0	1047	1	8	1049	6	0	1051	10	8	1053	15	0	1056	3	8
10	1048	14	3	1051	2	12	1053	7	5	1055	11	14	1058	0	7
4	1050	10	14	1052	15	8	1055	4	2	1057	8	12	1059	13	6
14	1052	7	9	1054	12	4	1057	0	15	1059	5	10	1061	10	5
8	1054	4	4	1056	9	0	1058	13	12	1061	2	8	1063	7	4
2	1056	0	15	1058	5	12	1060	10	9	1062	15	6	1065	4	3
12	1057	13	10	1060	2	8	1062	7	6	1064	12	4	1067	1	2
6	1059	10	5	1061	15	4	1064	4	3	1066	9	2	1068	14	1

ASSESSMENT.

		33	34	35	36	37	38	39
2	10	27 18 2	27 18 7	27 14 0	27 14 5	27 14 10	27 15 2	27 15 7
0	8	28 11 1	28 11 6	28 11 11	28 12 4	28 12 9	28 13 2	28 13 7
8	7	29 9 0	29 9 5	29 9 10	29 10 4	29 10 9	29 11 2	29 11 7
6	5	30 6 11	30 7 4	30 7 9	30 8 2	30 8 8	30 9 1	30 9 7
4	5	31 4 10	31 5 4	31 5 9	31 6 2	31 6 8	31 7 1	31 7 7
2	8	32 2 9	32 3 2	32 3 8	32 4 1	32 4 7	32 5 0	32 5 6
0	2	33 0 8	33 1 2	33 1 7	33 2 1	33 2 7	33 3 1	33 3 6
4	1	33 14 7	33 15 0	33 15 6	34 0 0	34 0 6	34 1 0	34 1 6
2	0	34 12 6	34 13 0	34 13 6	34 14 0	34 14 6	34 15 0	34 15 6
9	11	35 10 5	35 10 11	35 11 5	35 11 11	35 12 5	35 12 11	35 13 6
7	9	36 8 4	36 8 10	36 9 4	36 9 11	36 10 5	36 10 11	36 11 6
5	8	37 6 2	37 6 9	37 7 3	37 7 9	37 8 4	37 8 10	37 9 5
3	7	38 4 2	38 4 8	38 5 3	38 5 10	38 6 4	38 6 11	38 7 5
5	5	39 2 0	39 2 7	39 3 2	39 3 8	39 4 3	39 4 10	39 5 5
5	5	40 0 0	40 0 7	40 1 1	40 1 8	40 2 3	40 2 10	40 3 5
3	4	40 13 11	40 14 6	40 15 1	40 15 8	41 0 3	41 0 10	41 1 5
1	2	41 11 10	41 12 5	41 13 0	41 13 7	41 14 2	41 14 10	41 15 5
9	1	42 9 8	42 10 4	42 10 10	42 11 6	42 12 2	42 12 9	42 13 4
7	0	43 7 7	43 8 3	43 8 10	43 9 6	43 10 2	43 10 9	43 11 4
4	11	44 5 6	44 6 2	44 6 9	44 7 5	44 8 1	44 8 9	44 9 4
2	10	45 3 5	45 4 1	45 4 9	45 5 5	45 6 1	45 6 8	45 7 4
0	8	46 1 4	46 2 0	46 2 8	46 3 4	46 4 1	46 4 8	46 5 4
4	7	46 15 3	46 15 11	47 0 7	47 1 4	47 2 0	47 2 8	47 3 4
2	5	47 13 2	47 13 11	47 14 7	47 14 3	47 15 0	47 15 8	48 0 4
0	5	48 11 1	48 11 10	48 12 6	48 13 2	48 13 11	48 14 7	48 15 4
8	4	49 9 0	49 9 9	49 10 5	49 11 2	49 11 11	49 12 7	49 13 3
6	2	50 6 11	50 7 8	50 8 4	50 9 1	50 9 10	50 10 7	50 11 3
4	1	51 4 10	51 5 7	51 6 4	51 7 1	51 7 10	51 8 7	51 9 3
2	0	52 2 9	52 3 6	52 4 3	52 5 0	52 5 9	52 6 6	52 7 3
5	11	53 0 8	53 1 5	53 2 2	53 3 0	53 3 9	53 4 6	53 5 3
3	10	53 14 7	53 15 4	54 0 1	54 0 11	54 1 8	54 2 5	54 3 3
1	8	54 12 6	54 13 3	54 14 0	54 14 11	54 15 8	55 0 5	55 1 3

more uniform; the application of a rigid European test, similar to that in the measuring branch, can be enforced, and as little as possible will be left to the individual judgment of the classer, and this last point is one of great importance where a trustworthy agency cannot be procured.

In determining the elements which make up the first of the above, the productive capability of the soil, there were found to be three distinct orders of soil, of different degrees of fertility, which may be called from their color, black, brown and yellow, or gravelly, respectively. The relative value of these soils among themselves may be considered as in a great degree proportional to their depth, as on that depends their value for agricultural purposes, by enabling them to imbibe and retain moisture, which is the great element of fertility in India. By means of these considerations, we obtain an outline of a scale by which to gauge these soils among themselves; and in order to be able to draw up rules embodying these principles, we find that a depth of $1\frac{3}{4}$ cubits, say 2 feet 7 inches English measure, is ample to enable soil to retain the necessary amount of moisture, and that any greater depth is not attended with any increase of water-carrying capability. Yellow earth is but rarely found of a greater depth than one cubit, and from its more porous nature, in comparison with black and brown soils, that depth is found to retain water as well as any greater depth. Assuming therefore our maximum standard as 16 annas or 1 rupee for pure black soil of depth, the soils of inferior value to this will range themselves in order as in the following table:—

Class.	Relative value of class in annas or 16ths of a rupee.	SOILS.		
		1st order.	2nd order.	3rd order.
		Of a fine uniform texture, varying in color from deep black to dark brown.	Of uniform but coarser texture than the preceding, and lighter also in color, which is generally red.	Of coarse gravelly or loose friable texture, and color varying from light brown to gray.
		Depth in cubits.	Depth in cubits.	Depth in cubits.
1	16	$1\frac{3}{4}$	...	...
2	14	$1\frac{1}{2}$	$1\frac{1}{2}$	...
3	12	$1\frac{1}{4}$	$1\frac{1}{4}$	...
4	10	1	$1\frac{1}{4}$	...
5	8	$1\frac{1}{4}$	1	...
6	6	$\frac{1}{2}$	$\frac{1}{2}$	1
7	$4\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
8	3	...	$\frac{1}{2}$	$\frac{1}{2}$
9	2	...	...	$\frac{1}{2}$

By the above table we are enabled then to determine the relative values of these soils amongst themselves; but in addition to the color and depth of the soil, there are also other elements affecting its productive capability; in almost all soils there is present a mixture of deteriorating ingredients, or circumstances which tend to diminish its crop bearing powers. Those of the most ordinary occurrence are distinguished by the following conventional marks in the classers' field-books, as being convenient for notation—

∴ Denotes a mixture of minute fragments or nodules of limestone, "choon kud."

✓ Denotes a mixture of sand, called "walsur."

| " sloping surface, "ooturwut."

× " want of cohesion amongst the constituent particles of the soil, "reswut."

∧ Denotes a peculiar mixture more or less impervious to water, "kukul."

~~~~ " liability to be swept over by running water, "doopun."

□ " an excess of moisture from surface springs, "oopulwut."

> " a mixture of large nodules of limestone, "gochur."

The elements which are to be taken into consideration, therefore, in determining the value of dry crop land, are color, depth, and the presence or otherwise, of deteriorating ingredients or circumstances, which are technically called "faults" in the department. One such fault lowers a soil in which it is found one class in the above table, two lower it two classes, and so on, as shown in the following example. In effecting the classification of a field, the classer with the aid of the village map, enters an outline of its shape in his field-book, which he divides by intersecting lines into a number of equal compartments, sufficiently numerous to give a fair average valuation of the soil by an examination of the depth and quality in each compartment. These particulars and the class in which the soil falls, are noted within each compartment.

NORTH.

|                      |                                                                                       |                                                                                       |                      |                                                                                       |
|----------------------|---------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|----------------------|---------------------------------------------------------------------------------------|
| 7                    | 4  | 3  | 1                    | 2  |
| $\frac{3}{4}$<br>... | $1\frac{3}{4}$<br>.                                                                   | $1\frac{3}{4}$<br>.                                                                   | $1\frac{3}{4}$<br>.  | $1\frac{1}{2}$<br>.                                                                   |
| 6                    | 5                                                                                     | 4  | 3                    | 3  |
| 1<br>...             | 1<br>..                                                                               | $1\frac{1}{2}$<br>..                                                                  | $1\frac{1}{2}$<br>.. | $1\frac{3}{4}$<br>.                                                                   |

The figure in the left hand lower corner of each square indicates the depth of the soil, and the number of dots under it, the order of soil to which it belongs; one dot signifying the 1st; two the 2nd; and three the 3rd, order. The conventional marks in the right hand upper corner show the faults, each of which degrades the soil one class; from the order of soil, the depth, and the faults, is determined the class of relative value to which the compartment belongs, as indicated by the figure in the left hand upper corner. To take the instance of the lower compartment on the right of the field, the depth is entered at  $1\frac{1}{2}$  cubits, and the soil is of the first order, as shown by the single dot immediately below. This order and depth indicate the first class of relative value, but the presence of two faults (a mixture of sand and a sloping surface) indicated by the signs  $\vee$  1, requires the soil to be entered in the third class, as denoted by the figure 3, in the upper left hand corner of the compartment. It will also be seen from the example, that the same fault is sometimes entered twice in one particular compartment, which means that it exists in so great a degree as to require the value to be lowered two classes in consequence. In the right hand upper compartment also, it will be observed that two faults (limestone and sand) are bracketted together, by which is indicated that there is about half a fault of each and that the two together make up one full fault and lower the soil one class. The size of the compartments into which the number is divided varies with the area, and the uniformity or otherwise of the soil. In large numbers with a uniform soil, each compartment may be about two acres, but with smaller numbers, one acre or even less, if the soil vary, would be a proper size. The field operation is performed by digging a hole in the centre of each compartment, and gauging the depth of soil with an iron bar marked with cubits: the color of the soil and the faults are ascertained from an inspection of a clod of earth, taken up in the hand.

The Classer next proceeds to strike an average for the entire number from the value of these compartments, which is done in the following manner:—An abstract is entered in the book showing the number of compartments of each class, together with their aggregate value in annas, taken from the table; and the sum of these annas divided by the number of compartments, gives the average value of the number. The average value for the above example would be entered as follows:—

| Class.        | Number of<br>compartments. | Value of<br>shares in annas. |
|---------------|----------------------------|------------------------------|
| 1             | 1                          | 16                           |
| 2             | 1                          | 14                           |
| 3             | 3                          | 36                           |
| 4             | 2                          | 20                           |
| 5             | 1                          | 8                            |
| 6             | 1                          | 6                            |
| 7             | 1                          | 4½                           |
| Total, ... .. | 10                         | 104½                         |

Rs. 0-10-5 average value.

The classer also enters in his book all extrinsic circumstances affecting the value of the field, such as distance from drinking water, both for men and cattle, number and kind of fruit trees, &c. These books are also furnished ready lithographed to the classer similarly as to the measurers; and by saving him a considerable amount of hand copying, enable him to pass a greater portion of his time in the field. The comparison and testing of the numbers is also greatly facilitated by having each number with all its details on a separate page.

The actual determination of the quantity of deteriorating ingredients necessary to constitute a fault, by which the value of the land is reduced two annas in one rupee, or 12½ per cent., can only be correctly arrived at by constant practice whereby the judgment is fully confirmed. As the percentage of reduction is assumed as the invariable element, being always 12½ per cent., it requires a nice judgment to determine the exact amount of each ingredient or fault necessary to diminish the fertility of the land to that precise extent. It is a most difficult matter to establish a uniform standard of judgment on these points among the classers; but it is of such importance that it should be always kept in view. As an aid to its attainment, at the commencement of the working season, the Assistant assembles all the classers of his establishment at some village where a great variety of soils and cultivation obtains, and accompanies them regularly every day in the field for about ten days, until they are able to classify with precision and consistency. Where so much depends on the individual classer, in spite of all the rules we can lay down, it is evident that the older a classer is, the less liable he will be to err in his judgment; as a rule, we should guard against the employment of men too young for this branch. Amongst the most effective classers in an establishment,

will be found those who have worked for some years as measurers; they learn the work quickly, their previous training and knowledge enable them to class independently after a comparatively short time of instruction, and they can bring forward the faults of the measurer whose work they may be classing, and thereby provide an additional check on the accuracy of that branch of the operations.

The soils classed by the European Assistant are considered as a test of the classers' work, similarly to the system which obtains in the measuring department. He is, however, at a disadvantage in comparison with an Assistant in charge of a measuring establishment, inasmuch as he has no means of lightening or shortening the test labor, in any way commensurate with that effected by means of the theodolite for the former officer. It is evident from this that he must have fewer classers under him, or else that a less percentage of test must be taken; and as this latter would be objectionable, from 5 to 10 per cent. of test being considered indispensable to induce reliance on the whole work, the other expedient is adopted of decreasing the number of men; and from twelve to fifteen classers is placed under him as being the most that an Assistant can properly supervise.

When land is found to be in possession of the means of Irrigation, the propriety or otherwise of imposing an extra assessment on account of the increased productiveness of the land, ought to be determined by a consideration, whether the irrigational work which furnishes the supply has been built and kept in repair by Government, or is the product of private enterprise. Almost all tanks and *anicuts*, or *bundharas*, have been constructed by the State, and kept in repair by the present Government, and the imposition of an extra assessment cannot in any way prevent the construction of new ones, as these works are in fact beyond the means of individuals to execute. Wells, on the contrary, when intended for irrigational purposes, are almost always the result of private enterprise; but they are not exempted for that reason, inasmuch as some extra assessment has always been levied on them, and it has not been considered advisable to sacrifice a source of revenue of considerable amount in the aggregate, on account of the somewhat theoretical objection which exists to an enhancement of taxation on land thus irrigated, as having a tendency to discourage the digging of new wells.

The classification of water privileges where irrigated crops are grown, is a difficult and complicated subject, and presented for a long time

considerable obstacles to the formation of detailed rules for the purpose; this has been at last effected, but there are still some points on which the opinions of the most experienced officers differ. The operations require experience and judgment, and the superior classers are employed on these duties, as involving more responsibility than merely dry crop classification.

Where land is irrigated from tanks or dams, the duty of distributing the water is usually entrusted to a person called the "*Putkurree*," who enjoys some *enam* land for this purpose. The interests involved are not generally of any very extensive nature, the quantity of land irrigated from one of these works but rarely exceeding 50 or 100 acres, and the distributing channels are not provided with meters or gauges. A great facility under these circumstances, is given to the cultivators to obtain water surreptitiously, either by collusion with the putkurree, or by cutting the canal, which can be readily done at night. Those more wealthy and influential, in these and other ways, generally obtain more water than their due, to the detriment of their less fortunate neighbours, and are thereby enabled to raise superior garden produce which requires much water. Those revenue officers who are rather inclined to accept this state of affairs as unavoidable, as having its origin in human nature, and being incapable of amendment, propose to assess the crops grown rather than the land; and, by placing a rate upon the crops proportional to the amount of water that each consumes (those that require abundant waterings, as for instance sugar-cane, being placed highest, and thence downwards in gradations); they argue that the amount of water each individual has taken can be ascertained from the measurement of its resulting crop, and the assessment he ought to pay is at once found by multiplying the area by the modulus, or rate fixed for the particular crop grown; and there can be no doubt but that if the rate for each distinct crop be properly fixed by those well acquainted with garden cultivation, the result attained by this system will give a close approximation to the true assessment that each ought to pay. The objections to the system are, that it requires an annual inspection and measurement of crops, and that the amount each cultivator pays, fluctuates from year to year, and the system is hardly applicable to irrigation on an extended scale. This method of assessment is called the *tinnuswar*, and although very ingenious, is more perhaps suited to native ideas than to ours. Those who oppose this system would wish to see the water-rate

paid by each cultivator, fixed at an invariable amount on the area irrigated, which would be proportional to the water he ought to get, or was supposed to get, from the canal. Nothing could be fairer than this, and more consonant with European ideas, if it could only be carried out; but in practice, it is found that if the water-rates be permanently fixed, the system then possesses no power to meet and control those irregularities in the distribution of water, for which the *tinnuswar* or crop system, provides so excellent a check; and in consequence, the cultivation of sugar-cane and other water-consuming crops, is fostered on the lands of certain influential cultivators, and the result is that those whose water has been unduly appropriated, throw up their claim thereto and obtain a remission of assessment, so that the area under water-produce gradually contracts, the revenue declines, and a few cultivators make handsome profits.

The chief elements that form the value of a water supply from an artificial canal are quantity, quality, and the position of the ground, whether low-lying or elevated, as enabling the soil to retain moisture longer. The soil itself is classed very much according to the system laid down for dry crops; with this difference, that the water being supplied artificially, the depth of the soil does not increase its value to the same extent as in the case of dry cultivation, nor do the presence of faults or deteriorating ingredients decrease its value in the same proportion.

The quality of the water supply is soon ascertained by local enquiries, and from the nature of the crops grown. The quantity is determined by the abundance of the supply and the number of months for which it lasts. The following six classes are sufficient in practice to embrace all qualities of water supply from a canal, from the very best of that sort down to that obtained from the rain-fall alone.

*Class 1.* Where the supply is obtained from a good tank or river, in which the water lasts till the end of March or April, and the land lies sufficiently low to permit of the better kinds of sugar-cane being grown every second or third year.

*Class 2.* Similar to the above, but the land being somewhat more elevated, only the inferior kinds of sugar-cane can be grown.

*Class 3.* When sugar-cane can only be grown should the rains prove very favorable; and this may be the case when the supply of water is the same as class 2, but with the land still more elevated; or, secondly, when the soil is not elevated, but the supply of water

fails after the end of December or January; or, lastly, when there is no artificial irrigation, but the land is in a very low situation.

*Class 4.* When the soil is irrigated from an artificial canal, but is in too elevated a position to produce sugar-cane, but possesses sufficient moisture to admit of a rice and an after green crop; or if the after green crop cannot be grown, the moisture should be sufficient to produce an excellent rice crop; or when the land is not irrigated but is sufficiently low-lying to produce the above crops.

*Class 5.* The same as the above, only no after crop can be raised.

*Class 6.* When the land is not supplied artificially, but only by rain, and is in an elevated situation.

The supply of water to both rice and garden land is classed according to the above rules, but the 6th class is evidently not applicable to garden cultivation.

In classing the water obtained from Wells, the value depends upon the quality, whether sweet or brackish, the quantity or the number and size of the springs, and the expense of drawing it, which increases with the depth; also, whether there is sufficient land under the well to allow of a rotation of dry and wet cropping. All these points are noted by the classer, as well as all collateral points necessary to enable a judgment to be arrived at concerning the area the well is capable of irrigating, such as the number of water bags used, length and breadth of the surface of the water, depth of water in the well, and number of hours it can be drawn, especially in the hot weather.

It is as well here to notice the manner in which the assessment is levied eventually on this kind of land, before quitting the subject. It has always been considered good policy to encourage irrigated cultivation by imposing a low assessment, so that the profits upon the capital employed may be greater than is realized on that engaged in dry crop cultivation; so that the cultivators may acquire substance, and other agriculturists may be thereby stimulated to engage in this superior kind of culture. This was not the policy of native rulers, and our enquiries into the former condition of this class of men elicited the fact that, owing to an excessive assessment, they were little if at all better off in their circumstances than other agriculturists. In some extreme cases the assessment was found to be Rs. 40 per acre, and the proprietors were in consequence nearly ruined. The rates of the existing assessment, and the condition of the cultivators, as

well as other considerations, enable the settlement officer to judge of the extent of reduction necessary, and he accordingly fixes the maximum rate to be levied on canal or well irrigation; the rates for the lower classes can then be easily adjusted.

The Area and Class of the Soil and Water of each survey number have now been determined, and there remains to be shown how the Assessment is to be imposed on each. It has been found by experience, that on an average about one talook, or at the most two, can be conveniently settled by a Superintendent of survey, in each year, without prejudice to his other duties of check and control.

The strength of a survey is fixed at six measuring and two classing establishments, which are sufficient to finish this amount of work annually for the Superintendent's settlement. The revised assessment is introduced into entire talookas each year; as the records and revenue management of these, being perfectly distinct from the other districts, afford readier data to work with than would be the case if portions or fractions of these districts were dealt with separately. The first question then for consideration is the extent of territory within these districts, for which a uniform standard of assessment is applicable. Many portions of a district are naturally far more favorably situated than others, and these advantages consist for the most part of a superiority of climate, proximity to markets and outlets for produce. These are considerations of a permanent nature, and on which an enhanced assessment may be properly levied by Government; all other differences between districts caused by greater agricultural skill and increased capital of the cultivators should not be taken into account in determining the absolute assessment, being not of a permanent character, and as such a system would act as a tax on intelligence and progress, and have a tendency to produce a slovenly and unremunerative style of husbandry.

The district to be assessed is therefore divided up into such distinct portions or groups of villages, as on enquiry are found to be well defined from each other by strong natural differences of climates; and a different rate of assessment is imposed upon each proportioned to its ability to liquidate it. These natural differences are hardly ever found to be so numerous and varied in a talook of moderate size, say of 100 villages or so, as to demand division into more than three or four of these groups or classes, and these distinctions are rarely so strongly marked as to need the

difference of absolute assessment between each of these groups to be more than 20 or 25 per cent.

It only remains now to fix the absolute amount of assessment which it may be considered advisable to levy from the entire district about to be settled, as when once this is determined, the ratio in which the relative values of the numbers, as obtained from a multiplication of the classification by the acreage, is to be enhanced, will be the quotient obtained by dividing the former by the sum of these latter. This will give a mean ratio, and if the enhancement of some villages above this ratio, be counter-balanced by others being at a less ratio, the result will be the aggregate assessment required. The more usual method, however, is to effect the object by a kind of trial and error; by a consideration of the assessment of surrounding districts, and other matters, rates are fixed on the groups of villages, and the result of the assessment produced by multiplying by these rates and adding the totals together, is compared with the amount that is desired to be imposed, and then slightly re-adjusting these rates again, until the required result is obtained.

It is a very complicated question to determine what can safely be taken by the State, and still leave a sufficient surplus with the ryot to render him capable of improving his circumstances and extending his cultivation; and it is one which probably admits of no exact solution. Any one who attempts to ascertain with minuteness from the cultivators, the amount of their expenses for the cultivation of any given area and the value of the crops grown thereon, so as to be enabled to judge of the amount of assessment that can safely be levied, will find them unable to supply him with any trustworthy data. Instead, therefore, of attempting the solution by direct means, a method quite as efficacious for the attainment of the purpose in view can be obtained in an indirect manner, by enquiring into the past revenue management of the district and the relative amount and effect of the collections of each year. The cultivator has no other way of employing his spare capital than by an improvement or increase of his holding, and in those years in which the collections have been moderate, the cultivation may be reasonably expected to have increased during the succeeding year. This effect would also be produced by favorable seasons, by a sudden extension of the export trade and other causes; and, on the other hand, a decrease in cultivation may have been caused by a drought or famine or by a contraction of the export trade. In fixing

upon those years when cultivation was extending itself, in order to ascertain the origin or causes of this prosperity, it must clearly be ascertained that the increase of cultivation has been due to the lowness of the preceding collections, and not to other extraneous causes, and we may then rest assured that the agriculture of the country would continue to advance in prosperity if the State demand were lowered to this amount. The cultivator would then be in a condition to meet the full Government assessment, and to make yearly improvements or additions with the surplus left him. Under the old system, the assessment on the land has been so heavy, that it could only be discharged in years of exceptional prosperity, and any little surplus left with the cultivators in any one year was eventually screwed out of them in succeeding years, and cultivation again declined.

The information collected on the subject of past revenue settlements should enable us to trace with facility the mutual influence on each other of the assessment collections, and area in cultivation, and it will be found to be very difficult to obtain a clear conception of the subject from figured statements, however elaborate these may be. It can be done best by means of diagrams constructed so as to exhibit in contiguous columns by linear proportions, the amount and fluctuations of the assessment, collections, and cultivations for each of the years to which they relate. The specimen

| Periods.                                  | Assessment on cultivated land according to diagram. | Other items comprising grading farms, tax on sheep, and fruit trees, &c. | Revenue of villages, not included in diagram. | Total revenue from Government land. | Estimated survey rental. | Excess of survey rental over realizations of past years. |
|-------------------------------------------|-----------------------------------------------------|--------------------------------------------------------------------------|-----------------------------------------------|-------------------------------------|--------------------------|----------------------------------------------------------|
| Average of last 28 years,                 | 77,406                                              | 1,956                                                                    | 10,707                                        | 90,069                              | 1,15,000                 | 24,931                                                   |
| Average of 5 years ending 1833-34, ... .. | 63,280                                              | 1,508                                                                    | 10,707                                        | 75,495                              | 1,15,000                 | 39,505                                                   |
| Average of last 12 years,...              | 76,188                                              | 2,158                                                                    | 10,707                                        | 89,053                              | 1,15,000                 | 25,947                                                   |
| Last year, 1845-46, ...                   | 71,820                                              | 4,988                                                                    | 10,181                                        | 86,939                              | 1,15,000                 | 28,061                                                   |

herewith given, with the necessary explanation and the figured abstract, was drawn up by Major Wingate, when submitting his proposals for the revision of the assessment in the Bunkapoor Talooka, in the Dharwar collectorate in the year 1846, and will serve to explain the method of drawing up these synopses of the past revenue history of a district. Similar diagrams accompany all settlement reports submitted by the Superinten-

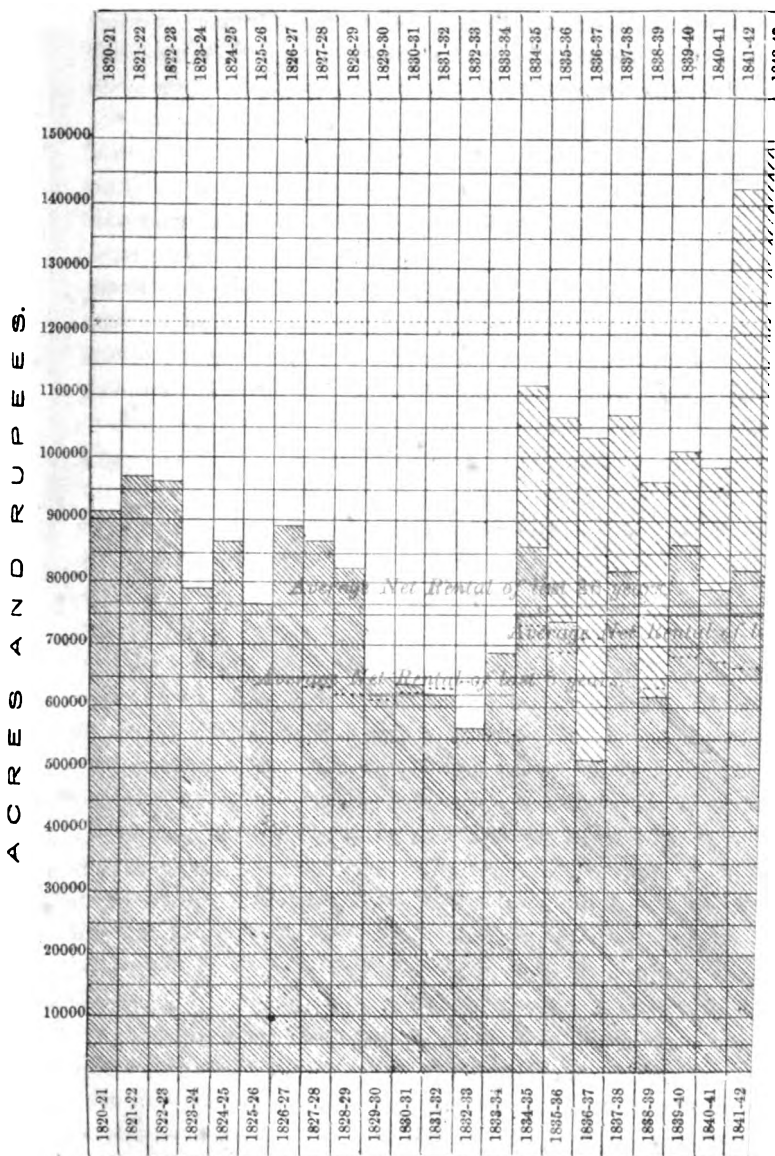
dents of Surveys for the introduction of the revised assessment into new districts; they refer only to villages under direct Government control, and the items of information are alike for each year, and bear reference to the same villages.

The main object of the survey is to afford relief to the cultivators of Government land, but the operations are extended over all alienated land included within the limits of villages under direct control. No reductions are made in the cesses levied on alienated land, but when it is found that these are in excess of the Government demand, the surplus is remitted to the alienee, and the land entered in the records as Government. There are numerous items of land revenue and "*hucks*," or dues to village officers and others, which are consequently excluded from the diagram, and these have to be separately noted and taken into account in order to complete the entire revenue record for the year in which the revised rates are introduced.

In the diagram above alluded to, Major Wingate selected the years 1829-30 to 1833-34, both inclusive, as showing the amounts of collection under which cultivation had been steadily progressing, and as furnishing us in consequence with the data necessary to settle on. It will be as well to show at this place how the final result is arrived at from the original observations in the field of the measurers and classers, by means of an example, so as to complete our view of the subject. Let the area of the "Number" be 27 acres 33 goontas, the classification 15 annas and 1 pie at a distance from the village site requiring a reduction of 2 annas, and that it be one of a group of which the maximum rate is Rs. 2-4 for dry crop. The classification reduced by 2 annas for distance from villages becomes 13 annas and this multiplied by Rs. 2-4, gives Rs. 1-13-5, which is considered as Rs. 1-13-6, it not being necessary to have any rates of less than half an anna. The product of this rate by 27 acres 33 goontas, is obtained from the assessment tables, of which a quarter of a sheet is here shown, and the result Rs. 51-4-10 is the assessment required.

It has been already stated that all imposts of a pernicious nature were abolished and others absorbed into the new assessment. And an example of each of these processes will serve to show what has been accomplished in each case, and the amount of benefit that has been conferred. A striking example of an impost at once hurtful to the cultivators, and through them to the State, is furnished by the tax that used to be levied on fruit trees.

DIAGRAM ILLUSTRATIVE OF THE EXTENT OF GOVERNMENT LAND IN CULT  
128 VILLAGES OF THE BUNKAPOOR TALOOK, WITH THE GROSS AND NET  
DURING THE LAST 28 YEARS, IN SO FAR AS THESE ITEMS ARE ASCERTAIN.  
THE ACCOUNTS.



# EXPLANATION.

The various items are measured by the Scale of Acres and Rupees carried across the Diagram.

The height of the Dotted Line carried across each column marks the extent of the Cultivation in Acres, and that of the upper Dotted Line the area of the whole Government Land.

The heights of the Darker Columns indicate the Net Rental, and of the Lighter the Gross Assessment, on the Land in Cultivation.

The Horizontal Red Lines mark the average Net Rental of the years indicated by the Columns they are carried across.

The Height of the Blue Column shows the estimated Maximum Rental of the whole Bunkapoor Talook, according to the proposed Rates of the Assessment, nine villages excluded from the rest of the Diagram being included in this column.

Ex  
Acres  
Gr  
same  
Ne  
Ar



The usual practice was to sell the produce of all such trees that stood on Government land to the highest bidder, whoever he might be, and in the event of the occupant himself not outbidding everybody else, the purchaser of the usufruct of such trees would have a right of way across his land, and of placing watchmen there to guard the fruit; this would be to the manifest detriment of both parties, the cultivator and the purchaser. The worst effect, however, of this impost was that no one was ready to plant trees, as the proprietorship was not guaranteed to them. Many talookas admirably adapted from the nature of their soil, for bearing mango, jack, tamarind, and other fruit trees, were found to be almost devoid of these valuable products, owing chiefly to the operation of this tax; and, after its abolition, the usufruct being guaranteed under the new rules to the occupant of the land, a great extension to planting was given, and numerous fine groves, chiefly in the neighbourhood of towns, have sprung up since then, while the planting of timber trees on the boundaries of numbers has been engaged in with spirit by the occupants. The attention of Government having been once turned to this subject, it was resolved with praiseworthy liberality, to encourage the production of these ornamental and useful adjuncts to the lands of villages, by permitting the assignment of a percentage of the land, in *enam* or rent free, to whomsoever would undertake to plant groves of valuable trees thereon, and the self-interest and pride of the villagers are alike engaged in forwarding these plantations. The produce of fruit trees standing in Government waste is still sold annually to the highest bidder, but the proprietary right in them, in addition to the occupancy of the number in which they stand, is purchaseable outright, once for all, at any one of these auction sales.

An illustration of taxes not perhaps of a pernicious nature in themselves, which have been absorbed in the land-tax, is afforded by the sheep and grazing tax. The former of these was levied on every hundred sheep, and has now been absorbed in the higher price which is obtained for the grazing of the waste lands, which, under the new rules, are sold annually to the highest bidder. The grazing farms are being gradually absorbed with the extension of cultivation, but so long as any waste remains in a district, it is let out annually, number by number, in the manner above indicated. In addition to these there were numerous "hucks," or dues levied in kind by different officials; these have been all abolished and compensation awarded by Government, whenever they are equitably entitled to it, to the recipients.

In all the districts that have been settled for many years, the revenue has been found to have recovered itself from the extensive reductions made at the time of the introduction of the Survey rates. Its success has been more marked in those districts where there was great scope for the extension of cultivation; and it may be said that wherever large quantities of land are out of cultivation, the fact may be accepted as an indication that the assessment is too high, and that the revised rates should rather err on the side of liberality than the reverse. In the extensive province of Khandeish, which is about half the size of Ireland, the population was about 60 to the square mile at the time of the Survey operations, although from the fertility of its soil, it could easily have subsisted four times that number, and the waste land was of such extent that in many talooks not even the attempt was made to divide it into Survey Numbers. The results of the survey operations in that province will, there is no doubt, in the course of a few years, afford a most striking illustration of the wisdom of those liberal concessions which have been lately granted. The provinces that appear to be exceptions to the rule of extensive reductions, are those whose history has not been so turbulent as the purely Mahratta provinces; the Concan, North and South, and the large opulent province of Goojerat, escaped in a great degree the scourge of war, with its accompanying evils; these districts have been nearly fully populated and cultivated since the period of the British Government, and any benefit that could occur either to the inhabitants or to the State, from a reduction of the assessment, is so trifling, as to demand but a moderate concession.

Another argument, if any more be wanted, in favor of liberality, might be found in the state of the ryots, who were almost always in a state of indebtedness to the *sircars*, or money lenders. In many districts nine-tenths of the cultivators were thus in the hands of these capitalists, and their condition mainly depended upon the individual character of their creditors. In some parts the agriculture was kept up in a flourishing condition by the capital thus employed, the owners being sufficiently enlightened to keep their clients in tolerably easy circumstances; but in others, their condition of indebtedness was not mitigated by any such advanced views.

To sum up these remarks, the introduction of the revised assessment is in general attended by an extensive reduction in the land-tax to afford relief to overburdened districts; but in exceptional cases, this rule must be departed from, should there be no valid reason for adhering to it.

Under all circumstances, it can be said with truth of the survey, that wherever the revised assessment is introduced into a district, the ryots in the course of a few years have emancipated themselves from debt and a new era of prosperity and progress has been commenced, which will secure the enduring loyalty of the inhabitants to the British rule.

Under the ryotwar system, the mass of the population is fostered and protected, but it must not be forgotten that the limit to the physical well-being of a country cultivated by peasant proprietors, is soon reached. Every one produces what is necessary for his own subsistence, and when all produce the like commodities, there can be but little of that internal exchange and trade, which forms the chief national wealth; and the prosperity of the country must depend on a much narrower basis, the state of foreign markets. This during the last few years has been unprecedently favorable, and the cultivation of cotton under the influence of the high prices ruling, has kept pace with the demand: it is not probable, however, that these prices will be permanent, and as a fall takes place, so will the area under exportable produce decrease and cause a reaction and a period of suffering to the population, unless the cost of production be in some manner correspondingly reduced. Government has all the advantages of the position of landlord to the cultivating classes, and can reserve for itself an ample return for its outlay on those extensive internal improvements necessary to increase the fertility of the soil, and maintain a constantly progressive state in their provinces.

In the above remarks on the Bombay Revenue Surveys, the printed records of Government have been liberally drawn upon, and in many places the phraseology has been preserved verbatim; these will be easily recognized by those conversant with the surveys, and it has not been considered necessary to mark them as extracts.

A. C.

## APPENDIX.

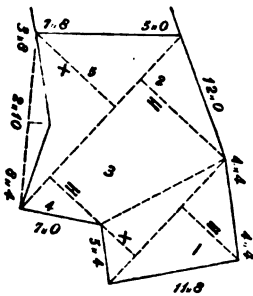
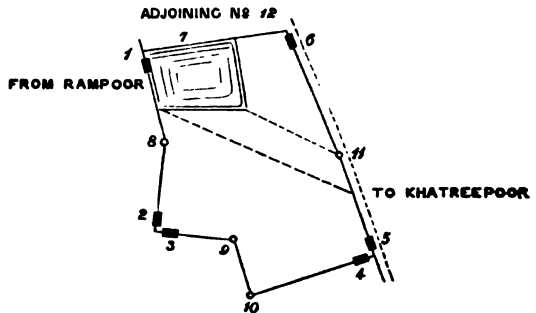
## FORM OF MEASURERS' BOOK.

DATE, 1st. Month, *November*. Year, 1863. Day, *Monday*. Present with the Survey in the Field, *Vitto Keroo*. Patell, *Hurmunt Govind*. Coolcurnee, *Roonjee Suddaseu Multadar*.

| Current Number. | Revenue survey Number. | Former Number, wholly or partly. | Name of field.   | SOIL.                    |        | Tenure.                | Owner, <i>Nagojee Chinnajee</i> .           | Present or absent. | Beegas. |
|-----------------|------------------------|----------------------------------|------------------|--------------------------|--------|------------------------|---------------------------------------------|--------------------|---------|
|                 |                        |                                  |                  | Kind.                    | Color. |                        |                                             |                    |         |
| 17              |                        | 21 wholly.<br>27 partly.         | Sweet ma' field. | Dry crop, rice and tank. | Red.   | Tulput pusait service. | Occupant, himself.                          | 0                  | 10-12-0 |
|                 |                        |                                  |                  |                          |        |                        | Cultivator, <i>Ramajee Govinda Cuddum</i> . | 1                  |         |

The Boundary Marks to this number as shown below, will be constructed by Peon *Nursoo Dewjee*.

NORTH.



Boundary Marks, numbered as follows, will be erected for this Number. Masonry pillars, none; stones, 8, 9, 10, and 11; earthen mounds, 1, 2, 3, 4, 5 and 6; the marks on the side, numbered 7, have been already constructed for Numbers formerly measured.

(Signed) WAMUN SUCCARAM, *Measurer*,

A. Estabt.

I inspected the above marks in the field this day, 10th November, 1863, and found them all completed, as above shown.

(Signed) WAMUN SUCCARAM, *Measurer*,

A. Estabt.

| Direction whence the length is measured. |                           | Length of Figure and distance where the cross-staff was applied. |                   | Breadth in Chains. |                    | Product. |     |                   | Kind of Soil.                 | Acres.  |               |            |
|------------------------------------------|---------------------------|------------------------------------------------------------------|-------------------|--------------------|--------------------|----------|-----|-------------------|-------------------------------|---------|---------------|------------|
| No.                                      | Direction.                | Offset.                                                          | Length in Chains. | Total.             | Half.              | Goontas  | As. | $\frac{1}{16}$ A. |                               | Total.  | Unculturable. | Remainder. |
| 1                                        | North-east,               | = 5 12                                                           | ..                | 6 12               | ..                 | ..       | ..  | ..                | Dry crop,                     | 6 14 14 | 1 12 0        | 5 2 14     |
|                                          |                           | + 5 0                                                            | 15 4              | 4 0                | 5 6                | 81       | 15  | 8                 |                               |         |               |            |
|                                          |                           | 4 8                                                              |                   | 10 12              |                    |          |     |                   |                               |         |               |            |
| 2                                        | North-east,               | = 5 8                                                            | 5 8               | 9 12               | 4 14               | 26       | 2   | 0                 | Rice,                         | 1 2 10  | ...           | 1 2 10     |
| 3                                        |                           | = 11 0                                                           | 11 0              | 9 12               |                    |          |     |                   |                               |         |               |            |
|                                          |                           |                                                                  |                   | 5 13               | 7 12 $\frac{1}{2}$ | 85       | 9   | 8                 |                               |         |               |            |
|                                          |                           |                                                                  |                   | 15 8               |                    |          |     |                   | Total,                        | 7 17 8  | 1 12 0        | 6 5 8      |
| 4                                        |                           | = 4 2                                                            | 4 2               | 5 18               | 2 14 $\frac{1}{2}$ | 11       | 15  | 18                | Talc square,                  | 7 20 0  | ...           | ...        |
| 5                                        |                           | + 8 4                                                            | 21 4              | 9 8                | 4 12               | 100      | 15  | 0                 |                               |         |               |            |
|                                          |                           | 18 0                                                             |                   |                    |                    |          |     |                   |                               |         |               |            |
|                                          | Goontas,                  | ..                                                               | ..                | ..                 | ..                 | 306      | 9   | 13                | Difference,                   | 0 2 8   | ...           | ...        |
| 6                                        | Deduct land included,     | + 8 2                                                            | 16 2              | 1 2                | 0 9                | 9        | 1   | 0                 | REMARKS BY ASSISTANT.         |         |               |            |
|                                          | Remainder,                | ...                                                              | ...               | ...                | ...                | 297      | 8   | 13                |                               |         |               |            |
|                                          | Acres and goontas,        | ...                                                              | ...               | ...                | ...                | 7 17     | 8   | 13                |                               |         |               |            |
| 1                                        | Rice land,                | = 3 0                                                            |                   | 3 4                |                    |          |     |                   |                               |         |               |            |
|                                          |                           | + 2 14                                                           | 13 2              | 3 4                | 3 4                | 42       | 10  | 8                 |                               |         |               |            |
|                                          |                           | 7 4                                                              |                   | 6 8                |                    |          |     |                   |                               |         |               |            |
|                                          | Acres and goontas,        |                                                                  |                   |                    |                    | 1 2      | 10  | 8                 |                               |         |               |            |
|                                          | Dry crop,                 | ...                                                              | ...               | ...                | ...                | 6 14     | 14  | 5                 |                               |         |               |            |
|                                          | Total, ..                 | ...                                                              | ...               | ...                | ...                | 7 17     | 8   | 13                |                               |         |               |            |
| 1                                        | Deduct for foot-path,     | ...                                                              | 19 0              | 0 4                | 0 4                | 4        | 12  | 0                 | Fixed by the Classing branch. |         |               |            |
|                                          |                           |                                                                  |                   | 0 4                |                    |          |     |                   |                               |         |               |            |
|                                          |                           |                                                                  |                   | 0 8                | 0 4                |          |     |                   |                               |         |               |            |
| 2                                        | Tank.                     | + 2 12                                                           |                   | 4 8                |                    |          |     |                   | Total acres,                  |         |               |            |
|                                          |                           | = 2 12                                                           |                   | 4 8                |                    |          |     |                   |                               |         |               |            |
|                                          |                           | 5 0                                                              | 10 8              | 9 0                | 4 8                | 47       | 4   | 0                 |                               |         |               |            |
|                                          | Unculturable goontas, ... | ...                                                              | ...               | ...                | ...                | 52       | 0   | 0                 | Deduct unculturable,          |         |               |            |
|                                          | Culturable acres, ...     | ...                                                              | ...               | ...                | ...                | 0 5      | 8   | 13                |                               |         |               |            |

## FORM OF CLASSER'S BOOK.

DATE, 1st. Month, *March*, 1863. Present in the field with the Classer Patell,  
*Hurree Bhaie Techabhaie. Coolcurnee, Kaloobhaie Dhurmdass.*

| NUMBER.           |          | Former No.  | Beegas. | Cultivated or waste when measured. | Name of field. | Soil.              | Tenure.     | Owner.                                                                               |
|-------------------|----------|-------------|---------|------------------------------------|----------------|--------------------|-------------|--------------------------------------------------------------------------------------|
| Survey.           | Current. |             |         |                                    |                |                    |             |                                                                                      |
| 174               | 92       | 534 partly. | 1-5-8.  | Cultivated.                        | Munguldass.    | Rice and dry crop. | Government. | Occupant, <i>Govinda bin Kalojee.</i><br><br>Cultivator, <i>none.</i> <i>Fallow.</i> |
| 1-7 Area.         |          |             |         |                                    |                |                    |             |                                                                                      |
| 0-6 Unculturable. |          |             |         |                                    |                |                    |             |                                                                                      |
| 1-1 Remainder.    |          |             |         |                                    |                |                    |             |                                                                                      |

## EAST OF PRECEDING NUMBER. (NORTH).

|       |       |     |       |       |
|-------|-------|-----|-------|-------|
| 1     | 2     | ^   | 1     | 6     |
| 1 1/2 | 1 1/2 |     | 2 1/2 | 12    |
|       |       |     |       | 18    |
| 2     | 3     | x   | 3     | 5     |
| 1 1/2 | 1 1/2 |     | 1 1/2 | 1 1/2 |
|       |       |     |       |       |
| 4     | 5     | ^ v | 6     | 7     |
| 1 1/2 | 1 1/2 | ^ v | 1 1/2 | 1     |
|       |       |     |       |       |

## CLASSIFICATION AS FOLLOWS:—

| Dry Crop, ... 0-33  |                 |           |         | Rice, ... 0-8                                                       |                |        |           |        |
|---------------------|-----------------|-----------|---------|---------------------------------------------------------------------|----------------|--------|-----------|--------|
| Cultivated, ... 0   | Waste, ... 0-33 |           |         | Cultivated, ... 0                                                   | Waste, ... 0-8 |        |           |        |
| Class.              | Annas.          | Portions. | Annas.  | Value of soil.                                                      | Water.         | Total. | Portions. | Annas. |
| 1                   | 16              | 1         | 16      | 6                                                                   | 12             | 18     | 1         | 18     |
| 2                   | 14              | 2         | 28      | Measurer has omitted to enter the rice.                             |                |        |           |        |
| 3                   | 12              | 2         | 24      | 4-0                                                                 |                |        |           |        |
| 4                   | 10              | 1         | 10      | 2-0 <input type="checkbox"/> Length, 4-0 ; Breadth, 2-0 ; Area 8-0. |                |        |           |        |
| 5                   | 8               | 2         | 16      |                                                                     |                |        |           |        |
| 6                   | 6               | 1         | 6       |                                                                     |                |        |           |        |
| 7                   | 4 1/2           | 1         | 4 1/2   |                                                                     |                |        |           |        |
| 8                   | 3               | 0         | 0       |                                                                     |                |        |           |        |
| 9                   | 2               | 0         | 0       |                                                                     |                |        |           |        |
| Total, ...          | ...             | 10        | 104 1/2 |                                                                     |                |        |           |        |
| Unculturable, ...   | ...             | 1         |         |                                                                     |                |        |           |        |
| Total portions, ... | ...             | 11        |         |                                                                     |                |        |           |        |
| Quotient, 10-5 1/8  |                 |           |         |                                                                     |                |        |           |        |

- 1 Distance from village, 1/2 mile.  
 2 Cattle are watered from tank, 1 1/2 mile.  
 3 Wells in repair, 0. Out of repair, 1.  
 4 Deduct as unculturable, according to portions, 0-1.  
 5 This No. is (not) usually manured.

- 6 Measurer has (not) made any mistake.  
 7 Fruit trees, 3 mango, 2 tamarind, 1 jack.  
 8 Rice land is watered from tank in No. 105.  
 9 Bagayet crops grown at intervals of 2 years from a well.  
 10 Rice is grown annually and other crops as well.  
 11  
 12  
 13  
 14  
 15  
 16  
 17

(Signed) *RAMCHISHN DAJEE, Classer,*  
*G. Establishment*

## VENTILATION AND COOLING\*

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IN 1862, as our readers are probably aware, a Royal Commission was constituted in England, to Report on the state and defects of the Barrack and Hospital accommodation provided for the army, and to suggest measures for its improvement. Its Report was presented in the following year ; and in 1864 a Supplementary Report was issued, containing suggestions for the Sanitary improvement of Indian stations, with special reference to the construction of Barracks and Hospitals in tropical climates. In 1863, the Government of India appointed Lieut.-Colonel W. A. Crommelin, C.B., R.E., an officer of much Civil and Military experience, to take up the matter locally, and with special attention to Indian requirements, and the important resolution of the Governor General in Council in the P. W. Department, dated 16th December, 1864, gives the final result of that Officer's labors for the last two years.

Although, however, the details of arrangement and construction of Barracks and Hospitals were thus practically settled after very full discussion, it was felt that the question of Ventilating and Cooling Barracks and other public buildings in India might, with advantage, be considered by a separate Committee, which was duly constituted at Roorkee in 1865 ; and their First Report has lately been presented. Although it is chiefly occupied by preliminary discussions necessary to clear the ground for useful results being arrived at, it sufficiently indicates the probable issue of the enquiry to make it worth while to state briefly the difficulties attending the

\* First Report of the Committee on Ventilation and Cooling of Public Buildings in India. Roorkee, 1866.

subject, and the points to which inventors' attention should be directed in their endeavour to solve those difficulties.

The Ventilation of buildings in cold or temperate climates, depends on the fact of the air inside a building being warmer and therefore lighter than the external air. If holes are left in the upper part of a room, the foul air will pass out of them and fresh air can come in through the windows or otherwise. If more powerful means are required, then regular ventilating shafts are provided, by one set of which the cold air comes in, and by the other set the foul air escapes. The up-cast and down-cast shafts of mines are arranged as is well known on this principle, and half the modern public buildings are ventilated in the same way—the heat of a fire or gas being used in the up-shafts to create a strong draft.

But in a great part of India, the temperature of the external air is very much higher than that inside a building; and that often for months together, and by night as well as by day. This fact appears to have been lost sight of by the London Commissioners on Tropical Barracks, their most important recommendations being evidently adapted only to a West Indian climate, or the climate of India near the sea-coast, and not to Upper India and its hot winds at all. Indeed, they acknowledge the difficulties on this point, and recommend its being locally taken up, as it has been. It is evident, from a little consideration, that the above fact prevents anything like self-acting ventilation, for doors and windows must be shut to exclude the hot air, while the foul air inside being cooler and therefore heavier, will not of its own accord pass out of openings above. To effect the admission of the one and the exit of the other, it will be necessary to create a powerful artificial draft.

But for some portion of the hot weather (as said above) it is necessary to cool the air previous to admitting it, and the two questions have to a certain extent to be considered together. What is now done, as is well known, is either to keep doors and windows shut all day long, an unhealthy practice where a number of men are in the same building, or to put a *tattie*, or grass screen in the doorways to windward, keep it wetted, and thus cool the hot air as

it passes through it—the temperature being lowered in this manner from  $5^{\circ}$  to  $20^{\circ}$ , varying with the heat and dryness of the blast.

The defects of this practice are several,—unless there is a strong wind blowing, very little air comes in through the *tattie*,—and if the wind is strong, it passes into the room in cold damp blasts, unhealthy to those who are near it, while at the further end of the room it may be scarcely felt. Unless the *tattie* is kept constantly wet, of course hot air, instead of cold, is drawn in, and it is difficult to keep the *tattie* properly wet by hand-labor alone. Moreover, the arrangement is only effective on the windward side of the building; the rooms to leeward must remain hot. The vegetable matter of the *tattie* under the constant influence of heat and moisture is also apt to decompose, and render the permeating air unwholesome.

Attempts have been made to remedy these evils. Grant's trough apparatus ensures a more equable watering of the *tattie*—and thermantidotes, consisting of an arrangement of blowers turning on a horizontal axle, and driven by hand or bullock-power, are used to create a blast when the wind is not blowing. There still remains however the fitful character of the blast, and the want of any means of diffusing it equably.

It may be as well here to note in passing, that Punkahs merely agitate the hot air inside, and though rendering it for the moment cool to those under or near them, do not at all lower the general temperature of a room, nor do they help at all in ventilating it. We shall speak of their arrangement presently,—but their expense and inconvenience make it very desirable to supersede them altogether, if possible.

More than one scheme has been proposed for cooling the air without the aid of the *tattie*, and it is possible that some of these may be effectual, but inventors are apt to forget the large quantity of cool air required—and the expense attending the arrangement. Nor will a complicated apparatus do for a country where unskilled workmen are alone available to repair it when anything goes wrong. One inventor, for instance, proposes to force the air through ice,

but makes no calculation of the enormous expense to be incurred in making the ice. A more feasible proposal is that of Professor Piazzì Smith, viz., to force the air through a worm like that of a still, surrounded by cold water; the air when thus cooled to be distributed as required—but the power required to overcome the great friction of the hollow tubes, and to provide an adequate supply of air, seems to be have been under-rated; a scheme on the same principle as this, but differing in detail, is still under consideration. Of the various kind of blowers, other than the ordinary thermantidote, which have been tried or suggested, Arnott's Hydrostatic Pump is the only one that promises well, and seems at all likely to succeed.

From all the discussion that has taken place, and with the numerous projects submitted, the results at present attained appear to be these:—

1st. That no arrangement as yet hit upon for cooling the air is better than the grass tattie; and that some better means for watering it is still desirable.

2nd. That during the rainy season it is not necessary to cool the air artificially, but simply to blow in a proper quantity of it.

3rd. That as a blower, nothing has yet appeared,\* preferable to one or other of the forms of the ordinary thermantidote, driven by coolies or bullocks, or in particular places by steam power.

4th. That the amount of fresh air required has been estimated by the English Commission as 20 cubic feet per man per minute, and this may be taken as the standard. The provision for any particular building therefore, is a simple matter of calculation, depending on its size, number of inmates, number of thermantidotes used, and the speed at which they are driven.

5th. That the proper mode of diffusing the fresh air is still an open question; probably it should be by flues from the thermantidote chamber, but whether under the floor or round the sides of the room; whether one or two large inlets will be best for a room; or

\* Unless Arnott's pump on the gasometer principle, which is still under trial, should prove effective and economical.

whether a number of small inlets is preferable, are still undecided points, and can only be settled by experiment.

6th. That from recent experiments which have been made, the position (as regards height) of the outlets for foul air is a matter of indifference. It will be forced out, wherever the exits are placed, if a proper supply of fresh air is forced in.

If it should eventually turn out, that in many buildings at any rate, Punkahs cannot be dispensed with, the best mode of pulling them with due regard to efficiency and economy has still to be decided. Grant's system of treadles, which promised well at first, seems latterly to have failed. Rotary punkahs have been several times proposed and rejected, and schemes of pulling punkahs by clockwork—by pendulums—and by falling weights, seem as yet not to have passed out of the regions of theory. It seems generally admitted now, that the old broad punkahs with short light fringes are far less effective than narrow punkahs with deep heavy fringes; and if their number is properly accommodated to the size of the room—and the pulling power to the number to be pulled—and if they are carefully hung, it does not seem likely from such evidence as has yet appeared, that the present arrangement will be in principle superseded.

The above remarks on an important question may be of use to many whose attention has been, and is now turned in this direction, as serving to show how the question at present stands, and what more is wanted. It is quite possible, however, that they may be modified by the time the next Report of the Ventilation Committee may be presented, and they are merely an expression of individual views.

J. G. M.

## No. CXI.

## THE ADEN TANKS.

*Compiled from an account of Aden by CAPTAIN PLAYFAIR, and from Official Records, by LIEUT. S. S. JACOB, Assist. Engineer.*

THE scarcity of water supply must always have been a cause of anxiety to those who have from time to time inhabited Aden. Water of a good quality, but in limited quantities, is found at the head of valleys within the crater and to the west of the town; as the wells approach the sea, they become more and more brackish, and those within the town are unfit for any purpose save ablution. These are in number about 150, of which perhaps 50 are potable, and yield an aggregate quantity of about 15,000 gallons per diem. They are sunk often in the solid rock to a depth of from 120 to 185 feet, and in the best one, the water stands at a depth of 70 feet below the sea level. An abundant supply of water is procurable on the northern side of the harbour but the difficulty of bringing it into Aden and its liability to be cut off by hostile Arabs, have hitherto rendered it almost unavailable. So great has been the demand, that the brackish water brought from Sheik Othman, a village five miles distant, has often been sold to the shipping and others, for as much as Rs. 8 per 100 gallons.

A project for bringing fresh water from the interior by an aqueduct is now under the consideration of Government.

It was doubtless the want of this common necessary of life which induced the first inhabitants to provide some means of storing supplies of water, and the features of the rocks were well adapted to suggest the construction of Reservoirs or Tanks.

In the centre of the Peninsula of Aden is a range of hills, which rises

almost perpendicularly to a height of 1,760 feet, and forms the wall of the crater of Aden. On the western side the hills are very precipitous, and the rain water descending from them is rapidly carried to the sea by means of long narrow valleys. On the interior or eastern side the hills are quite as abrupt, but the descent is broken by a large table land occurring midway between the summit and the sea level, which occupies about one-fifth of the entire superficies of Aden. This plateau is intersected by numerous ravines, nearly all of which converge into one valley, which thus receives a large portion of the drainage of the peninsula. The steepness of the hills, the hardness of the rocks, and the scanty soil upon them, all combine to prevent any great amount of absorption; and thus a moderate fall of rain suffices to send a stupendous torrent of water down the valley, which ere it reaches the sea not unfrequently attains the proportions of a river.

To collect and store this water the Reservoirs were constructed. They are extremely fantastic in their shapes; some are formed by a dyke being built across the gorge of a valley; in others the soil in front of a re-entering angle in the hill has been removed, and a salient angle or curve of masonry built in front of it; while every feature of the adjacent rocks has been taken advantage of, and connected by small masonry channels to ensure no water being lost. The overflow of one tank has been conducted into the succeeding one, and thus a complete chain has been formed.

There is a tradition in Aden, that about A. H. 906 (A. D. 1500) the individual who was then Governor persevered in digging wells for sweet water, and being successful the reservoirs were permitted to fall to ruins, or to be filled up with the débris washed down from the hills, which would be sure to happen sooner or later, as there were no shield bunds; and in 1859, when the tanks were in process of restoration, although the channel had been cleared for about a quarter of a mile above the upper tank, a storm which occurred brought down such a large deposit of stones and gravel, that Captain Fuller in 1860 constructed shield bunds across the necks of the water-courses leading to the tanks. Below the shield bunds, and in addition to them across the main ravine, are two bunds which form lakes, and these are connected with the tanks below, by pipes which can be shut off when necessary.

In the shield bunds are inserted grated sluices 2 feet square, to allow water to pass when it rains but slightly, and before it has time to be absorbed by the rock.

In 1854, Captain Playfair, Assistant to the Political Resident, turned his attention to these tanks, and on his own responsibility undertook the task of restoring them; the expense being met by the Municipal Fund, and by the money realized by the sale of water. A few ruined tanks on the sides of the hills which never were buried or concealed, were the only visible remains of the ancient reservoirs; but as the work progressed, the magnitude of the system became apparent, and a further measure of assistance was afforded to Captain Playfair by the quit rents charged on building grants, being appropriated to the object.

Subsequently, at the request of Brigadier Coghlan, then Political Resident at Aden, Government granted such sums of money as from time to time were required to carry on the restoration without further reference. Each month, as further excavations were made, and the débris with which they were filled was removed, new tanks came to view, and so the work progressed under the Superintendence of Captain Playfair till February 1857, when illness compelled him to return to Europe, and the work was made over to the Executive Engineer, Aden. Up to that time, tanks had been completed, the aggregate capacity of which amounted to about 3,538,000 gallons, and the expense incurred in effecting this, amounted to no more than Rs. 11,542, of which Rs. 6,500 had been granted by Government.

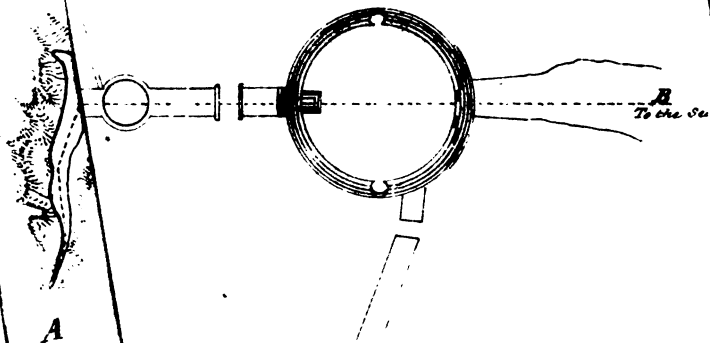
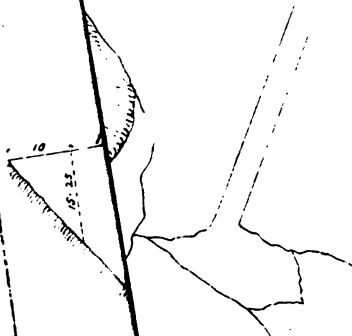
Subsequently, when a violent fall of rain had afforded the necessary experience regarding the style of work required, and the size of the aqueduct necessary to carry off the overflow of No. 1 Tank; Captain Playfair's aqueduct was replaced by one better adapted to resist the immense force exerted by the stream; the walls of the tanks repaired and cleared out by him were also heightened so as to double their capacity, and one tank was greatly increased by using it as a quarry for stone required in the work.

The plan will show the position of the tanks with reference to each other, and the sections will show the depths on the section line; but the bottom of each tank presents more or less an irregular, fantastic appearance, according as the natural surface of the rock has been plastered over, or masonry has been used.

Each tank is connected with the succeeding one by an open or covered duct, and as soon as one is full the water is conducted to supply the next tank, until the whole system is full; and when the last, a large circular

# THE ADEN TANKS.

100



100 feet.

1. THO: 7-5 500 feet.



tank, has received its supply, the surplus water is carried to the sea by a channel 60 feet wide, the sides of which are dry rubble (slope 1 to 1) with a masonry coping; and across it at every 30 feet masonry bunds are placed below the surface to protect the bed from scouring.

The plan on which the last, the circular tank, has been constructed is worthy of note; it is built in a series of rings or off-sets, increasing in diameter from the bottom upwards; the perpendicular distance between each off-set is about 5 feet, and the off-set itself about 1 foot in width. There are two places where these off-sets have been omitted to facilitate the drawing of water; over each a pulley can be arranged for hoisting the bucket. The advantage of these off-sets is the facility with which it enabled men in the first instance to construct the tank and afterwards to effect repairs.

All the tanks are furnished with flights of small steps constructed on the sides wherever necessary or convenient.

Perhaps it may prove useful to state the manner in which these tanks have been plastered. Whenever any uncertainty existed as to the nature of the ground, it was roughly paved, leaving joints of about 1 inch width; this lessens the chance of crevices occurring between the stones which might sometimes occur if they were set close. On this, concrete composed of equal parts of lime and gravel was well rammed. The thickness of concrete depends upon the height from which the water had to fall; about 1 foot in thickness of concrete for 10 feet fall is sufficient. Over this, 3 inches rough casting (composed of 1 part chunam, 1 part sand, and 4 lbs. hemp, per 100 square feet, well mixed) is laid in layers of about 1 inch at a time; and when the rammer emits a clear hard sound, the final coat of plaster is added, composed of 10 parts chunam and 1 part sand.

The lime at Aden is obtained from coral, and is of good quality. Care should be taken to prevent heavy rain from falling on the plaster until it has properly set, and it should also be shaded from the sun in the hot weather.

The total contents of the Government tanks, including upper lakes formed by bunds, are about 11,000,000 gallons. A moderate fall of rain, say about 3 inches in 3 hours, would fill the whole system, and in a few times would repay Government well for all outlay incurred: but unfortunately we have had so little rain in Aden since the tanks have

been completed, that it is not fair to draw conclusions. Every shower of rain saves Government so many rupees, and gives the troops and others at Aden the blessings of good sweet water. Hitherto the water collected, owing to the scarcity of rain, has not proved anything like sufficient.

S. S. J.

## No. CXII.

## ROADS IN COORG.

*Abridged from a Report by MAJOR R. H. SANKEY, R.E., Assistant to the Chief Engineer, Mysore.*

IN 1862 a small platform bridge 9 feet wide by 4 feet high, placed in one of the numerous short embankments on the Mercara-Veerajendrapett road in Coorg was carried away by a flood, and the Engineer, Mr. Stoddard, submitted an estimate amounting to Rs. 2,110, for reconstructing the work, increasing the bridge to a span of 12 feet, and raising the embankment throughout—making, in fact, apparently all reasonable provision for meeting the requirements of the highest probable flood.

But the floods of 1863, proved much more serious than had been anticipated, and a second design had to be framed, for a bridge of double the capacity. Last year's floods coming down with still greater power, and further the labor rate having sensibly increased, a third revision was found essential, bringing the estimate up to Rs. 14,960, or seven times the amount originally contemplated.

Viewing the whole circumstances of this case, and others bearing a close analogy to it, the Chief Engineer considered a strict enquiry on the spot essential, and with this object I proceeded to Coorg on the 19th ultimo. Having now carefully inspected the works in question, I am clearly of opinion that the Executive Engineer has acted with all reasonable foresight, in framing his successive estimates, with the data of previous floods before him, but that from the daily changes now being wrought, in the physical condition of Coorg, these data cannot be accepted as guides to the future.

In the former condition of the country, when dense rolling forest covered all but the mountain tops and the rice lands in the deep intervening valleys, the rain-fall was in part sucked up by the redundant vegetation, in part absorbed into the earth—being stopped from flowing off by thickly interlacing roots—in part evaporated from countless leaves and stems, and only probably a comparatively small portion, enabled to flow off at once into the various streams. It appears to me however, that in consequence of the great areas of forest land, now laid bare yearly by the planter, the rain-fall is discharged much more rapidly down the mountain slopes than was formerly the case, among other results giving rise to floods of yearly increasing magnitude. That such must necessarily be the result of extensive clearings, would I should think be at once admitted. I shall give hereafter certain proofs that at least the argument does not rest on theory—meanwhile the mere statement of the fact, in reference to a country with the known heavy\* rain-fall of Coorg, must give rise, to vague apprehensions for the future.

The consideration of the general question, as to the effects of clearings in other tracts as well as Coorg, on the bridges, anicuts, and other river works, down to the sea, though naturally following, is much beyond my powers and present object, I trust however I may be excused for deeming it of sufficient importance, even in the limited sense of its direct effect on Coorg works, to warrant my converting what was originally intended as a simple professional report on two or three individual works, into one of a more general nature, relating to the present position of the Department and the work before it, under the peculiar circumstances above described.

The present time also appears for other reasons, suitable to such a consideration of our position. It was not till three years after the British had possessed themselves of the country, that the impossibility of moving a force into South Coorg—to subdue the rebellion which had there sprung up (1837)—demonstrated the absolute necessity of constructing some kind of Military road, and the Sumpagee ghaut was made by Lieutenant Fast of the Engineers. The Anachowkoo road and Periambody ghaut were finished some twelve years later, also as a military necessity—the old line to Cannanore, through Wynaad and by the Perriah pass, proving altogether impracticable. The connecting road between Mercara and Veera-

\* Rain-fall at Mercara—1863-64, 135 inches; 1864-65, 143 inches. It is believed to be much heavier at Periambody ghaut.

jendrapett, with a similar military object, was made shortly afterwards. At this moment these three military roads, remain practically the\* only ones devoted to wheeled vehicles in the country, and it will be seen from what follows that even these—masterpieces of engineering as they were, when first driven through almost impenetrable forests—are in many places quite unsuited to the requirements of the cart traffic which has now set in upon them, and which with the altered physical conditions above alluded to, coupled with other causes, threatens to render them entirely unserviceable, unless energetic measures be adopted for their preservation, and reconstruction in places. When in addition to this it is borne in mind, that hardly a portion of Coorg, with the exception of Nalknad, remains unoccupied by planters, there can be no reasonable doubt that the whole country will be the scene of European enterprise, in a very short period—Coorg in fact forming with Monzerabad on the north, and Wynaad on the south, a vast connected colony. It therefore appears to me perfectly clear, that even were the main roads above alluded to, in thorough working order, they would only in a very partial degree, meet the first wants of the country, and that an imperative necessity exists for devising some practical means of giving a more extended series of communication.

To facilitate reference I have constructed the accompanying Map, from such information as I could procure. The Trigonometrical Survey shows only the old native tracks, and it may be doubted whether the topographical features are very correctly indicated. We have no actual surveys of the Ghaut Roads; they are however here I think sufficiently well laid down, to answer my present object. The heights above sea level have been determined from means, struck on the observations of the Rev. Mr. Richter, Mr. Stoddard, and myself; being however taken with the Aneroid, they can only be accepted as approximations.

With reference to the condition of the Ghaut roads, in regard to gradient and soil, I would invite attention to the longitudinal sections herewith given. Though the slopes have been roughly determined, without the use of the instrument, they will be found sufficiently accurate for all practical purposes, and show at a glance the weak points claiming early attention.

First in the list is the Mercara-Fraserpett road, 19 miles. This is

\* Carts, it is true, have passed over the new Mercara-Codlipett road, but the work is far from complete.

probably the most defectively traced line in the country, for it will be noted that although there is only about 1,000 feet difference in level between the termini (giving an average fall of 1 in 100), there are two places between the 3rd and 5th miles, with gradients of 1 in 9, and 1 in 10, and many others with 1 in 15 and 16. The present condition of the steepest portion is most distressing. The longitudinal slopes being as great or greater than the side slopes, the water tears down the centre of the road, ripping up everything but large boulders, and the surface repairs, made from the trifling maintenance allowance, Rs. 150 per mile, are altogether useless.

The Coorg hills being composed of metamorphic rock in which felspar is largely present, all near the surface is decayed, and there is very little really good gravel to be procured. Good gravel indeed appears only to be met with in laterite formations, at a few points along the Tulla Cauvery road; also between Veerajendrapett and Perimbady, and again on the Bittengall road with perhaps a few other isolated spots. Metal is procurable either by blasting, or from the embedded boulders met with in excavating the scarps. While therefore presenting great facilities for first formation, it is evident that very serious evils result from the geological structure of Coorg, in regard to two of the main requisites of ghaut roads. The first is, that the foundation of the road must be soft and yielding, and that there is no proper top dressing present, for such metalling as may be laid down; the second, that the side scarps and other portions readily yield, and fall away with the slightest run of water on the surface—there in fact being no coherence in the soil.

To my mind therefore, a new trace of at least all portions, with gradients above 1 in 18 is a first necessity. The portion between Mercara and Sonticoopa being the worst, I would urge an entirely new line being made. Without a more careful examination of the country, trial traces, levels, &c., it would of course be quite impossible to say what actual line should be adopted, I am however satisfied that on all professional grounds, as also from the stringent orders issued by the Government of India, in regard to gradients of ghaut roads, (the maximum having been expressly limited to 1 in 22,) no other conclusion can be arrived at, than a thorough reconstruction, for the upper portion of this road. Between Sonticoopa and Fraserpett, it will also be observed, that there are in places, very objectionable gradients. The adoption of zig-zags, or a slightly more





circuitous route in one or two places, amounting in the whole, to (say) a reconstruction of 3 miles, should I imagine, suffice. I would also observe that in addition to other objectionable features, high jungle lines the road closely for several miles, chiefly in its lower portions, and if not removed at once by planters (the undergrowth being left to preserve the surface) should be cut down to 15 yards on either side of the road. Halting places for carts and cattle off the road should be provided, and stringent regulations enforced regarding their use.

The Sumpagee Ghaut,  $19\frac{1}{2}$  miles in length, and leading direct to Mangalore, is the next line claiming attention. This great work, the first of the 14 or 15 roads now carried through the Western ghats, is undoubtedly the best in Coorg, and so far as I can judge only requires trifling rectification between the 9th and 10th miles. At the upper portion of the mile the slope is 1 in 12, and for a short distance approaching a bridge over a ravine, at the 10th mile, as much as 1 in 6 or 7. There is a deep narrow gorge at this point, which no doubt rendered the selection of a better line almost impossible, with the features of the neighbouring slopes, shrouded in dense forest. Even now with nearly all laid bare, it is no easy matter to choose another, and although from my own personal examination, I am satisfied the line can be carried by a zig-zag in another direction, very careful alignment will be required. At a rough estimation, I should say  $2\frac{1}{2}$  miles of new ghaut would have to be made. It will be observed that from about the  $2\frac{1}{2}$  to the 4th mile, there is a counter gradient; this however was essential, in order to get over the saddle on one of the lower spurs of the range, running off towards Tulla Cauvery. The ghaut is nearly metalled throughout, indeed I might say paved, in its lower portion. The metal is staring and gritty, and I should fear would in great measure be swept away, if means cannot be found before next May, for protecting it with gravel, and a well formed up roadway.

Several slips have occurred in this line, the most serious one being below the 10th mile stone. This resulted in a great measure from the clearings both above and below the roadway, and though a passable road has been constructed across the breach, some permanent arrangement must be made for diverting the upper drainage, and leading it off to the stream below. The side cuttings in the first mile near Mercara are extremely heavy, one double escarpment being about 90 feet high, and the drop on the lower side of the road precipitous to a degree. Some thick growth should be

encouraged here to obviate all possibility of a slip which, if it occurred, would be fraught with the most serious consequences. Halting places for carts are also required on this ghaut.

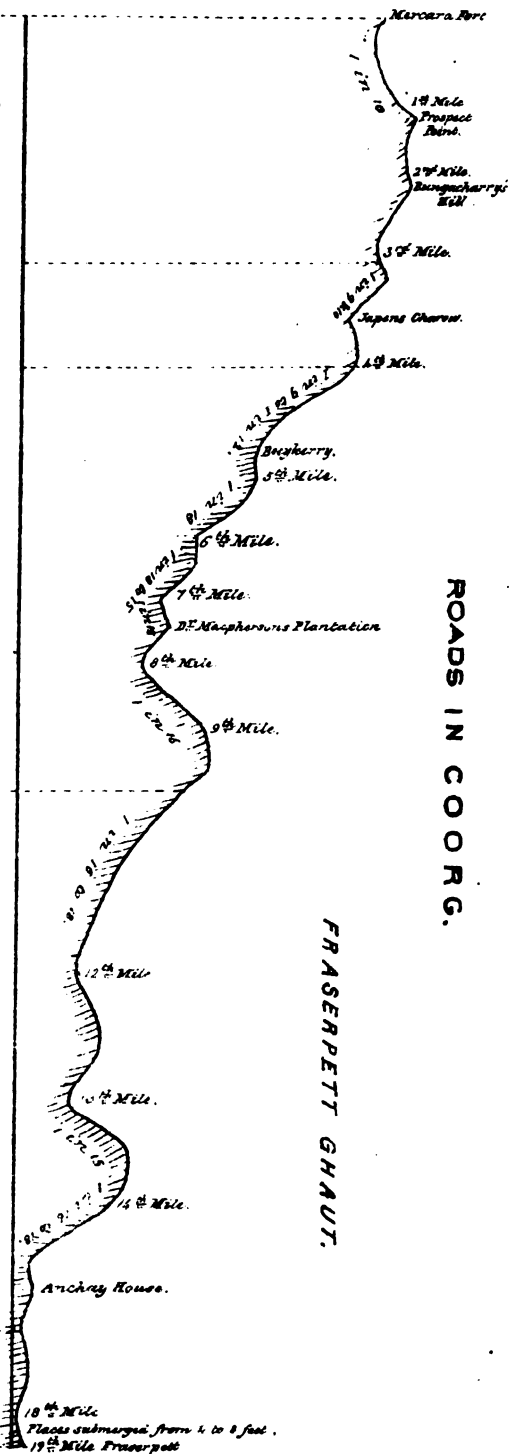
The total fall in the first 15 miles of this Ghaut is about 2,900 feet, which gives 1 in 87 for the whole line, but it will be observed that the influence of the counterslope has prevented this being worked out. From the foot of the ghaut to the town of Sumpagee,  $4\frac{1}{2}$  miles, the fall is only about 55 feet.

The next Ghaut in order of succession, is the first  $2\frac{1}{2}$  miles of the road leading out of Mercara, towards Veerajendrapett. At the end of the 1st mile and after passing the second, the gradients are 1 in 9, and in nearly all other portions excessively severe, so much so indeed that I would beg to recommend entire reconstruction. The side cuttings in the upper portion are also extremely heavy, and as this part perhaps afford the most marked example of the effects of clearings above ghaut roads, I herewith attach a rough sketch which I made of the first mile of this ghaut, as seen from the Sumpagee. Here it will be observed on the central hill, that the planter, to prevent the soil being washed away from his trees, ran the horizontal drains *a, a, a, a, a*, but these becoming surcharged, burst at different points, forming the perpendicular channels *b, b, b, b*, at the end of each of which, most formidable breaches have occurred. These four slips in this short space are each I should say at least 100 feet high. On their occurrence it took several days with the utmost exertions to clear the road, and in two cases the breaches carried away the roadway itself, occasioning the most formidable chasms on the lower side. My own opinion is that unless some thick growth be at once encouraged on this hill, the next monsoon will see these breaches greatly extended. In fact, there appears every likelihood of the original form of the hill being altered, and the work, in preserving the road, becoming endless.

As a distinct proof that to upper clearings, are to be attributed nearly all the serious slips which have taken place, I would point to the present condition of the cutting mentioned above, as also to the weathered, and apparently perfectly safe condition of many other similar scarps, where the upper surface of the hill has not been disturbed. Every one passing through Coorg, has been struck with the gigantic trenches, carried through deep valleys, and along the tops of the highest hills, serving as ancient boundary marks (Kodungas). Some of these are nearly 40 feet from

ROADS IN COO R.G.

FRASERPETT GHAT.



A small amount of fair Gravel here and there procurable.

Metal procurable only by blasting, difficult.

Metal procurable, only by blasting.

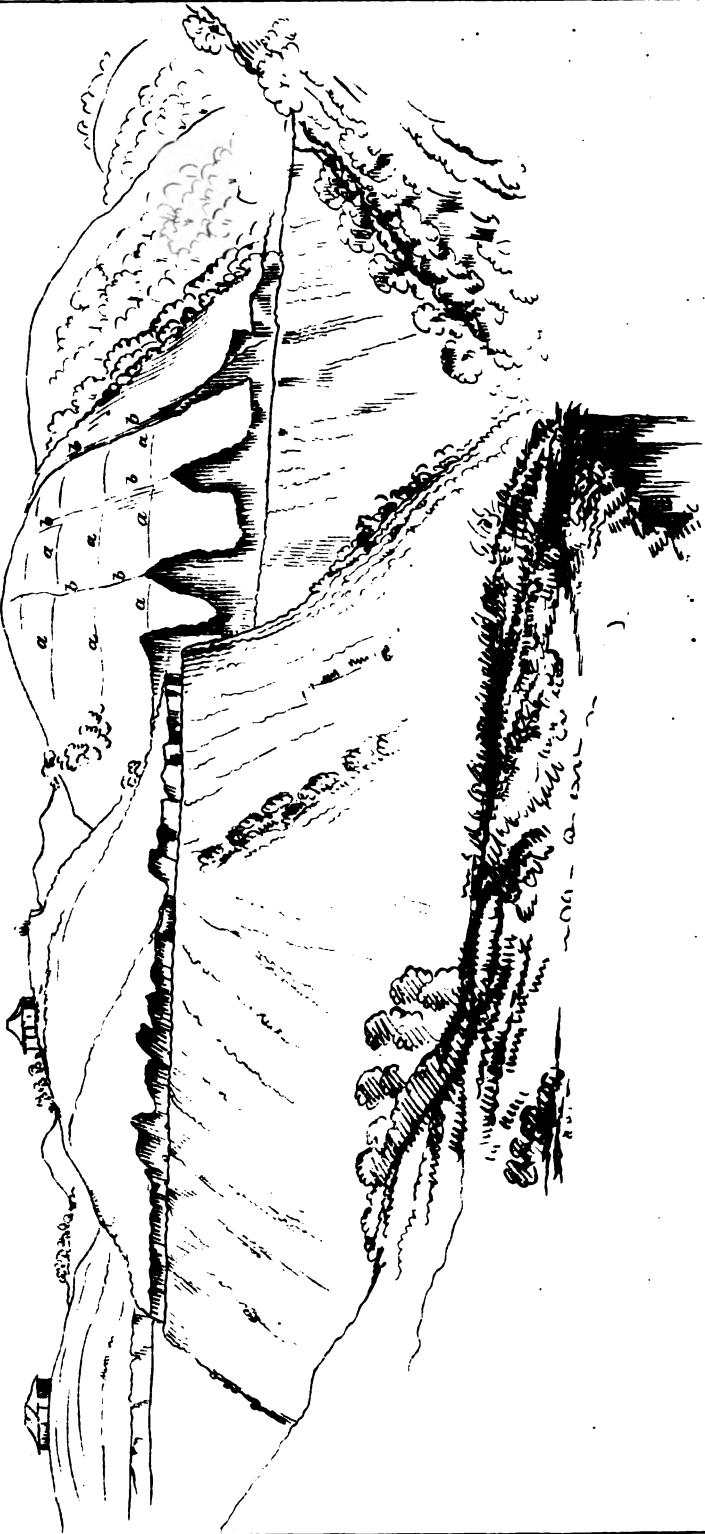
Bad soil. No gravel Metal from 1 to 2 Miles.

Gravel of some kind to be had. Metal, stone procurable within a mile.





PUBLIC WORKS IN COORG.



LITHO: T. C. PRESS.



summit to bottom of ditch, and often taken along hill sides with an angle of  $80^\circ$  to the horizon; yet though hundreds of years old, the edges of most of them are as sharp as possible, in spite of the natural incoherence of the soil. This simply results from the surface not having been ever disturbed.

The total fall in this ghaut is about 550 feet in  $2\frac{1}{2}$  miles, giving 1 in 24 over all; there are however two short counterslopes, which have thrown out the remaining gradients.

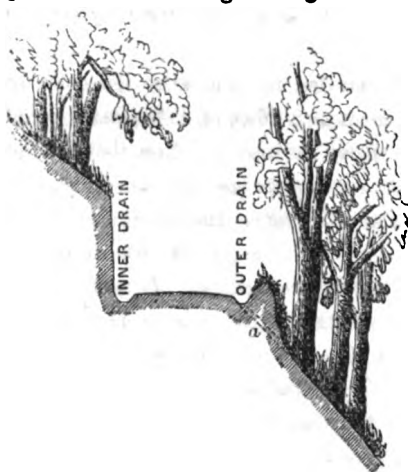
The fourth and last of what may more especially be termed, Ghaut roads in Coorg, is that at Periambody—10 miles in length—leading down towards Cannanore. It will be observed from the section, that for the first  $2\frac{1}{4}$  miles the slope is sufficiently gentle, but for the three-quarters of a mile just above the Wotacolly bridge, there is a distressing gradient of 1 in 10 and 12. The road after this is easy and level in places to beyond the 4th mile, from which it drops down to Woority with generally far too steep a gradient.

I have very little doubt, that by carrying the line along the southern slopes of the hill at Wotacolly,  $1\frac{1}{2}$  or at most 2 miles of new ghaut would overcome the objectionable gradient above the bridge. Now that the hill sides have been laid bare and planted, it is easy to see that an alternative line lies in this direction; but when Captain Francis laid out the ghaut, so dense was the undergrowth and vast the forest overhead, that no neighbouring feature of the country could be seen from below. It was only in fact by lighting fires along the trace and standing on a bare topped mountain, commanding the ghaut, that the direction with reference to the adjoining ground could be ascertained. The alteration of the lower portion of the ghaut is a different matter. Though undoubtedly desirable, it is not easy to see how it could be effected. The point on the section, named the Jemadar's rock, is, so far as I can judge, the top of a precipice of sheet rock, across the face of which it having been found impossible to work, it was allowed to rule the gradient down to Woority. Once this point was accepted, I conclude there was nothing for it but to lay out the ghaut as it now exists; the hill side, along which it is carried, being at far too steep a slope to allow of length being gained by a zig-zag.

I found the upper portion of the ghaut, where the gradients are easy, all in fair enough trafficable condition and being metalled, but the evils of too steep a gradient were at once apparent lower down. Previous to the ghaut

roads being taken over by this Department in 1862, the Madras Government had spent some Rs. 60,000 in metalling this line, but chiefly from steepness of gradient, the metal (unfortunately very thinly laid on, and placed on an imperfectly barrelled road) was almost wholly swept away, and only traces of it can here and there be observed. In the first rough shaping of the ghaut, many boulders had been left, and others of a smaller size were probably thrown in from time to time, to fill up the deep channels cut by the water tearing down the ghaut; its dreadful condition can therefore hardly be exaggerated.

In speaking of the Veerajendrapett Ghaut, I have shown the effects of clearings above hill side scarps. The portion of this (the Periambody) Ghaut already cleared, showed in many places on the other hand, the evils of clearing on the lower side of the road, where the side slopes are great. When forming the original roadway, Captain Francis adopted a simple

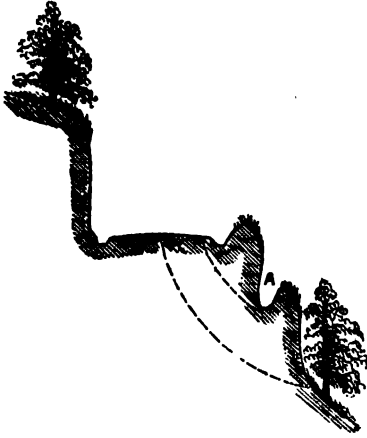


barrelled surface as in ordinary roads, thus throwing half the drainage over the hill sides, by small cuts (a) from the outer drain at every 30 or 40 feet, as roughly shown in the side section. The plan answered admirably in the former uncleared state of the hill sides, fewer cross drains being found necessary, and the thick vegetation on the outer slopes preventing the chance of the soil being washed away and breaches resulting. The moment however

the slopes were cleared of jungle, the whole condition of matters changed. The planter to prevent the soil being washed from the lower slopes, very naturally cut the longitudinal drain A, in the next section. This unfortunately operating in undermining the bank, frequent breaches of the nature shown by the dotted lines, have been produced.

The Executive Engineer, to help out matters as much as he could, has been endeavouring to dispense altogether with the outer drain, by raising the outer side of the road, and throwing the whole drainage into the inner drain, which having thus double its previous work to do, required to be

cased by new cross drains at closer intervals; 52 extra cross drains are



therefore now in the course of construction, but the attendant difficulties are of a very serious character. To obtain an outfall for these drains, which shall be free from the chances of occasioning frequent breaches, seems very nearly an impossibility where the hill side is laid bare, and unless very thick planting can be maintained down the side of the channels, I do not see how the matter can be managed.

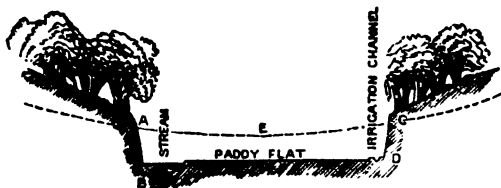
For all existing uncleared ground along ghaut roads, I would venture strongly to urge the necessity, of preserving a belt of low jungle, both on the upper and lower slopes, of from 40 to 50 yards wide. Indeed to ordinary observers, it would appear to be quite as little in the interests of the planter, as of Government, to cultivate slopes which are so steep that the upper mould is easily washed off, and where, as is not unfrequently the case, such slips occur that plants and all are washed into the valley below. Hill sides are now planted at angles of  $45^{\circ}$ ,  $50^{\circ}$ , and even  $60^{\circ}$  to the horizon, when it would hardly appear possible to preserve for any length of time, the surface soil on slopes of more than  $20^{\circ}$ . I am informed that it is the practice on steep slopes, to plant the coffee trees closer together, but in any case the ground between must be kept clean and free from weeds, so that the evil is only very slightly mitigated.

There are now about 7 miles of the Periambody ghaut to which my remarks especially refer, as the forest is as yet standing, and it is with regard to this I should be glad to see some decision arrived at. The slopes are extremely steep for the last 6 miles of the ghaut, and all along may be observed the noblest spars of Poon (*Calophyllum bracteatum*), Anjely (*Artocarpus hirsuta*), Chittagong wood (*Cickrassia tabularis*), Honay (*Pterocarpus marsupea*), Sumpengi (*Michelia champeca*), Red Cedar (*Cedrela toona*), and many other timbers, whose value on the coast is I understand rising daily, and which therefore, it would appear most desirable to conserve.

Having described at more or less length, the ghaat portions of the through main lines of communication, I would beg to draw attention to the two connecting links, viz. the road from the foot of the Veerajendrapett ghaut to Perimbady— $21\frac{1}{2}$  miles—and that from Perimbady through Attoor and Tittamutty, leading towards Mysore— $39\frac{1}{2}$  miles to the frontier.

As both these lines partake very much of the same characteristics, I may at once state, that they are a perpetual series of rises and falls, being carried across low spurs of hills, with intervening paddy flats. The gradients are frequently very bad indeed, but being for the most part over short pieces, I would not suggest any rectification at present, draught cattle being able to make the needful exertion when the strain is not too continuous; metal however should undoubtedly be employed, and the form of the road preserved. Felling of high jungle on either side is also much needed in many places.

The point however chiefly requiring attention in both roads, is how to deal with the embankments crossing paddy flats; these having suffered most severely from floods, during the last three years—these floods, as I have at the commencement stated, being I believe progressive, in proportion to the extent of land cleared for planting, and liable as has already been the case, to stop all communication, by blowing up the bridges, &c. These flats or cultivated Coorg valleys, present quite a peculiar section,



the result no doubt of the incoherent nature of the soil before alluded to. Instead of gently sloping off into the valleys, the hills terminate

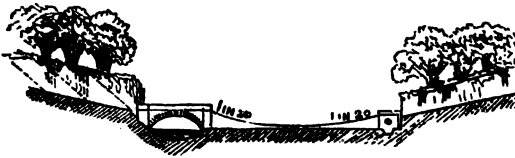
always in abrupt banks (AB and CD in the above section,) which vary from 20 to 40 and 50 feet high—the stream shown at the left corner, having probably wandered from side to side, (*i. e.*, from B to D,) much in the manner of the Ganges, and other rivers of Upper India, within the limits of their “Khadir.” An irrigation channel taken off high up, runs usually along the other side (D), and the stream when surcharged, inundates a large portion, if not the whole intervening space. These paddy flats vary in width from 100 to 500 yards as a rule. Some however in South Coorg much exceed this, presenting magnificent sheets of cultivation girt by densely wooded hills.

In carrying a road across such places, (they are met at distances vary-

ing from half to two miles apart,) the plan adopted was to throw an arch over the stream at B, also a tunnel for the irrigation channel at D, the roadway being formed in embankment, somewhat as indicated by the dotted line in the above section. In the middle of this embankment at E, was also constructed a small bridge for the discharge of surplus inundation water.

These arrangements answered sufficiently well, so long as the floods remained within their original bounds—now, however, that the tendency to increase yearly has shown itself in several cases, the irrigation drain at D, and in more cases, the small bridge at E, have blown up. Five embankments crossing paddy flats between Mercara and Veerajendrapett, have thus suffered during the past two years. In the early part of this monsoon, the Kokeloor embankment, close to Veerajendrapett, was for the first time since its construction, (supposed to be 15 years ago,) over-topped, the flood standing 4 feet above the small central bridge, which it fairly blew up, transporting the whole of the materials to a distance of some 50 or 60 feet. The bridge over the stream at B, has always been saved by the destruction of the smaller one at E, the inundation water thus venting itself—but it is perfectly clear that if we go on increasing the embankment to what we consider a safe height, and rebuilding the central bridges at E, considerable risk will be incurred of throwing too great a portion of the flood through B, and destroying thus the main works. Most of the latter are single span bridges of 40 to 55 feet, and were very costly.

In dealing with what, as I judge, has now become a gradually accelerating force, the first necessity is to provide for the safety of the bridges at B.



I would therefore instead of raising the embankment and rebuilding the bridge at E, cut down the former and omit the

latter, making the whole assume the section shown, which allows the inundation after a few feet rise to flow over the centre of the embankment and thus vent itself innocuously.

There are only two essentials in dealing thus with the matter, viz., first, that the gradient of the approaches shown should be a maximum; and secondly, that the central point of the embankment should be kept as low as

possible consistent with this. I have every reason to believe that no flood would thus interrupt the communications more than three days at the farthest, and a few trifling repairs to earthwork would suffice after its retirement.

Having now reviewed the state of the main lines, I will briefly refer to those under construction or proposed.

The road now under construction between Mercara-Somwarpett—and Codlipett—44½ miles—was commenced some three years ago, and during last year had made such advance as to admit of carts going over it. Of course however the work is far from complete. The original idea in thus connecting Munzerabad and Coorg, was to run the line to Sonticoopath, but it was afterwards altered to Mercara, as holding out greater advantages. The line having been laid out, under stringent regulations in regard to gradient, and the trace receiving great attention, the result is a road with uniformly the best gradients in this Province. With one or two very trifling exceptions, I think the maximum gradient throughout the line as far as Somwarpett, may be pronounced to be 1 in 18; 1 in 20 is common on the ghaut portions. In ascending the hill beyond Somwarpett, I fear the gradient is 1 in 16, but after that to Codlipett, 1 in 19 and 20 is the maximum—the line in most places being very easy and often nearly level. Most of the roadway is 18 feet wide. There are places 16, others 14, and even only 12 feet wide: but these form a small proportion, and I should think that in three months the full width will be attained from first to last. The work is progressing with very creditable activity.

For the Choranhully, a single timber trussed span of 50 feet is proposed; for the Mahdapoor two similar spans, and for the Huttyhulla three spans of 50 feet. All of these streams run eastward, forming after their junction the Haringhy river, which joins the Canvery a little above Ramasammy Cunavi. The Choranhully is narrow, and having a rapid longitudinal fall, comes down with great force when in flood—a causeway is therefore inapplicable, as also the maintenance of communication by means of a ferry. I see therefore no other course than to construct the bridge as proposed. The Mahdapoor has already had a rough stone causeway thrown over it, which has perfectly withstood the last two monsoons. As it answers every purpose of cart traffic for nine months in the year; and as further, the communication during the remaining three, is now again—

tained by basket boats, (two wretchedly small affairs which should be replaced by a proper ferry boat,) I do not see any very urgent necessity for bridging the stream. The same remarks apply to the Huttihully, across which the Executive Engineer is about to construct a causeway, similar to that at Mahdapoore.

The next work of communication now under execution by this Department, is the trace of the proposed line from Veerajendrapett, viâ Ammuty and Seedapoore to Fraserpett—in all 28 miles. Of course, like all Coorg roads, the trace is up and down hill, and crosses paddy flats at every one or two miles. I found however the gradients all very fair, the only real difficulty being in, and immediately leading out of, the town of Veerajendrapett itself. Within the limits of the town, the main streets of which have gradients of 1 in 10, it has been found necessary to bring in the new line from the Mercara road, and then take it by a zig-zag up the face of a hill to the east and over a saddle.

In addition to the roads designed, and carried out from Imperial funds, others are now being constructed by planters from their own private means. Though not having personally inspected these, and thus unable to offer any accurate information regarding them, I think it only right to place on record, however imperfectly, the facts connected with this new and encouraging element of advance, and have therefore shown roughly on the map, the direction of two of the most important of the lines in question.

Having now shown generally the condition of the existing work in Coorg and what rectifications are urgently called for, I now turn to a matter of very nearly equal importance, namely the communications needed to keep pace with the rapid spread of European enterprise in nearly every part of the Province.

The Bagamungalum-Sooleah road, has already been sufficiently alluded to. That proposed from Veerajendrapett, viâ Nalknad to Bagamungalum, would if added, open up probably the finest forest land in the country, and with the Sooleah road, supply a through independent Western communication, valuable alike for commercial and administrative purposes.

The next line, namely, that proposed from Veerajendrapett to Wynaad, would I presume lead, as I have roughly shown on the map, through the town of Kuggutnad, and I would recommend that advantage be taken of this new proposed line to Kuggutnad, to open an entirely new road over

this portion, tending more to the east where the lie of the ground appears favorable.

From all that I can gather, it would appear that Kuggutnad in addition to this direct connection with Veerajendrapett, would equally need a line leading eastward towards Mysore, joining the Anchowkoor road at some such point as Tittamutty.

The Seedapoor-Fraserpett, and Seedapoor-Periapattam proposed lines, have already been sufficiently adverted to above; it only therefore remains to note that from Fraserpett to Somwarpett, on the Mercara-Codlipett road. The necessity for this road has long been urged, I have therefore roughly shown on the map the direction it would take.

The total length of these several district roads may be assumed roughly at 156 miles. To attempt to open these, as fully bridged cart roads, even without metalling, would certainly not cost less than Rs. 3,500 per mile, or a total of Rs. 5,46,000, an amount that with the more urgent calls for rectifying the defective ghaut roads and other engagements, renders it impracticable to aim at this high standard. The main object, which is to execute these works at once, would moreover be defeated. After giving every consideration to the subject, I venture to believe that the real wants of Coorg, would be met by a system of roads suitable to pack-bullock traffic, but traced with such care and deliberation, that they may be individually worked out to cart roads, the moment funds can be spared. Such roads, three yards wide everywhere, with log bridges, maximum gradients on all straight portions of 1 in 19, and at all bends, of 1 in 22, and having causeways over the largest streams, could, I am satisfied be opened for Rs. 600 per mile, allowing the whole network to be executed for Rs. 93,000—or, if the work is to be done in four years—requiring an assignment of say Rs. 25,000 per annum, in each successive Budget.

Very little more than the actual tracing need in practice fall on this Department, as I have no doubt the planters would find it for their own interest, to take certain lengths of line in their neighbourhood upon contract, and work them out by estate coolies. Nay more, I should think, they would be perfectly willing to do the work at once, if guaranteed repayment by Government within the specified four years. However, this is a question they can better answer for themselves. It is clear that for them to do the work, would disturb the labor market less than if we did it, and being all of a simple nature and precisely similar to work done

every day on the estate, I think it would be found to answer. The Executive Engineer should of course alone lay down the trace and specification for the work, naming the terms, and exacting the strictest adherence to all, on penalty of non-payment. The interests of all parties it seems to me, would thus be met.

As showing the importance of such a system of roads, I would beg to make a brief quotation, from an able and suggestive article on "the Southern Ghauts," in No. LXXVI. of the *Calcutta Review*, for 1868. The reviewer observes: "We have stated above that in 1853, the Madras Commission on Public Works found that the roads of Canara were returning to Government a nett profit of 20 per cent. from the two sources of land and salt revenue; we shall now take the ten years from 1851 to 1860, and show what has been the progress from about the last year, on which the Commission forwarded its report, to the last at our command. Omitting all fractions below a quarter of a lakh, we find that the import trade rose within the above period from  $4\frac{1}{2}$  lakhs to  $25\frac{1}{2}$  lakhs; the value of exports rose from  $30\frac{1}{2}$  to  $102\frac{1}{2}$  lakhs; thus the whole trade increased from  $34\frac{1}{2}$  lakhs to  $127\frac{1}{2}$  lakhs. In the same period, the salt revenue rose from £14,000 to £31,000; that is to say, was more than doubled"—and more in the same strain. Since this remarkable statement was made, the spring which has been given to enterprise in Coorg, has mainly taken place, and if we could only analyse the returns, the direct gain by Madras would, I am satisfied, be shown to be equal to the whole demand I have ventured to claim for the Public Works in Coorg.

Before closing this Report it is necessary I should remark that in the matter of labor there are great difficulties in this province. During the monsoon, when the ghaut roads require close daily attention, hardly a man is to be had. Mysore coolies who all belong to the agricultural class, have by that time mostly vanished, or find easier and more congenial work on the coffee estates, where each man in addition to his 4 annas per diem, can turn a few annas by the sale of firewood, &c. Mapillay coolies, who require Rs. 10 per mensem, will only work in the low country at the foot of the ghauts. Madras men will again only work on the Periam-bady-Anchowkoor road, salt fish being easily procured there, &c.

The extreme unhealthiness of portions of the ghauts also frightens labor away from our works. Not a single cooly can at times be induced to go down the Sumpagee ghaut in the monsoon. Many years ago

Captain (Major-General) Frederick Cotton, proposed to establish single cooly huts at every mile, but this as well as other similar attempts in the same direction, have failed signally. Mr. Stoddard has however now, with the sanction of the Chief Engineer, commenced the construction of permanent cooly lines at convenient distances and in comparatively healthy localities. Nine of these now in hand are shown on the map. A small hut attached answers for the road overseer. This system certainly holds out fair hopes of success, but still labor must remain precarious and expensive, coming as it does from a distance.

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*P.S.*—Since writing the above, I have incidentally learned that the same hurrying down of floods adverted to above, accompanied by breached roads and blown up bridges, followed the first clearings in Ceylon, but that some kind of equilibrium has been of late years established by a sensible falling off of the yearly quantity of rain—to the extent of one-third the previous amount. My informant, however, could neither afford me accurate information nor refer me to any printed record. Should this enquiry prove to be well founded, a serious question will follow as to the effects of clearings on the summer water of the Cauvery and the irrigation dependent thereon.

R. H. S.

BANGALORE,  
11th November, 1865.

## No. CXIII.

## ON THE THEORY OF ARCHES.

BY ALEXANDER H. MACNAIR, Esq., *Resident Engineer, E. I. Railway.*

THIS paper is an attempt to construct a theory which shall be of practical value, and to demonstrate the same without the aid of the higher mathematics. In order to present it in a form sufficiently complete to be intelligible, within the limited space which can be afforded, much of the reasoning is merely indicated, and no effort has been made to distinguish what is novel from that which is only a reproduction of the works of others.

**MOTION AS OPPOSED TO STABILITY.**—The failure of an arch or other building implies motion among its parts, for it cannot be said to have failed till this has occurred.

A stone resting on the plane AB, Fig. 1, and still remaining in contact with it, may be moved in either of the following ways:—1st, It may slide towards A or B. This is called motion of translation. Or 2nd, It may turn on the edge A or B. This is called motion of rotation. Or 3rd, It may, by increased pressure approach nearer to AB, or *vice versa*. If the pressure is insufficient to crush the stone, it will tend to produce rest or stability, but otherwise motion or failure. And no other kind of motion can take place in the stone still remaining in contact with AB, which is not a combination of some or all of the above.

Now, if the pressure be unequal, the stone may be crushed at one end of AB and not at the other, causing a motion of rotation; the centre of which is a point between A and B. And this is the only case which occurs

in practice in an arch. Therefore the stability of arches is endangered *only by unequal pressure.*

[Throughout this paper the points of support of the arch are regarded as immovable.]

**THE LINE OF PRESSURE.**—Let Fig. 1, be the vertical section of a stone of equal thickness, passing through G its centre of gravity, and intersecting its horizontal plane of support in the line AB. It is evident that the line of direction (of gravity) GC bisects AB, that the pressure on AB is equal everywhere, and that the total pressures on each side of GC are equal to each other.

In Fig. 2, let the *shape* of the stone be altered, its weight and other conditions remaining the same as before. Then the total pressures on each side of GC, are still the same, but the pressure is greater at A than at C, and at C than at B, because C is nearer to A than to B.

If now, as in Fig. 3, we make  $CD = CA$ , and cut off that portion of the stone supported between D and B, and support it on the stone itself, so that the centre of gravity remains on the same vertical line, the area of support is thereby diminished, at the same time that the pressure at A is reduced, because the pressure on AD is now made equal everywhere.

In Fig. 4, let GC be the line of direction (of gravity) of an arch stone supported on AB. The pressure is greatest at A.

In these examples GC is the Line of Pressure.

But the arch-stone may be acted upon by another force besides its weight, as for instance, an external force in the direction DE, *Fig. V.* Then the centre of pressure is at E, where this intersects the direction of gravity. And the Line of Pressure is in the direction of the resultant of the two forces, intersecting AB in some point F; and the pressure is greatest at A or B, according to their proximity to F, and equal everywhere only if F bisect AB.

To put these results into the form of a definition. In the vertical section of an arch, at right angles to its axis, there is a line of contact between every two adjacent voussoirs, and a point in that line which divides equally the total pressure exerted by these voussoirs against each other. The line which passes through all these points is the **LINE OF PRESSURE.**

[I have pursued this investigation on the hypothesis that the material is compressed, and that the resistance developed, (which is the pressure,) is

THEORY OF ARCHES.

Fig. 1.

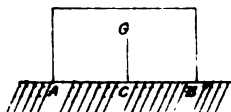


Fig. 2.

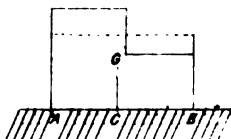


Fig. 3.

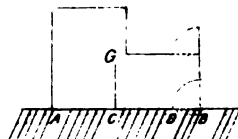


Fig. 4.

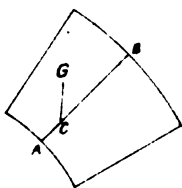


Fig. 5.

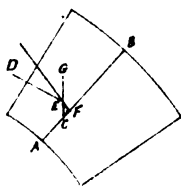


Fig. 6.

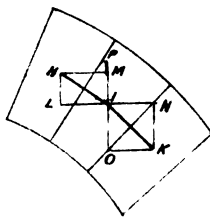
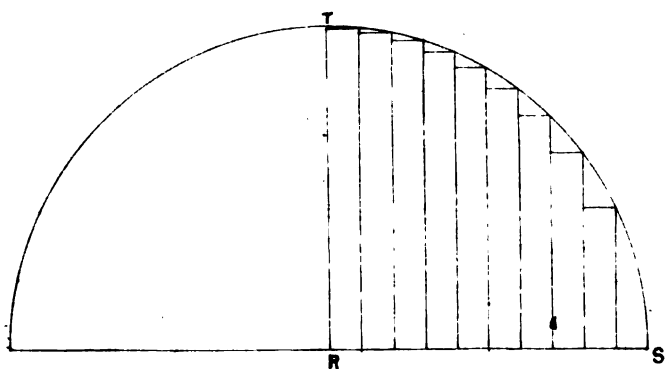


Fig. 7.





correctly measured by the amount of compression. The following is the result in algebraic symbols—

$$\begin{array}{l}
 a = \text{AF.} \\
 b = \text{FB.} \\
 p = \text{pressure at F (mean)} \\
 x = \text{ditto A (greatest)} \\
 y = \text{ditto B (least)}
 \end{array}
 \left| \begin{array}{l}
 x = p \frac{b^2 + 2ab - a^2}{b^2 + a^2} \\
 y = p \frac{a^2 + 2ab - b^2}{a^2 + b^2}
 \end{array} \right|
 \begin{array}{l}
 \text{Let } y = 0 \\
 \text{then } x = p\sqrt{2} \\
 \text{and } b = a(2.4142)
 \end{array}$$

so that if AF is not more than two-fifths of FB, there will be no pressure, but an open joint, at B.]

Before proceeding to the next head, it is necessary to define the sense in which certain terms are used in this paper.

*Moving Load* requires no explanation.

*Permanent Load* is that which is necessary to render the arch useful. At the crown of the arch there are always the *arch-stone* and the *permanent load* on it, and occasionally the *moving load* also. The permanent load is uniformly distributed over the span of the arch.

*Backing* is that which remains on the arch-ring when the moving and permanent loads are both taken away. It is more or less essential to the stability of the arch, and in reference to its weight, must always be taken into consideration along with the arch-ring.

*Arch-ring* requires no explanation.

*Structure* includes all of the above except the first.

CAUSES WHICH DETERMINE THE LINE OF PRESSURE.—1st. *Weight of Structure*.—In illustration of this I shall consider one case, viz., that in which the structure is designed so that the Line Pressure shall bisect all the lines of contact. And for the present let the Permanent load = 0.

In Fig. 6, let HI, IK, be straight lines joining the centres of gravity of three arch stones, of such dimensions that the horizontal distance of I from H is equal to that of K from I. It is required to determine the conditions of stability of the middle stone, so that the Line of Pressure may pass through the points H, I, and K.

The diagram itself will show how this is accomplished. The point I is kept at rest by the equal and opposite horizontal forces, LI and NI, and the vertical forces PM + MI, which are together equal to the opposite force OI. Now MI is the whole weight supported at H; and because

this is not sufficient at I we have to add PM, which must therefore be the weight of the arch stone at I, and the backing directly above it. It remains to calculate PM.

In Fig. 7, we pass on to the consideration of blocks of masonry having their centres of gravity in vertical lines which are at equal distances from each other. These blocks make up the structure, which in this case consists of the arch and backing alone. And by comparing Figs. 6 and 7, it is evident that to calculate PM for any one of the vertical lines, we must find the length of the portion cut off from that line, and deduct from it the length of the portion cut off from the line before it (towards the centre). The remainder is PM. This can be done in various ways.

Tables are given below for Radius divided into 10 equal parts. Their application will be readily understood, bearing in mind that PM, at the crown is *half* the weight of the vertical block, and in every other position it is the *whole* weight. The first three Tables are general. No. IV. requires to be made out for each arch, after the Radius of the Line of Pressure and depth of the key-stone are known. It is subdivided to show the difference in backing between two arches otherwise alike, caused by a difference in the depth of the arch stones, which is worthy of notice. Fig. 8, shows two semi-arches drawn according to this Table.

RADIUS DIVIDED INTO 10 EQUAL PARTS.

| No. of<br>division from<br>centre. | RADIUS = UNITY. |                                                                    |                                                   | RADIUS = 10 FEET.                                  |                                                   |
|------------------------------------|-----------------|--------------------------------------------------------------------|---------------------------------------------------|----------------------------------------------------|---------------------------------------------------|
|                                    | Table I.        | Table II.                                                          | Table III.                                        | Table IV.                                          |                                                   |
|                                    | Versed sines.   | Differences of<br>versed sines or<br>lengths cut off<br>in Fig. 7. | Differences of<br>last Table, or<br>value of P M. | Height of<br>block, when<br>key-stone =<br>1 foot. | Height of<br>block when<br>key-stone =<br>2 feet. |
| 0                                  | ·0000           | ·0050                                                              | ·0050                                             | 1·00                                               | 2·00                                              |
| 1                                  | ·0050           | ·0152                                                              | ·0102                                             | 1·02                                               | 2·04                                              |
| 2                                  | ·0202           | ·0259                                                              | ·0107                                             | 1·07                                               | 2·14                                              |
| 3                                  | ·0461           | ·0374                                                              | ·0115                                             | 1·15                                               | 2·30                                              |
| 4                                  | ·0835           | ·0505                                                              | ·0131                                             | 1·31                                               | 2·62                                              |
| 5                                  | ·1340           | ·0660                                                              | ·0155                                             | 1·55                                               | 3·10                                              |
| 6                                  | ·2000           | ·0859                                                              | ·0199                                             | 1·99                                               | 3·98                                              |
| 7                                  | ·2859           | ·1141                                                              | ·0282                                             | 2·82                                               | 5·64                                              |
| 8                                  | ·4000           | ·1641                                                              | ·0500                                             | 5·00                                               | 10·00                                             |
| 9                                  | ·5641           | ·4859                                                              | ·2718                                             | 27·18                                              | 54·36                                             |
| 10                                 | 1·0000          |                                                                    |                                                   |                                                    |                                                   |

THEORY OF ARCHES.

Fig. 8.

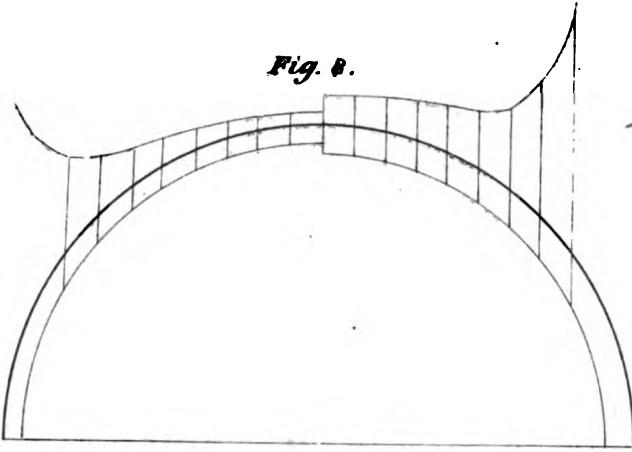


Fig. 9.

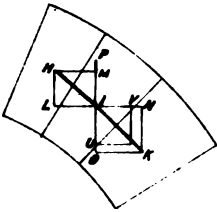


Fig. 14.

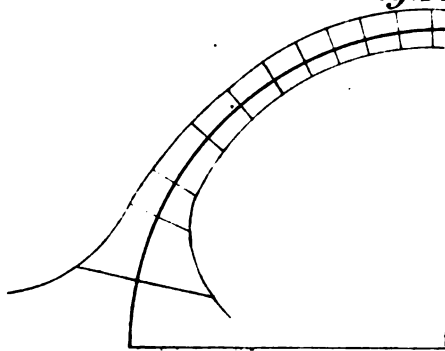
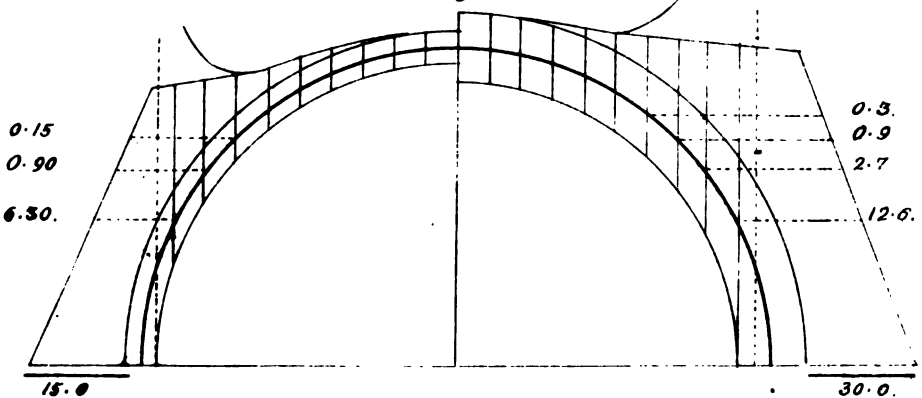


Fig. 10.



LITHO: T. C. PRESS.



This reasoning is believed to be correct for that portion of the arch which is near the crown; for there are no forces acting on it, except its own weight, and the resistances by which it is supported. But as we approach the abutment, another force comes into operation which increases the stability of the arch without adding to its weight. In Fig. 9, let PM be determined by convenience instead of calculation, and be less than  $OI - MI$ . Then making  $IU = IP$ , there remains a horizontal thrust VN to be balanced. This will be accomplished if we have on the abutment at or above that height, a weight of masonry sufficient to resist the horizontal thrust VN by its friction, the abutment itself being immovable. Fig. 10, shows the same two semi-arches designed according to these principles. The two vertical dotted lines show the theoretical division between the *backing* which acts directly by its weight, and the *masonry* which acts by its friction. The horizontal dotted lines indicate the points in the Line of Pressure which receive support from this last, and the figures outside give the sectional area which I have calculated is required at each point. The whole horizontal thrust of the arch must of course be balanced by the whole friction developed. It is only further necessary to provide against the backing being overturned, which I have here done by extending its base. This is not advanced as a desirable model to copy in actual construction. It is the development of the theoretical principles on which we should design an arch, to stand even when built of very soft materials, because they would be used to the best possible advantage.

We have hitherto considered *Permanent load* = 0. But to make the arch of use there must be some permanent load. It will form a portion of PM at each point, but the relative values of the different PM will remain as before. Indeed there is no reason why the moving load also should not be included in PM, as we shall see further on.

2nd. *Elasticity of the Materials of Construction.*—The most general notion of elasticity is an effort on the part of the elastic substance to assume its normal shape. Those dimensions which have been extended tend to reduction, and those which have been compressed, to increase. As we assume no adhesion in the materials of the arch, the elasticity in this case includes *compressibility* alone. If the compressibility were great, it would materially affect the Line of Pressure, by *shortening* the arch after it was built. But it is so small that we may neglect its operation in this

respect. It affects the Line however through the masonry which acts by its friction. For this masonry exerts no pressure on the arch till it is first pressed by the arch, which the compressibility of the material does not permit without an *increase* in the length of the radial line, accompanied by a *decrease* at some other point, probably at the crown. Hence the form of the arch undergoes alteration after it is built, in consequence of compressibility. It is enough to direct attention to this fact without attempting to push the investigation further. We cannot prevent the operation of the cause, but we may do something to neutralize its effect in practical construction.

3rd. *Moving Loads.*—We have seen that we may construct an arch so that the Line of Pressure shall bisect the lines of contact under one set of conditions. The converse of this is a problem much more difficult to solve, viz., to determine the position it will assume under different conditions.

If we fall back on the principle of applying more weight to counteract the horizontal thrust as the resultant becomes more nearly vertical, we shall find that the weight required at the springing of a semi-circular arch is nothing less than infinite. Hence we might be justified in concluding that the Line of Pressure will bisect the line of contact at the springing or a little below it, and that this result would not be affected by any change in the moving load which is finite. There is no doubt that this conclusion is theoretically perfectly correct, and there seems to be no reason why the Line of Pressure should not follow exactly the same curve, when we balance by other means the horizontal force for which this infinite weight was required. The subject is difficult to reason upon and not directly profitable, for there is no practical question as to the stability of the lower part of a semicircular arch. And we shall fall into no practical error if we assume that the horizontal distance between the extremities of the Line of Pressure does not vary, whatever may be the variation in the load, and adopt this principle as the ground work of our reasoning in arches of every variety of form—segmental, elliptic, or otherwise.

If a given load be placed in any position on an arch of which this principle is true, we know at once how much of its weight is supported at each end of the Line of Pressure, because we know its horizontal distance from each end. And we shall determine the amount of horizontal thrust due to the load, if we can ascertain the vertical position of its point.

of support. Now, this is approximately the same as that of the block of masonry on which it rests. If we assume them to be identically the same, we may combine the pressures of the structure, and the moving load, both vertical and horizontal, and so construct a curve which will vary but very slightly from the actual curve of the Line of Pressure. (Figs. 11, 12, 13.) But after having determined the *shape* of the curve, and knowing the *horizontal* position of its extremities, we have yet to fix its position vertically, which we may do, approximately, by taking into consideration the elasticity of the materials. For we know that the pressure on the outside of the arching will be greatest at *a*, and on the inside at *b*, and that the Line of Pressure will adopt such a position as to equalize these greatest pressures. And without entering into calculations it is sufficient to suppose that this is accomplished when the curve at *a* and *b* is equally distant from the line which passes through the middle of the arch ring; by which the vertical position becomes definitely fixed.

We can thus determine the Line of Pressure when a given load is placed on an arch, in which the Line of Pressure would pass through the middle of the arch-ring when there was no load on the structure. Conversely we may design the arch to satisfy this condition when a certain Moving load is on the structure, and then determine the position of the Line when any portion of this load is taken away. This is the method here adopted, for the following reason :—

Let  $n$  = greatest Moving Load which can possibly be placed on one division of the arch, of which there are 20. Then the whole load may possibly be  $20n$ , but not more. And as this will cause the most severe test which can be applied, we ought to design the arch so that the Line of Pressure shall pass through the middle of the arch-ring when the load is  $20n$ .

Figs. 11, 12, 13, show the position of the Line of Pressure, calculated according to these principles under several different conditions.

In Fig. 11, the semicircle shows the Line of Pressure under the maximum load ( $20n$ ), and the other curve shows it when all the load is removed.

In Fig. 12, the sharper curve shows it under a load of  $7n$  applied at the crown, the remaining load of  $13n$  being removed from the haunches ( $6\frac{1}{2}n$  from each side). The disturbance of the Line under this load is a *maximum*, that is to say, it would approach more nearly to a semicircle, if the load were either increased or diminished. The flatter curve shows the Line of Pressure under a load of  $9n$  applied at the haunches ( $4\frac{1}{2}n$  on each

side), the remaining load of  $11n$  being removed from the crown. The disturbance in this case also is a *maximum*.

Fig. 13 shows the Line of Pressure when the load is removed from one side altogether, and also from the central division, being the nearest approach to an arch loaded on one side only, which the present method of investigation admits.

These curves are calculated on the hypothesis that the load  $n$  is equal to 4 times the weight of the block of masonry whose centre of gravity lies in the vertical radius, which is of course greatly exaggerated. I have done so to show a sensible difference between the different curves, on the small scale on which they must be printed. With the exception of the semicircle they are, as explained, only approximations, but probably close approximations, to the true curve of the Line of Pressure under the conditions indicated.

The effect of *velocity* in increasing the pressure of a Moving load is a consideration closely connected with this subject, regarding which however there is but little known even in the case of iron girders, and still less in any other.

DEPTH OF ARCH-RING.—An arch-stone may be considered in two ways, viz:—1st, As a portion of the arch necessary to its stability; and 2nd, As a portion of the arch which enables it to carry loads.

1st.—In Figs. 6 and 7, I have illustrated the conditions of stability of an arch constructed to stand by itself, without reference to its capability of sustaining any load. The weights of different portions and the pressures exerted by them are there measured by constant quantities, which must bear the same proportion to each other in every case. If, therefore, the material which we select to build the arch be sufficiently strong, the quantity in which we use it is a point of no importance. If the arch can be built of brick, it is just as strong if it be only one brick thick as if it were ten. For every square inch of sectional area to support weight, we have exactly the same number of cubic inches of material to be supported. We may increase or diminish the quantity as we choose, but we can neither increase nor diminish the pressure per square inch.

2nd.—Let us now consider the arch stone as a portion of the arch which enables it to carry loads. If the material be, however little, stronger than is necessary to support the arch, its remaining strength is available to carry loads. Here the depth of arching becomes important, for the excess

THEORY OF ARCHES.

Fig. 11.

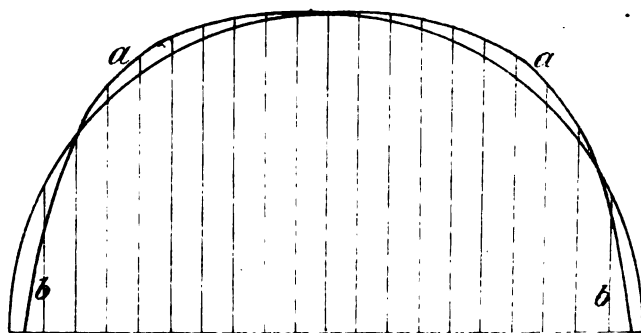


Fig. 12.

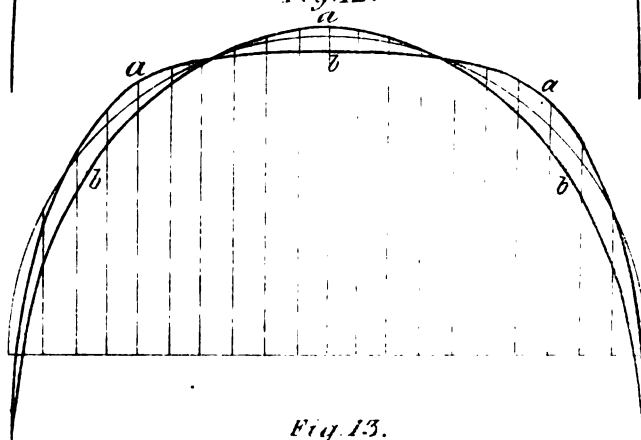
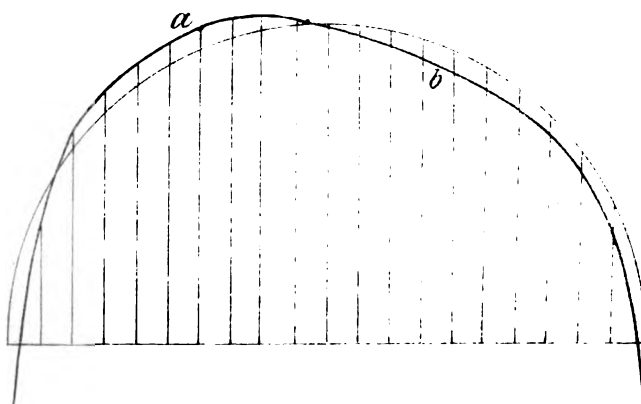


Fig. 13.





of strength in one square inch of bearing surface becomes multiplied by the number of square inches, and the load which the arch may sustain is therefore in proportion to its depth. Moreover, if the load be not all permanent, there must be a certain depth in the arch-ring on account of the disturbance in the Line of Pressure caused by an alteration in the moving load. Therefore an arch-ring which has to sustain any load, requires a certain amount of depth to give it *strength*. And if any portion of the load be variable, it requires a certain amount of depth to give it *stability*.

Although it is necessary to consider the arch stone in these two ways separately, in order to arrive at a correct notion of the duties which it has to perform, we do not require to keep up the distinction any longer. Having assumed the greatest possible moving load, we may combine that with the weight of the structure. Then the arch-ring is of sufficient depth when the two following conditions are fulfilled:—1st, The extreme pressure must not be greater than the material can resist; 2nd, The depth of arch-ring must be sufficient to permit the greatest possible disturbance of the Line of Pressure without bringing it dangerously near to either extremity of any one of the lines of contact.

This phrase “dangerously near” has a precise meaning. When the whole arch is uniformly loaded with its greatest possible moving load of  $20n$ , the pressure in each line of contact is equal everywhere. When any portion of this load is taken away, the total pressure on each line of contact is diminished, but the Line of Pressure having been disturbed, it is greater at one end than at the other. And if the pressure at either end exceed the original pressure under the load of  $20n$ , then the Line of Pressure has approached “dangerously near” to that extremity.

The next step towards the depth of arch-ring is to ascertain the rule according to which it ought to vary in arches of different proportions. The object in view is of course to secure an equal degree of stability in each. Now the stability of the arch is affected by the four following magnitudes:—1st, The radius of the Line of Pressure, or (in less accurate terms) of the arch at the crown; 2nd, The depth of arch at the crown; 3rd, The weight of the structure; and 4th, The weight of the moving load. Moreover, it is evident that if we increase the weight of the moving load, or decrease the depth of the arch, we must increase the weight of the structure, or decrease the length of the radius, to obtain the same degree

of stability in the arch. This condition does not imply a proportion between the four terms, yet we see that if we make them proportional it will be satisfied to some extent. For, if we make the radius to the depth, as the weight of the structure is to the weight of the moving load, then we cannot increase the load or decrease the depth without either increasing the weight of the structure or decreasing the length of the radius. But it is more in accordance with the principles already laid down to compare the weight of the moving load with that of the structure and moving load combined, which we may call the *whole weight*. Now let  $R$  = radius,  $D$  = depth,  $L$  = load,  $W$  = whole weight; and let  $l$  = load, and  $w$  = whole weight, of an arch whose radius and depth are each = unity. Then the proportion is  $R : D :: W : L$ , or  $\frac{D}{R} = \frac{L}{W}$ . Now, the load being the same per foot run for every arch, may be expressed in general terms  $L = Rl$ , and the whole weight depending on the length of radius and depth of arch-ring,  $W = RDw$ , whence the general equation becomes

$$\frac{D}{R} = \frac{Rl}{RDw}; D^2 = R \frac{l}{w}; D = \sqrt{R \frac{l}{w}}$$

so that the depth of arch should vary as the square root of the radius

$\sqrt{\frac{l}{w}}$  being a constant quantity.

I have not been able to assign a value to this constant. The value given in practical treatises is 0.12 for single arches, and 0.17 for arches in series. There is no doubt that these values have been arrived at by careful comparison of good examples; whether the result can be verified by theoretical reasoning is a point I am at present unable to determine. The proportion which should exist between  $l$  and  $w$  is probably involved in the conditions required to prevent the Line of Pressure from approaching dangerously near to either extremity of the line of contact (see above).

If it be desired to increase the depth of arching from the crown towards the haunches, as is frequently done in segmental arches of large span, the principles of this theory can readily be applied to lay down the rule according to which the increase should be made. In Fig. 6, the total pressure on I from above is HI, and on K is IK. Therefore, the strength of the arch between I and K should be greater than that between H and I in the proportion IK to HI. In Fig. 7, we may at once proceed to the limit, and make the lengths of the arcs cut off be the measure of the depth at the middle of each arc. These arcs give nine

dimensions, and we can also find two more, viz., one at the crown where the pressure is only horizontal, and its measure is one division (one-tenth) of the radius, and the other at the springing, which is infinite.

This principle may be applied with advantage in very large segmental arches, in which the rise is not more than one-fourth of the span, see Fig. 14, which is drawn according to the following Table, giving the calculated depth for the nine intermediate points when the depth at crown is 1.

| Horizontal distance. | Depth. | Horizontal distance. | Depth.    |
|----------------------|--------|----------------------|-----------|
| Crown.               | 1.000  | 0.6                  | 1.198     |
| 0.1                  | 1.001  | 0.7                  | 1.318     |
| 0.2                  | 1.012  | 0.8                  | 1.522     |
| 0.3                  | 1.033  | 0.9                  | 1.928     |
| 0.4                  | 1.070  |                      | 4.509     |
| 0.5                  | 1.120  | Springing            | infinite. |

**POINTS OF RUPTURE.**—If the theory now submitted be correct, we shall be able to get rid of these points altogether. An arch designed according to this theory, if it be loaded with its greatest possible load of  $20n$ , has then no points of rupture. It may fail if the material be simply crushed, but not otherwise; for the Line of Pressure bisects all the lines of contact, and the pressure in each of these is therefore equal everywhere.

Such is the condition of the arch under the *greatest* possible moving load. Therefore, we cannot possibly disturb the Line of Pressure, except by *taking away* some of the load. Suppose we take away all the load from one side of the arch and none from the other; then we have disturbed the Line of Pressure probably to the greatest extent possible. But we have also reduced the moving load by one half. We must now ascertain whether there is any portion of the arch-ring under these altered circumstances which bears a greater pressure than it did at first. If there is *not*, then there is no point of rupture. If there *is*, we may still hope to remedy the defect by an alteration in the proportions of the structure and its load.

To ascertain whether any point of rupture does exist, is simply a matter of calculation, which the theory shows us how to perform approx-

imately. Nor is this all; for the approximation may be used as a fresh point from which to start new calculations, the results of which will be still more near the truth. And I have no doubt that by successive approximations we might attain to any required degree of accuracy. Thus it may perhaps be possible to lay down a certain proportion between  $l$  and  $w$  (see above) which will exclude the possibility of a point of rupture in any arch designed according to the formula  $D = \sqrt{R} \sqrt{\frac{l}{w}}$ .

SUMMARY.—The propositions advanced in this paper are briefly these:—

1st.—That it is in our power to cause the Line of Pressure to bisect all the lines of contact between voussoirs, under one set of conditions.

2nd.—That we should construct the arch so that these conditions shall be satisfied when the greatest possible load is placed on every portion of the arch.

3rd.—That the depth of arch-ring of an arch which does not carry weight is independent of its span or radius.

4th.—That the depth of arch which is required in proportion to its radius, depends on the proportion which exists between the weight of the structure and of the moving load, and also in some respects on the velocity with which the load moves; and that the conditions of this latter relation are but little known.

5th.—That arches may be designed in which there shall be no points of rupture, properly so called.

A. H. M.

25th June, 1866.

## No. CXIV.

## RIVER WORKS ON THE GOGRA.

*Memorandum on the means employed for the demolition of Sunken Trees and Kunkur Rocks on the River Gogra in Oudh.* BY LIEUT. W. J. CARROLL, R.E.

THE banks of the Gogra for a large proportion of its course, from the north of Oudh to its junction with the Ganges above Dinapoor, consist of alluvial soil, deposited by the river itself in its higher floods, and liable to be demolished as rapidly as they are formed; in their destruction, villages and trees are carried away, and the latter, when of any size, generally remain fixed in the bed, and become dangerous obstacles to navigation, more especially in the rains.

In addition to this danger, common to all rivers with alluvial banks and subject to severe floods, there are a large number of sunken kunkur rocks and ledges projecting from the main bank where it is formed of that material. Many of these rocks are detached, but the majority of them are connected with the bank by beds of kunkur at greater or less depths under the surface. They are in fact but the more elevated portions of such beds, and the complete demolition of a rock, would, in the majority of cases, involve the removal, not only of such portions as appeared near or above the surface, but also that of large contiguous beds in depths of several feet of water, which is, a much more extensive operation than that generally implied by the "removal of a sunken rock."

During the last two cold seasons, works have been in progress for the removal of these dangers. In the case of trees sunk in the channel, no difficulty has been found that cannot be easily surmounted; but the

method that has been used for the removal of those buried in sand below water-mark is still open to improvement. For the removal of kunkur rocks, no large operations have been yet undertaken, and the mode which has been employed in the little that has been done, may, perhaps, also be improved upon. Operations were commenced last year under unfavorable circumstances, and without the time for procuring proper appliances; the means first employed will therefore be quoted rather as examples of what to avoid than of what to imitate; in this way they may be of some service.

It is necessary, in the first place, to describe the general features which produce the difficulty of removing a sunken tree. The current of the Gogra flows in many places  $2\frac{1}{2}$  miles an hour, or 3.6 feet a second. This speed is quite common round the edges of a kunkur rock, or between the branches of a sunken tree; in many such places it is much higher than this, and as the pressure of the current is proportional to the square of the velocity, the difficulty of working boats, or placing charges of gunpowder may be considered to increase in the same ratio. The trees are found sometimes wholly, sometimes partially, immersed in the channel, or they are found partly or wholly buried in the sands, and only creating danger in the rains, when the floods rise over their branches and hide them; or they are found thrown up on the sands and not imbedded, or lying fallen on the banks ready to be swept in at the next floods; but wherever they are found, they offer a very indifferent mark for the action of gunpowder. The roundness of the branches and their small surface compared with their strength, the toughness of the roots, and the massiveness of the stem, combine to make the removal of a large tree a tedious and difficult matter. It presents no large and weak surface like the hull of a sunken ship, and it lies usually in shallower water which offers less resistance as tamping to the charge. When broken up, the pieces, often of great weight, have to be dragged in and lifted up upon the high main bank, to prevent their being again carried into the river during floods, and becoming fresh obstacles. The above description applies to the largest class of trees, of which many have been found with stems 10 feet and more in diameter. The removal of a small tree is of course proportionally easier.

The means employed for the blasting of trees last year, in the absence of better ones, were charges of from 25 to 50 lbs. of gunpowder, contained in tin cylinders, and fired by means of tin tubes rammed with fuze

composition, and attached to the cylinders by a water-proof joint. The cylinders were provided with loops of iron-wire projecting from the side, by means of which they could be lowered into the selected spot, by sliding them down bamboos, previously driven in and stayed against the branches of the tree. This method of placing the charge has been retained, as it is found that no moderate weight attached to the cylinders will retain them in their places in a strong current, and because in many places a diver cannot be safely sent down to place the charges.

The mode of firing by fuze tubes was abandoned as soon as possible; it was very inconvenient at any time, and the tubes were liable to break; they were also very uncertain in depths even of 6 feet, and they could not be employed at all in considerable depths.

Bickford's fuze was not procurable at the time, and Brunton's water-proof fuze, though obtained, was not of the quality fitted for burning to any depth under water with certainty. Bickford's fuze has since been obtained from the arsenal at Allahabad, but has also proved uncertain in depths of from 10 to 15 feet. However, I am not aware whether it is of the same quality as that employed in submarine works in England, and denominated Sump fuze; and it is moreover, possible, that the working of the fuze, and the friction against the branches of the tree caused by the strong current in which it was here used, may have rendered it less water-tight than it would be in still water.

A third method of firing charges employed last year, and in the present, has been found very effective and,—granted that the cylinder and tube have been properly tested,—it is perhaps the most certain of all. Instead of the thin tin tubes above described, a tube of about three-fourth inch diameter is employed, and soldered into the cylinder near one edge. A thin bamboo lashed to the cylinder and tube secures the latter from being injured, and the cylinder and tube thus prepared and tested can be stored in the magazines ready for use. The testing is done simply by filling the cylinder with water, through the tube, till the latter is full to the top. If the cylinder will stand the pressure of a 10 feet head of water thus applied without leakage, it will bear to be immersed (when filled with the charge) to a depth of 15 feet, or if very tightly filled, to a depth of 20 feet. The charges thus prepared may be placed, as before described, by sliding them down on bamboos into the chosen spot. The firing is effected in the following way, which I believe to be novel. Into the top of the tube,

which projects above water, is fixed a fuze which is rammed in a tin tube 9 inches long and of a slightly conical shape. The composition of the fuze contains near its head a pellet of iron of about half the diameter of the lower end of the tube. The burning of the fuze makes the pellet red-hot; it is prevented from blowing out upwards by two cross wires, and consequently when the fuze has burnt out, the pellet drops through the tube, and ignites the gunpowder. A large number of charges have been fired in this way, and no failure has ever occurred through the pellet's not falling or not being hot enough. Charges thus prepared have been used in from 15 to 20 feet of water, and it is manifest that with flexible tubing, such as block tin gas-pipe, that they might be employed in much greater depths and with some advantage where time did not admit of the construction of a galvanic battery. The fuzes should be rammed with ordinary fuze composition, which is a mixture of—

|                          | lb. | oz. |
|--------------------------|-----|-----|
| Saltpetre, . . . . .     | 3   | 4   |
| Sulphur, . . . . .       | 1   | 0   |
| Mealed powder, . . . . . | 2   | 12  |

and care should be taken that the pellet is always considerably smaller than the tube it has to fall through, and that it is not angular in shape.

But though the above may be a better method than employing quick-match or filling the tube with composition, where, for want of better means, it has to be employed, it possesses all the objections common to the tube system, and is altogether a less workman-like way of proceeding than the use of the Galvanic or Magnetic Battery. The former has not been employed on this river; for though one was constructed, the materials at hand were not sufficient to make it of the required power, and it was put aside for future completion. Full information on the subject is given in Volumes IV., VI., and VII. of the "Professional Papers of the Royal Engineers," new series, and in Mr. Tresham's pamphlet on its employment on the Ganges River works.

The Magnetic Battery has been employed this year with success, and though the mode of using it and the construction of the fuzes are amply detailed in Messrs. Wheatstone and Abel's Report on the subject in Volume X. of the Professional Papers, Royal Engineers, part may be repeated here in order to render the account of the rough but effective fuze here employed more distinct.

The ordinary fuze consists of a wooden plug carrying a gutta-percha core in-

serted through its axis, and containing two fine copper wires insulated from each other. The core projects three-fourths of an inch from the lower extremity of the plug, and its end is cut off clearly, so as to expose the extremities of the wire, which are one-sixteenth of an inch apart. The upper ends of these insulated wires are separated from each other, and put into connection with two small copper tubes or eyes, which are fixed cross-ways in the head of the plug. These eyes are intended for the reception of the main wires of the battery, and the current in passing has to flow by the insulated wires contained in the core of the fuze, and to leap the interval of one-sixteenth of an inch which separates them. To enable it to do this, the exposed ends of the wires are covered with an explosive composition of feeble conducting power, consisting of an intimate mixture of the following ingredients:—

|                          |           |           |
|--------------------------|-----------|-----------|
| Sub-phosphide of copper, | . . . . . | 10 parts. |
| Sub-sulphide        "    | . . . . . | 45   "    |
| Chlorate of potassa,     | . . . . . | 15   "    |

About a grain of this composition is inserted into a small cap of metal foil which is twisted on the end of the gutta-percha's core; and the bursting charge is contained in a tin tube of a few inches in length, which is fitted on to the end of the fuze plug, and corked at its lower extremity.

When the fuze is about to be used, and has been prepared in the manner described, the end of the wire which leads from the battery is pressed into one of the copper eyes, and another shorter wire is pressed into the other eye, and its upper extremity put into connection with the outer surface of the vessel containing the charge, if it be of metal or with a metal plate attached to it; if it be of wood, the circuit through the fuze and main wire is completed by the water between the surface of the cylinder (or the metal plate), and a metal plate attached by a short wire to one of the poles of the battery, and immersed in the water. The neck of the cylinder through which the fuze has been inserted is of course stopped with a water-tight plug. The charge being thus prepared and placed, the boat containing the magnetic battery is withdrawn to a convenient distance, and the charge is fired by a smart turn of the handle of the battery, which, by causing the armatures of the magnets to rotate before their poles, produces the succession of induction current necessary for ignition. The main wire leading from the battery must be carefully insulated from the water, and the connection of the return wires with the water carefully made. The other connections with fuze and battery need not be made with as much

care as when working with the galvanic battery; for, here we have to deal with electricity of higher tension than is produced by any galvanic battery of moderate power.

This description of the fuze and its use, all of which may be found in greater detail in Messrs. Wheatstone and Abel's Report, above referred to, will enable me to dispose of the rough, but effective fuze, here employed in a few words. In place of the wooden plug, a cork is employed, which does the double duty of holding the gutta-percha core and of corking the cylinder. The core itself, instead of the carefully manufactured article above described, may be simply made by taking two pieces, each a few inches long, of single insulated copper wire cut from the coil employed as main wire, cleaning them for about half their length, and fusing them together by passing a hot iron over the gutta-percha with which they are covered. They are then pressed together till the ends of the wires are one-sixteenth of an inch apart. A shorter interval may be employed with advantage, say one-twenty-fifth of an inch. This core is passed through the cork, and the portion of the fuze wires which have been cleaned and exposed, project above it for the purpose of making connections. One of these, supposing the fuze to be primed and placed in the cylinder, is bent over and put into connection with the metal of the cylinder, generally by folding it up with a little slip of tin projecting from the neck; the other is put in connection with the main wire of the battery.

The priming of the fuze is previously effected by cleaning the inner end of the core, wrapping a small paper cartridge round it, inserting a grain of the magnet fuze composition, and filling the rest of the cartridge with mealed powder slightly rammed, to prevent it and the fuze composition from separating from the end of the wires. The end of the cartridge may be plugged with wax. This small cartridge is quite sufficient as a bursting charge for 50 lb. charges; but for larger charges, a larger one would be preferable, and could be tied round the cork, which would then be passed altogether into the charge, and other arrangements made for corking the cylinder.

A water-proof substance must always be employed to cover the top of the cork, and protect the connection of the main wire with the fuze which is just outside it, from the water. The substance here employed is that called Kitt composition; it consists of a mixture of the following ingredients, slowly heated together:—

|                      | lbs. | oz. |
|----------------------|------|-----|
| Resin, . . . . .     | 7    | 8   |
| Pitch, . . . . .     | 6    | 14  |
| Bees' wax, . . . . . | 6    | 14  |
| Tallow, . . . . .    | 1    | 14  |

In warm weather it should be kept cool in water, or it becomes too soft to use with convenience; in other respects it is perhaps the best and most flexible water-proofing that can be employed—an important point where any fuze or wire leading from the cylinder is liable to flexure or vibration.

The only precautions that are necessary to be taken with these fuzes, beyond the perfect insulation of the main wire from the water, are that its connection, which is just outside the cork, should be kept out of contact with the surface of the cylinder, and that the cylinder itself should not be washed over with any water-proofing which would insulate it from the water and check the return current. The main wire should also be tied to the cylinder, so as to prevent any strain coming on the fuze or its connections.

The percentage of failures with these fuzes has been exceedingly small. Out of 60 charges lately fired in depths of from 8 to 20 feet of water, and varying in amount from 50 to 450 lbs., there have been only two failures; and these were due probably to defective insulation of the main wire and not to the fuze.

The Magnetic Battery and insulated wire were obtained from the Telegraph Department; the latter is copper of about one-eighteenth inch diameter, coated with gutta-percha. The battery is contained in a box about 14 inches square and 9 inches high. Its great advantages over the Galvanic battery are, that it requires the use of no liquids; it is always ready for use; its power is constant; and it is more compact and less liable to injury. The magnet fuze composition I obtained through the kindness of Lieutenant Wallace, R.E., who employed it in somewhat similar operations on the Hoogly. He had the ingredients prepared, I believe, at the Calcutta Mint, but as it may sometimes be impossible to procure it, it is important to know a substitute. Mealed powder\* when moistened to a certain extent is an excellent one. The mode of preparing it is described in the Royal Engineers' Professional Papers before referred to, but may be repeated here. Dissolve chloride of calcium in alcohol till the solution is saturated; steep mealed powder in it till it has thoroughly imbibed the alcohol and with it the chloride of calcium. Dry the mealed

\* Could not be depended on during the hot winds or very dry weather.—W. J. C.

powder completely, and preserve it so in a closely stoppered bottle. When required for use, a few minutes exposure to the air will, by absorption, render the powder sufficiently moist for use; this may be known by its showing a tendency to collect together into small granules. It may then be used in precisely the same manner as the sulphide of copper composition. Twelve or fourteen trial fuzes have been fired with this composition in succession without failure, but it has not yet been employed in place of the magnet fuze composition; the trial was considered to prove that it was sufficiently certain for ordinary use. Mealed powder may also be moistened to the proper degree for priming fuzes by simply folding a small quantity in thin cloth, and breathing through it. It is apt, however, to dry too soon, and it is not by any means certain of ignition. Nothing further need be said on the subject of *firing* charges, but it may be added that the charges in common use are 25 and 50 lbs. ones, contained in tin cylinders. For use in depths of 15 feet and less, these cylinders require no strengthening, but for greater depths they should be strengthened with either stays or rings.

It will render this account more complete, to give a few instances of the demolition of Trees, out of the number that have been removed this year.

In December, a large semul tree, lying 200 feet from the banks at a village called Chupree, was removed by blasting. The depth of water at the root, which lay up-stream, was 20 feet, and the current  $2\frac{1}{2}$  miles per hour. A number of separate branches spread out under and above water, and were demolished by separate charges of 25 to 50 lbs. of powder. The root and stem gave most difficulty; the latter was however broken by two successive charges and separated and dragged to shore by crab-capstans. The root which spread out in irregular masses to a diameter of 20 feet facing the current, resisted a great number of charges, and several cylinders were broken on its projections; others of the charges broke off portions, but brought other new ones up to the surface. The tree was finally demolished after the expenditure of 850 lbs. of powder. It would have been a manifest saving of time if a 400 lbs. charge could have been placed near the root, but the strength of the current, and the shape of the root, rendered it impossible.\* The crab-

\* Large boats could not safely be got into position in front of such a tree, and even if they could a cask large enough to contain 400 lbs. of powder would offer such a surface to the current as to be quite unmanageable; in some positions a cask may be sunk by another plan, described further on.

capstans employed were roughly made, but have proved very serviceable. They are a convenient mode of obtaining great power, and a few carpenters and blacksmiths can make up one in a day or two.

In February, a large tree lying near the bank at the village of Tajpoor was removed. The stem was a mass of wood of about 10 feet in diameter, and the same in length. The branches were demolished in the ordinary way, but 50 lbs. charges had no effect on the stem. As its upper side projected above the surface of the water, it was ultimately split up by small charges placed in holes bored in the wood. Here also a charge of 300 or 400 lbs., if effective, would have saved time; but neither was there a good position for one, nor do I believe that it would have had any further effect than to throw the stem a short distance to one side or other, as the wood was perfectly sound, and of great strength.

Near the same place a large tree lying half on the bank and half in water was demolished by a 200 lbs. charge followed by a few small ones. The charge was placed in a cask under a hollow of the tree and in the water; the timber directly over the charge was about 12 feet thick, and embraced a palm tree that had grown with it. The timber around it was completely shattered by the explosion, but the palm itself was unhurt. Here the good effect of the charge was due to the timber being rather decayed, and to the good position in which it was placed.

In February, two trees, each 9 or 10 feet in diameter, were removed from the river at the village of Belthfah. The water was too shallow for the use of large charges. On one of them a few 25 to 50 lbs. charges were first employed, and the stem was lifted out of the sand so as partly to project above water; it was then split up by small blasts placed in the wood, and its demolition completed with 25 and 50 lbs. charges. The other tree was removed in the same manner, and in both cases the fragments, which were large, were dragged out by three capstans working together, and hauled up the main bank by an English gyn. Attempts made at the same place to remove a sunken banyan tree were unsuccessful. The roots resisted several small charges, and ultimately a charge of 165 lbs., and a force of 10 tons applied by means of capstans and cables, had no effect in tearing them asunder.

In February, a large tree lying on the sands above the water level was demolished by means of two 25 lbs. charges, fired simultaneously in the following manner:—From the main wire of the battery, a branch was led

to each charge, and as the cylinders lay in dry sand, whereas a moist connection is necessary to complete the return circuit, the return wires of the fuzes were connected with metal rods driven down into the sand till moisture was reached. To make the connection more perfect, water was poured over each cylinder and the sand round it. The battery was 400 yards away at the edge of the river. The return wire and plate were immersed in the water as usual. Both charges ignited perfectly simultaneously.

In March a large tree lying in deep water and a strong current at the village of Tickyah, was partially removed. Here also two charges were fired simultaneously, but with little effect; ultimately a charge of 450 lbs. was sunk and fired in the following manner:—A cask was prepared and tarred, and two rings of hoop-iron were nailed on its ends, so as to project from its sides and allow it to slide down a rod. A bamboo 4 inches in diameter was driven in the best spot available, and the cask was passed on to this by means of the rings; it then stood floating on the water in an upright position and empty, but with the fuzes prepared and inserted. In this case the independent fuzes were employed, as it would have been a difficult matter to recover the cask had one failed. The cask was filled and sunk in its place in a depth of 20 feet, by weights; the bamboo was securely stayed against the tree, and the main wire being connected with one of the fuzes, the boats were drawn away, and the charge fired.\* The effect was not so good as might have been expected; some lower branches were separated and the tree was thrown into an upright position, but the stem was quite uninjured. The remaining operations require no notice.

A tree buried in the sand and liable to become dangerous on the shifting of the channel, was attacked in the following manner:—Its position and size were first ascertained with iron sounding rods. The stem was found to be 8 feet under the sand, and 7 feet 9 inches under the water level. A good position being selected, an iron tube 11 feet 6 inches long and 1 foot in diameter, was driven down beside it to a depth of 11 feet by means of a *ringing* engine. The tube was then bored out to a depth of 10 feet with a boring tool 10 inches in diameter, and provided with a leather sand valve. A 50 lbs. charge was passed down the tube to that depth, and the tube was drawn by a differential pulley hung to the *ring-*

\* In this manner the drag of the current on the cask was rendered harmless, and in spite of it, the charge was successfully sunk into its position under a perfect network of branches, in a place where it would have been quite impossible to bring a large boat.

ing engine. The charge was fired by means of a tin tube and pellet fuse but without much effect. It was neither large enough, nor had it been placed deep enough. The tube should have been driven 12 feet deep, and a 100 lbs. charge placed at a lower level than the stem. Time did not admit of repeating the operation, but the more dangerous part of the tree was removed by other means.

In this operation the Ringing engine was worked in the following way :—The rope attached to the ram was passed down, and through a block at the rear of the engine ; it was carried a long distance to the rear, attached to a peg, and worked alternately by two parties, one of which took it up when the other dropped it, and the ram had fallen. In this manner nearly double the ordinary number of blows were delivered in a minute, and the men were not fatigued to the usual extent ; but of course a double working party was necessary.

A large tree, lying in the sands near a village called Gyaspoor, was removed by small blasts fired in holes made by means of a lever drill. This drill, which was made up out in camp, consisted of an iron frame, carrying a wheel 1 foot in diameter, and working on a vertical axis. The frame was provided with keys for clamping it on a square iron-rod 5 feet long, and pointed at one end. This rod could be readily hammered into the stem of any tree it was required to bore, and the drill clamped to it could thus be brought to bear in any desired direction—vertical, sloping, or horizontal—the axis of the wheel was pierced to carry a square iron-rod, in the lower end of which the drill bits were fixed. The upper end was pointed, and pressure was applied to it by means of a lever clamped at any required height to the rod driven into the timber. The drill was driven from a 3-feet wheel placed in any convenient position ; it was capable of boring 3-inch holes with moderate rapidity.

The preceding examples are sufficient to illustrate the mode in which the demolition of trees has been carried out. A few words may now be said on the removal of sunken Kunkur rocks.

The features that these rocks usually present have been already described, and it only remains to state the means that have been employed in attempts to remove them. The first trials were made last year on a small rock of thin kunkur, lying in from 2 to 6 feet of water, and in a strong current. The apparatus employed was a species of small cofferdam of a portable character, consisting of an outer and inner frame and sheeting,

and including between them 2 feet 6 inches thickness of strong clay puddle. The space enclosed was a rectangle of 4 feet 6 inches by 3 feet 6 inches, the object being to dry a space sufficient for a miner to work in, and drive a shaft down through the kunkur, in which a large charge might be placed and fired. The outer sheeting of the dam was supported by four frames, rectangular in shape, and each 10 feet by 3 feet 6 inches high, braced diagonally and made of  $3\frac{1}{4}$  inches sál scantlings. These frames when bolted together at the angles formed a square enclosure, within which the sheeting was put down vertically in 6 inch widths. The sheeting was supported at the back by longitudinal pieces parallel to the top and bottom rails of each frame, and  $2\frac{1}{4}$  inches within them. These pieces could be put in position after the frames had been bolted together.

The inner framing was constructed in the same manner, only smaller, so as to allow the space between the walls required for puddling. The surface of the rock being very irregular and steep, it was necessary to put down the cofferdam in the following manner:—Two boats were anchored over the rocks, and the outer frames previously bolted together so as to form a square enclosure, were let down into the water. A few pieces of sheeting were then dropped in at the angles, and wedged when resting on the rock. The position and stability of the frame being thus secured, the remaining sheeting and the inner frame were rapidly put in, and the puddling commenced. The attempt to dry the dam failed; it was found that the substratum was sand; and the water came up through cracks with which the surface of the kunkur was covered; but there is no doubt that this kind of dam could be used occasionally with advantage where the material to be removed is solid rock or kunkur underlain with clay; it is very portable, and could be put down and taken up much more rapidly than a dam supported by any arrangement of jumpers driven into the rock.

The next attempt on the same rock was made with boring tools of rough construction. A portion of the kunkur in 4 feet depth of water having been broken up, an attempt was made to bore down, through the substratum, with the object of placing a 50 or 60 lb. charge at a depth of 6 feet, or thereabouts, below the kunkur. This attempt also failed from the fact of the sandy substratum being too fluid to retain any hole.

Trials were next made on a rock 80 feet long by 50 feet in width, and partly above water; the substratum in this case being clay, the boring tools proved quite effective. The operation of placing and firing the charges

ultimately took the following shape:—A 2-inch iron-bar was first driven down into the kunkur to a depth of 6 or 7 feet, and drawn; into the hole thus formed, a small charge of powder contained in a thin cylinder of tin was inserted to a depth of 6 feet and fired. It was found that this charge by its explosion produced a narrow crater in the kunkur about 6 feet deep, and after clearing the hole with a boring tool about 1 foot in diameter, a 50 lb. charge was readily placed at a depth of 6 feet under the kunkur, whether under or above water. It made little or no difference in the rapidity of the operation whether the kunkur lay under or over water. The hole having been tamped, the charge was fired with the pellet fuze,\* producing a crater of about 18 feet in diameter, and 6 or 7 feet deep. In this manner the rock was rapidly blown away to a depth of 6 feet under-water, the whole operation not lasting more than ten days, and had arrangements been more perfect, this time would have been shortened very much.

In the beginning of the present season, attempts were again made on kunkur underlain with sand, and under 3 feet of water. The following method was now adopted:—Boats were prepared with framing, and planks sufficiently strong to bear a heavy strain; they were anchored over the rock with an interval of a few feet between them, and lashed together by cross-ties. A light triangle was erected on the boat, and from it was first suspended a beam of wood, shod with a heavy cast-iron pile-shoe, and slung from a pulley. This was worked up and down like the ram of a Ringing engine till the surface of the kunkur was completely broken up over a small space. On the spot thus broken up, an iron-tube 11 feet 6 inches long and 1 foot in diameter, was now placed, and driven by a ram slung from the triangle, and worked as before described. When driven to a depth of 7 feet, it was bored out, and a charge of 50 lbs. placed at a depth of 6 feet under the kunkur. The tube was then drawn with a differential pulley, and the boats being removed, the charge was fired by means of Bickford's fuze, producing a crater 16 feet in diameter and 5 feet deep. The operation occupied about 8 hours, but it was not repeated, because the river was too high at the time to make it of any real advantage except as an experiment. Since that time no operations have been undertaken against kunkur rocks, except the following, which was also purely experimental.

The kunkur beds at Hurdee are the most extensive on the Gogra; they

\* This was one of the earliest operations, and no galvanic or magnetic battery was at hand.

lie at various depths, and several rocks jut above the surface, or are just concealed by it when the river is at its lowest level. But whatever their total extent may be, there is no doubt that the removal of about 10,000 square, or 20,000 cubic, yards of the most prominent rocks would greatly improve the channel. It remains to be seen then to what extent the experiments that have been made justify us in supposing that this can be done within a reasonable time and at moderate cost. As in the previous experiments, boats were moored over the rock; this time in from 4 feet 6 inches to 5 feet of water, and a current of more than 2 miles per hour. The other arrangements were the same as before, but as the kunkur here lay to an indefinite depth, and partially mixed with clay, the tube before used was not necessary. A 2-inch iron-bar was driven straight down into the kunkur to a depth of 6 feet, and drawn by means of a differential pulley assisted by block tackle worked from a capstan. The hole thus made was slightly rymed out with an iron tool for the purpose, and a slender sal pile was driven down, deepening and widening the hole to a diameter of 3 inches;\* it was rapidly withdrawn, and a charge of 8 lbs. contained in a tin cylinder was pressed down into the hole to a depth of 8 feet. This was fired, and the hole produced, which was as narrow at the mouth as at the bottom, was cleared out with a boring tool 1 foot 7 inches in diameter and 16 feet long; into this a diver descended, and reported that it was about 2 feet in diameter the whole way down and 8 feet in depth. A charge of 60 lbs. was all that was available at the time, and it failed through the breaking of the cylinder; but this failure in no way affects the principle; moreover other charges were fired successfully under the same rock, in the same manner; but this instance is given, as it was the most successful one in the product of a large and deep shaft.

The centre of the above charge was at a depth of 7 feet 6 inches under the surface of the kunkur, and with a further depth of 4 feet 6 inches of water above it. Now, although we have no exact data for the influence of this depth of water, we may presume that it will necessitate a considerable increase of the charge in order to produce the same effect as in air. The charges ordinarily used to produce three-lined craters in earth are calculated as  $\frac{1}{4}$ th the cube of the Line of Least Resistance, whereas I propose here to employ charges of  $\frac{1}{3}$ rd cube of L. L. R. On this supposition, the

\* In loose kunkur of this description a wooden pile will act effectually as a wedge to widen a hole already formed, but it cannot be driven in the first instance even if shod with iron.

quantity of powder required at that depth to produce a three-lined crater would be 140 lbs; and we may, perhaps, calculate that on an average, charges of 150 lbs. would produce craters of 20 feet in diameter; where the water was deep, they would, perhaps, produce less than this; where shallow, more. Part of the débris from such craters would generally lie about the edges, part would be blown to a considerable distance, and part would fall back into the crater where it would be harmless, being at a considerable depth under the surface. On the débris which lay round the hole, the current would act powerfully, separating the clay and reducing its bulk to less than half the original; the nodules of kunkur themselves would be carried away in the floods, or even if they remained they would be at a much greater depth under water, and could never bind again into a surface as compact as the original. Thus it seems likely that, even were the blasting operations not assisted by dredging, the result would still be to break-up, disintegrate, and reduce in bulk the whole rock, and leave the kunkur in such a condition as to be acted on by the succeeding floods, and to be gradually carried away altogether.

On such an extensive rock surface as that of Hurdee, it would be easy to accommodate three or more working parties,\*—we may suppose three,—and it is not too much to assume that, with the proper appliances, each party would fire three charges in a day. Eight charges a day would be a fair allowance for the whole three parties, and supposing such charges to be placed at two-lined intervals, or 14 feet apart, the whole number of charges required to break up a surface of 10,000 square yards would be 462, the quantity of gunpowder about 70,000 lbs., and the number of days in which it could be done 58; but allowing for unavoidable delays and occasional bad weather, it would be well to calculate on the operation lasting three months, which is about the length of the season most favorable for such work.

The cost of the operation may be roughly estimated as follows :—

|                                                                                                                      | RS.          |
|----------------------------------------------------------------------------------------------------------------------|--------------|
| Working parties, including crews of three pair of boats,<br>20 men each, at an average rate of wages of Rs. 5, . . . | 300          |
| Three Lallas in charge of boats, at Rs. 15, . . .                                                                    | 45           |
| Hire of additional boats for carriage of men and materials<br>to and from shore, . . . . .                           | 100          |
| Total . . . . .                                                                                                      | 445 monthly. |

\* Each pair of boats would take up a considerable space in order to keep the moorings clear of each other.

As experiment has not yet decided how far it would be necessary to assist the action of the charges by dredging away the débris into deep water, the hire of the three boats, at Rs. 30 per month each, will be added to the above :—

|                                                            |       |
|------------------------------------------------------------|-------|
|                                                            | RS.   |
| Brought forward,                                           | 445   |
| Hire of three boats for dredging at Rs. 30 per month, each | 90    |
|                                                            | <hr/> |
| Total,                                                     | 535   |
|                                                            | <hr/> |
| Total boat hire and labor for three months,                | 1,605 |

The work would of course require the presence of an Engineer and a European Overseer, whose salaries however will not appear here. The expenditure on materials would be trifling except that on vessels to contain the charges. This expenditure could be reduced to a minimum by employing either 100 or 200 lb. charges, in either of which cases, the original powder barrels would be placed in the mines, and no expense would be incurred beyond that of making them water-proof.

If 150 lb. charges be employed, as here contemplated, the cost of tin cylinders should be added to that of preparing the barrels, as it would be necessary to employ for each 150 lb. charge, one 100 lb. barrel, and one 50 lb. cylinder.

|                                                                |       |
|----------------------------------------------------------------|-------|
|                                                                | RS.   |
| Cost of preparing 462 barrels, at 8 annas each,                | 231   |
| 462 tin cylinders, at Rs. 1 each,                              | 462   |
|                                                                | <hr/> |
| Total,                                                         | 693   |
|                                                                | <hr/> |
| Making a total expenditure during the progress of the works of | 2,298 |

The first cost of preparations and of a stock would be as follows :—

The boats employed for boring and for placing the charges should belong to Government; but their cost would be a charge only against the first operations, as the same boats would answer for all subsequent ones, as well as for any of the ordinary works of the season. Allowing two 150-maund boats to each working party, at a cost of Rs. 1 per maund of tonnage, the estimate would be as follows :—

|                                           |       |
|-------------------------------------------|-------|
|                                           | RS.   |
| Six 150-maund boats, at Rs. 150 each,     | 900   |
| Decking and strengthening do., at Rs. 50, | 300   |
|                                           | <hr/> |
| Total,                                    | 1,200 |

## PLANT.

|                                                    | RS.          |
|----------------------------------------------------|--------------|
| Six 2 feet diameter boring tools, at Rs. 50, . . . | 300          |
| Three triangles, at Rs. 50, . . .                  | 150          |
| Three differential pulleys, at Rs. 100, . . .      | 300          |
| Three crab winches, at Rs. 100, . . .              | 300          |
| Miscellaneous, . . .                               | 150          |
| Total, . . .                                       | <u>1,200</u> |
| Grand total first cost of boats and plant, . . .   | 2,400        |
| Grand total cost of labor and materials, . . .     | <u>2,298</u> |

The above estimate for plant does not include jumpers, hammers, Ringing engines for driving the jumpers,\* by which are here meant simply pointed bars of iron, not steeled; blocks and some smaller stores, which in this case happen to be in hand at present. Had these to be included, they would increase the estimate by about Rs. 400.

Taking the figures as they stand, and adding 10 per cent. to cover contingencies and the wear and tear of tools and cordage :—

|                                                        | RS.          |
|--------------------------------------------------------|--------------|
| The total first cost of boats and plant will be . . .  | 2,640        |
| The total cost of labor, boat-hire and materials . . . | <u>2,528</u> |

These amounts represent the cost of the operations on a sunken rock, as it would be charged against the sum appropriated for works, and it takes no account of the cost of European supervision and of gunpowder, which would not be so; but where the expenditure of gunpowder is so great, its cost, if it entered the estimate would become by far the largest item. In the foregoing estimate the cost has been worked out by calculating merely from the extent of the surface of rock to be demolished, and it has been tacitly assumed that the charges would in every case reduce the kunkur to a safe depth below the surface. This depth may, and has been assumed as 6 feet, but every additional foot that could be obtained would be of value, and be worth a proportionate increase of expenditure. In order to obtain a clear depth of 6 feet in every case, it would, perhaps, be necessary to use larger mines where the kunkur lay nearer the surface, and smaller where it lay deeper. But it is thought that the average taken, namely, 150 lbs. for each mine, is on the safe side of the truth.

\* The jumpers on all the rocks yet tried could be hammered directly down through the kunkur, which of course can be much better done with a Ringing engine than by hand. In the case of block kunkur it would be necessary to work the jumper in the ordinary fashion.

The difficulty previously mentioned, namely, that of entirely dispersing the kunkur thrown up by the explosion of a charge, might be partially obviated by using rather larger charges than those proposed, or by dredging, or by both methods. It is a matter for experiment, as no sufficient data for it exist at present; but it is suggested that it would be economical to work only on the deeper part of a reef according to this method; and where cofferdams could be constructed, to employ them for the removal of all rock within 2 feet 6 inches or 3 feet of the surface, as in such shallow water they would be readily and cheaply constructed. Cofferdams appear to have been employed on the Ganges river works with a certain degree of success, but at an enormously greater cost than that here estimated; there are also certain objections to their use, which cannot be gone into here, and many of the rocks spoken of have a sandy substratum which would not admit of their employment.

The above description and estimate will answer their purpose, if they be considered to show the feasibility of removing kunkur rocks on a large scale at a reasonable cost. On such a scale as here contemplated their removal is—by the ordinary methods of blasting—by no means a simple engineering problem, and an inspection of the rocks themselves, with masses jutting up here and there and the current racing over sunken beds between them, is not at all calculated to re-assure the Engineer, who has not at the time decided on his means of attack.

W. J. C.

## No. CXV.

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### THE HURROO BRIDGE—LAHORE AND PESHAWUR ROAD.

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*Designed and Constructed by* **LIEUT.-COL. A. TAYLOR, R.E., C.B.**

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THE Bridge consists of 10 spans of 40 feet each. The piers and superstructure are of timber; the abutments of rubble masonry. The depths to which the different piers and abutments are carried are shown in the drawings. The timber work throughout is of heart of deodar, all sap wood being rejected.

*Piers.*—Are shown in full detail in the drawings. Every timber is in one length, excepting only the waling pieces on the pile heads. The lowest pairs of horizontal waling pieces are reduced to 10 × 6 scantling, to admit of timber of the required length being obtained from the Cabool river. The bolts are throughout of round iron  $\frac{3}{4}$ -inch diameter.

*Abutments and Wing Walls.*—Are founded at the depths shown, and are built of coursed rubble with the following exceptions:—The wheel-guards are of cut bricks-on-edge, and the parapets are furnished with a cap of cut brickwork, 6 inches thick, laid on edge.

*Superstructure.*—Corbels on pile heads are 12 inches wide and 10 deep, and are firmly bolted to the tie-beams, each by two bolts of  $\frac{3}{4}$ -inch round iron.

*The Beams* are 10 × 6 scantling, except the last length at each end resting on the abutments, which is 10 × 9, to give depth sufficient to admit of the abutting blocks being countersunk into it to a depth of 3 inches. No joint in a tie-beam within 6 feet of a pier; the drawings show in detail how the joints are made. The pieces all abut against each other with

square ends; the keys are of seasoned seesum. Each tie-beam is supported by two  $\frac{1}{2}$ -inch iron rods.

*Vertical Posts over Piers.*—Details are given in the drawings.

*Straining Beams* are secured to the roadway beams by four trenails of  $1\frac{1}{2}$  inches diameter of dry khaw wood.

*Roadway Beams.*—Scarfs in roadway beams are made in the places, and in the manner shown. Details are given in the drawings.

*Roadway Planking.*—The planks supporting the railing struts are 6 inches thick, no piece being less than  $9\frac{1}{4}$  feet in length; they are secured to the roadway beams by spikes 11 inches long. Remainder of planking 4 inches thick, secured by spikes 8 inches long. Each end of every plank rests on a beam and is secured to it by two spikes; elsewhere one spike secures each plank to each roadway beam. The lengths of planking break joint throughout.

*Wheelguards* are in long lengths, of  $10 \times 8$  scantling. The different lengths abut against each other in each case over a block with square ends, and are kept in position as shown in figure. The hard wood key is of seesum or khaw wood.

*Wall Plates on Abutments.*—The tie-beam is notched out  $1\frac{1}{2}$  inches to receive the wall plate.

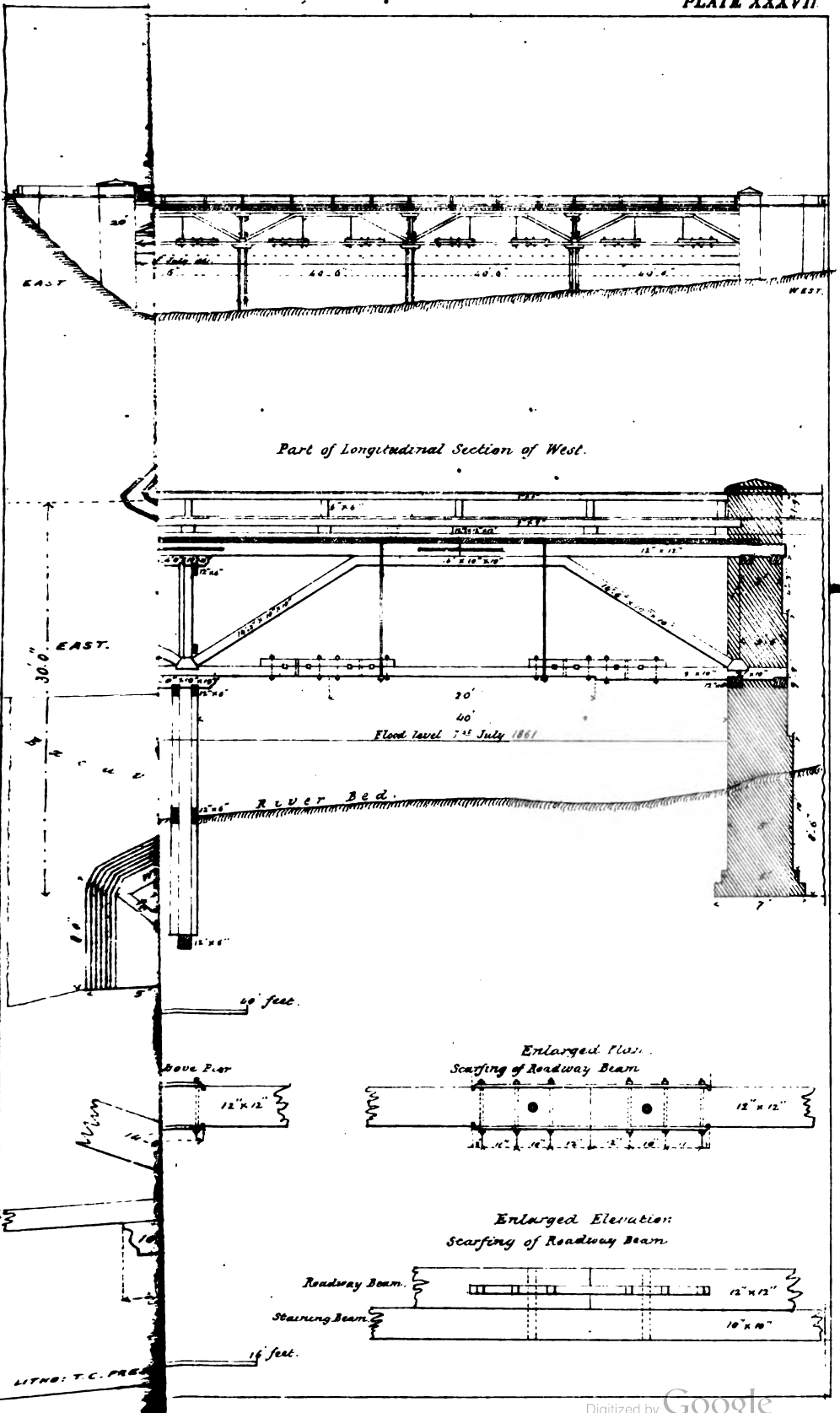
*Metalling* is of broken stone.

*Painting.*—The railings, including verticals and struts, are painted in three coats of white lead and oil.

*Tarring.*—The wheelguards, wheelguard blocks, roadway planking, on both sides, and all woodwork, thence to water level including wall plates, and all touching surfaces, are payed over with pine tar.

#### ABSTRACT OF ESTIMATE.

| c. f.     |                                                                   | Rs.       |
|-----------|-------------------------------------------------------------------|-----------|
| 187,188   | Earthwork, excavation in boulders, at Rs. 6 per 1000, ...         | 823-128   |
| 10,480    | " " in sand-stone, at Rs. 10 per 1000, ...                        | 104-800   |
| 33,725    | " filling in and ramming, at Rs. 5 per 100, ...                   | 168-625   |
| 21,416-42 | Pucka rubble masonry with cut-stone faces, at Rs. 19 per 100, ... | 4,069-119 |
| 239       | Brickwork, at Rs. 26 per 100, ... ..                              | 62-14     |
| 18,325-4  | Deodar wood work, at Rs. 2 per cubic foot, ... ..                 | 26,650-8  |
| 98-55     | Hardwood work, at Rs. 4 per cubic foot, ... ..                    | 394-2     |
| mda.      |                                                                   |           |
| 17,095-56 | Iron-work, at Rs. 18-12 per 100, ... ..                           | 3,205-417 |









## ABSTRACT OF ESTIMATE.—(Continued.)

| s. l.                                      |                               |     |     |     | RS.        |
|--------------------------------------------|-------------------------------|-----|-----|-----|------------|
| 76,898-94                                  | Tarring, at Rs. 2 per 100,    | ... | ... | ... | 1,527-978  |
| 3,016                                      | Painting, at Rs. 5 per 100,   | ... | ... | ... | 150-800    |
| 46                                         | Driving piles at Rs. 15 each, | ... | ... | ... | 690        |
| Total Rupees, ...                          |                               |     |     |     | 87,847-007 |
| Add contingencies, at Rs. 5 per cent., ... |                               |     |     |     | 1,892-85   |
| Total,                                     |                               |     |     |     | 39,739-857 |

ATTOCK, }  
8th January, 1862. }

A. T.

## No. CXVI.

## MANUFACTURE OF IRRIGATION PIPES.

*Memorandum on Machine-made Earthenware Pipes for Irrigation.*BY CAPT. W. JEFFREYS, R.E., *Exec. Engineer, Ganges Canal.*

THE complete adaptability of earthen-ware pipes for all purposes of irrigation and drainage may now be considered an established fact. To meet a want so universally felt, steps have been taken by the Government for promoting and developing the growth of this useful description of manufacture. Potteries have been established at certain stations, and the services of professional hands have been obtained from England. We may then safely predict that the day is not far distant when they will come into general use.

The object of this paper, which relates more especially to the employment of earthen-ware tiles for irrigating purposes, is to show the results of the first experiments of the kind which have been made in these Provinces. But before proceeding to consider the processes employed in their manufacture, it is necessary to say a few words on the causes which led to their adoption in the Irrigation Department.

On all canals it has been found necessary to regulate the quantity of water supplied to cultivators, by constructing in the banks of *rajbuhas* (minor irrigating channels) outlets of a fixed section, the size depending on the area it is designed to irrigate. For this purpose wooden boxes or covered-in troughs, (termed *colabas*,) embedded in the *rajbuha* bank had been used for many years past in these Provinces; but their employment is open to the following objections:—

I. Their great original expense, the cost of each *colaba* varying from Rs. 5 to 8 each.

II. The necessity of their frequent renewal. For in order that they might be as cheap as possible, common wood such as jamun, semul, mangoes, and others, were used in their construction. They were unseasoned and of a perishable nature, and the consequence was that new colabas had to be supplied yearly; this was a heavy tax on the cultivators.

III. For the same reason, that of economy, the workmen nearest at hand (frequently unskilled) were employed in constructing these colabas. They were consequently ill made, of varying section and apt to leak; the result of which was an irregular supply of water, serious breaches in rajbuha banks, and loss both to Government and the cultivators.

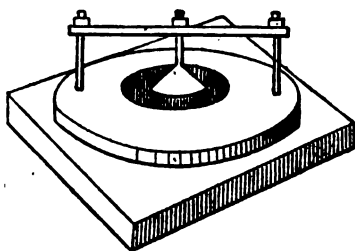
IV. In consequence of the yearly renewal of colabas, cultivators came to regard their water-courses as temporary channels, and on receipt of a new colaba often shifted their heads to suit their convenience. Little care was therefore taken in the construction of these channels, which are still in a lamentable state causing everywhere percolation and great wastage of water.

To remedy these evils earthen-ware tiles were first introduced by Mr. Macrone in the Allypore Division of the Ganges Canal, in 1862. They were thrown and moulded on a potter's wheel and were burnt like tiles in an open clamp. They were made in three sizes, of  $8\frac{1}{2}$ , 6 and  $4\frac{1}{2}$  inches in diameter, respectively. The cost of each joint was from 2 to  $2\frac{1}{2}$  annas, so that for 10 joints which were required to traverse the bank of an ordinary rajbuha, a cost of Rs. 1-4 only was incurred. When embedded throughout in lime, 3 inches in thickness, they were found to be tolerably durable; and many can now be pointed out, which have been in use from two to three years without any apparent deterioration. The great advantages derived from the use of earthen-ware tiles, both for economy and durability, soon led to their adoption in other divisions, and it is now believed that the manufacture of wooden colabas has been altogether discontinued.

Although an improvement on the old box, the tiles made by native potters are still very defective. They are necessarily crooked and are not of uniform size throughout. They are but imperfectly burnt, and being porous, they cannot resist the action of water, and must in course of time decompose. A perfectly true sound glazed earthenware pipe would remove all the evils above alluded to, and would be useful, not only for irrigation outlets, but for all purposes of irrigation and drainage to which

it may be applied. To attain this object, a manufactory was established at Nanou with a view of making experiments, the results of which are embodied in this memorandum.

The moulding machine consists of a strong wooden vertical cylinder, 5 feet 6 inches in length by 20 inches in diameter, supported on beams firmly embedded in masonry. It is constructed of well seasoned secsum, 3 inches in thickness, secured on the outside with four iron bands,  $\frac{1}{2}$ -inch in thickness. In the cylinder is a piston worked by a wooden screw, 8 inches in diameter, and at the lower end is inserted a dod or die of the following shape.



The clay, after being previously prepared and worked up to the required consistency, is thrown into the cylinder and pressed out of the dod by the action of the screw. The clay as it escapes is evidently moulded into the form of a pipe.

Below the die is a moveable platform balanced by means of weights attached to ropes running over pulleys, and arranged in such a manner that the resistance offered should just be overcome by the descending clay. When the necessary length of pipe is attained, the action of the screw is stopped; the pipe is cut off with a piece of thin wire and removed to the drying sheds. Being relieved from the pressure of the clay, the platform ascends to its former position, and the operation is repeated. The cylinder full of clay contains twelve 8-inch pipes. In this manner 250 to 300 can be taken out in one day.

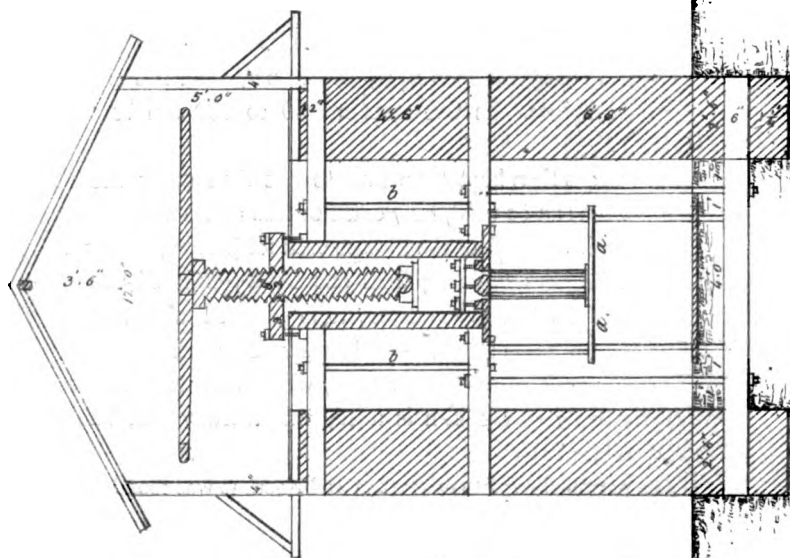
The pipes are then kept from four to five days under sheds to dry; if exposed to the sun or wind, they crack or lose their shape.

Appended is a sketch of the furnace used for burning the pipes. It has six arched furnaces radiating from one centre, enclosed under a conical shaped dome, 18 feet in diameter; it is supplied with four air holes at top and six fire holes below, as well as two doors. The pipes are stacked in an upright position as closely as they will lie, one course above another, and as the body of the kiln is filled, the doorways are built up with kucha or refuse bricks.

From continued experiments made at Nanou, it was found that it requir-

# MANUFACTURE OF IRRIGATION PIPES.

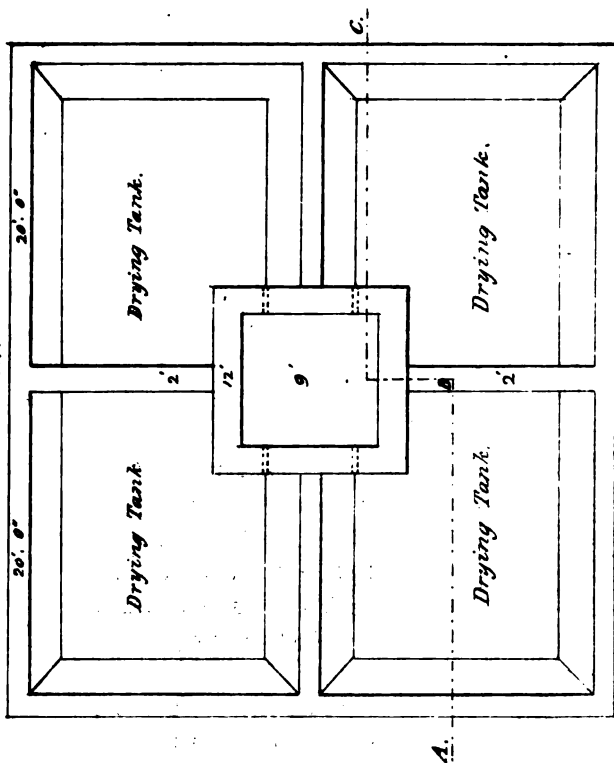
Section of Tile Making Machine & House.



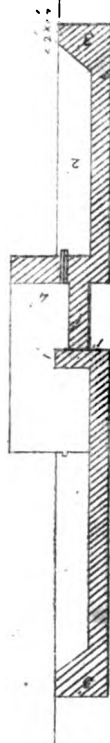
a. Movable platform suspended from stingers b.b.

Scale, 6" = 1"

PLAN.



Section on A.B.C.

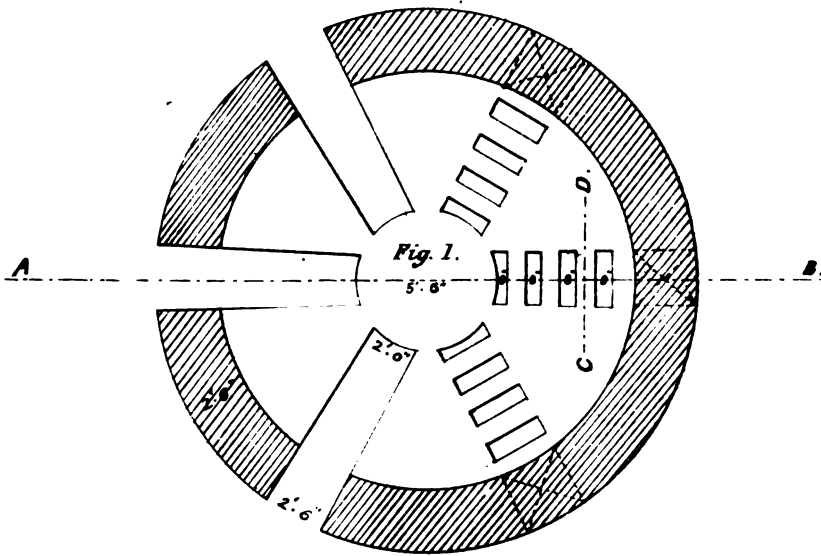
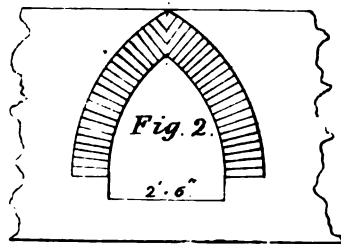


Scale 12' = 1"

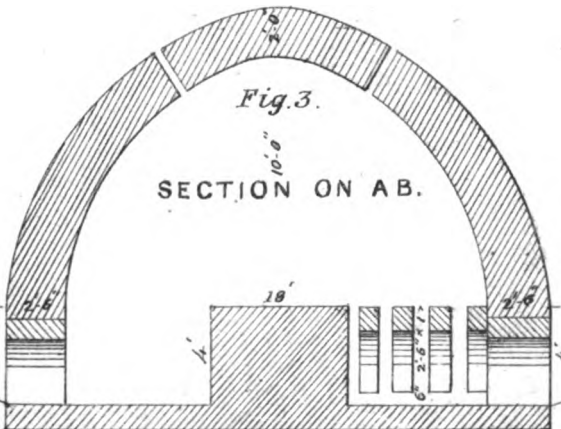


MANUFACTURE OF IRRIGATION PIPES.

*Sketch of Kiln at Nanou for burning Tiles.*



SECTION ON CD.

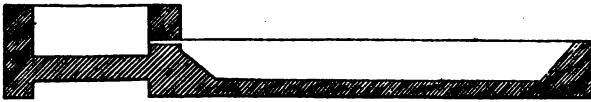


SECTION ON AB.



ed 36 to 48 hours to burn the pipes thoroughly. The tiles are gradually brought up to a red heat and maintained so for 12 hours; after which the kiln is raised to the greatest heat possible, that is until the flame and the pipes are of the same color, and this is kept up for 24 hours. The kiln is then allowed gradually to cool, the admission of cold air being carefully guarded against. In the N. W. Provinces the fuel best adapted and most easily procurable is dry babool wood; but where coal can be obtained at a moderate cost, it would no doubt be preferable.

Great care should be taken in the preparation of the clay, as any particles of stone or kunkur left in the clay, are liable to stick in the die and score the surface of the pipe. The most efficient and least expensive method of removing all foreign particles and rendering the clay fit for use is the *blunging* process. It was found most successful, and gave a fineness of texture to the ware which is quite unattainable by pugging or any other method. Two sets of masonry tanks, one raised 2 feet above the other, were constructed, the upper communicating with the lower by means of pipes built into the masonry, 2 inches above the flooring of the former.



The clay was then thrown into the upper tank, mixed with twice its bulk of water, and worked by means of a long wooden spade (termed a *blunger*) until a perfectly smooth pulp was obtained. The mixture was then drawn off into the lower tank, the smaller particles being held in suspension, while the heavier particles fell to the bottom and remained in the upper tank. After ten or twelve days exposure to the sun, the clay was fit for use, without any further labor being required upon it.

When this process is employed in damp climates like that of England, the moisture can only be driven out by artificial means, viz., heat or pressure. This would prove too expensive, except in the manufacture of porcelain or china ware. But in this country where the powerful agency of the sun can be obtained at all times, the desired result is brought about by the simple process of evaporation, and that at no outlay whatever.