April 14, 1863.

JOHN ROBINSON M'CLEAN, Vice-President,
in the Chair.

The following Candidates were balloted for and duly elected :—
WILLIAM DENT DENT, M.A., JOSEPH FOGERTY, JOHN LEWIS,
GEORGE WIGHTWICK RENDEL, and THOMAS CHARLES TOWNSEND,
as Members; HENRY WILLIAM FERDINAND BOLCKOW, HENRY
BOLDEN, OWEN BOWEN, CHARLES WILLIAM ROBERT CHAPMAN,
JOHN DAVIS, CHARLES GOTT, CHARLES TOWNSHEND HARGRAVE,
CHARLES LÖWINGER, RICHARD CHRISTOPHER RAPIER, and ALFRED
RUMBALL, as Associates.

No. 1,090.—“Description of the Line and Works of the Scinde
Railway.”¹ By JOHN BRUNTON, M. Inst. C.E., F.G.S.

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

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

¹ The discussion upon this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

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

Attention was immediately drawn to the Indus Valley route, having Kurrachee as its sea terminus; and a concession having been granted to Mr. W. P. Andrew in 1855, a company was formed, called the Scinde Railway Company, but embracing under its management not only the Scinde Railway proper, or the line from Kurrachee to Hyderabad upon the Indus, but the Punjaub line, from Moultan to Lahore and Umritsir, and a flotilla of steam boats on the river, with a view to complete the through communication. (Plate 10.) Three distinct capitals were originally raised, under the following titles:—1, The Scinde Railway; 2, The Indus Steam Flotilla; and 3, The Punjaub Railway. The accounts of these sections are kept perfectly distinct, while economy and harmonious working are secured, by the concentration of the management in the hands of one board of directors. Within the last three months, another section of this great scheme has been intrusted by Government to the Scinde Railway Company. It is called the Delhi Railway, being an extension of the line from Umritsir to Delhi, where it will form a junction with the northern terminus of the East Indian Railway. The lengths of these sections are respectively;—Scinde Railway, from Kurrachee to Kotree, on the Indus, 108 miles; Indus Steam Flotilla, Kotree to Moultan, 570;¹ Punjaub Railway, Moultan to Lahore, 222, Lahore to Umritsir, 32 = 254; Delhi Railway, Umritsir to Delhi, 300. Total, 1,232 miles.

It is to the construction of the first section of the line, between Kurrachee and Kotree, (Plate 12,) that this communication is specially devoted; and it is hoped that the facts thus recorded may be useful, not only to the Engineers whose professional labours may lie in India, but also to those Contractors who may find it their interest to undertake the execution of the great works which the extension of the railway system throughout India will infallibly render necessary. Although this section of the entire system is the shortest, it constitutes, as has been graphically observed, 'the neck of the funnel.' Over it must pass, not only the whole of

¹ This distance being measured upon the river is, on account of the windings, fully 100 miles more than the direct line by land.—J. B.

the existing traffic, but as the other sections are completed, the developed commerce of this vast territory, hitherto locked up, will pour in upon it, taxing its capabilities as a means of communication, and, doubtless, realising the sanguine anticipations of its promoters.

Kurrachee, the western terminus of the railway, is situate in lat. $24^{\circ} 47' 21''$ and long. $66^{\circ} 58' 15''$, and is not only the natural port of Scinde, but also of the Punjab and of Central Asia. The plan, (Plate 11,) shows its form. Like many other land-locked harbours, it has the disadvantage of a bar at its mouth; but, nevertheless, the depth of water upon the bar at ordinary tides is sufficient to admit ships drawing 17 feet to 18 feet, and at spring tides, ships drawing 21 feet have passed in with safety. When once within Manora Point the depth of water is much greater, as is shown by the soundings upon the plan. The fast-increasing traffic of the port, and the large size generally of the vessels trading there, demanded that some measures should be taken to increase the depth of the water over the bar, thus rendering the entrance to the harbour available at all seasons; and that, by the erection of wharves and other appliances suggested by modern science, greater accommodation should be afforded. With this view her Majesty's Government, in 1856, applied to the late Mr. James Walker, F.R.S. (Past-President Inst. C.E.), for a Report upon the subject; and in 1858 he submitted plans, sections, and estimates for various suggested improvements. These recommendations were accepted by the Government, and immediate steps were taken for carrying them out. The groyne shown at A, (Plate 11,) is now advanced for about one-half its proposed length, and the result already is an increased depth of water on the bar. There is no doubt that when the works in progress are completed, Kurrachee Harbour will take a high rank as a safe and commodious port.

The population of the town of Kurrachee is about 60,000, and is rapidly increasing. The number of vessels entering and clearing outwards is shown in the following Table :—

Year.	Arrivals.		Departures.		Total.	
	No.	Tons.	No.	Tons.	No.	Tons.
1854-55	1,086	56,695	1,103	58,194	2,189	114,889
1858-59	1,589	131,311	1,654	138,171	3,243	269,487
1859-60	1,656	148,096	1,577	142,647	3,233	290,743

The principal articles of export consist of oil seeds, and grain of all sorts, wool, cotton, hides, indigo, munjeet, drugs and dyes, raw silk, fruit, and saltpetre. The import trade comprises cotton

piece goods, woollen goods, malt liquors, railway materials, metals, wines and spirits, tea, coffee, timber, pipe staves and casks, regimental necessities, spices, fruit, oilman's stores, and wearing apparel.

The following Table shows the increase of the import and export trade :—

Year.	Imports.	Exports.	Total.
	£.	£.	£.
1843-44	121,150	1,010	122,160
1844-45	217,700	9,300	227,000
1845-46	312,900	40,500	353,400
1846-47	293,400	49,300	342,700
1847-48	287,872	154,730	442,602
1848-49	344,715	107,133	451,848
1849-50	419,352	114,378	533,730
1850-51	425,831	196,461	622,292
1851-52	489,220	244,122	733,342
1852-53	535,690	376,337	912,027
1853-54	..	..	900,000 ¹
1854-55	604,000	629,000	1,233,000
1855-56	628,913	604,440	1,233,353 ²
1856-57	685,665	734,522	1,420,187
1857-58	1,081,101	1,078,128	2,159,229
1858-59	1,540,605	1,044,272	2,584,877
1859-60	1,712,751	947,335	2,660,086 ³

Within the last two years, a large number of European and native mercantile firms have established themselves in Kurrachee, and have erected extensive warehouses, in order to meet the rapidly increasing trade of the port. Her Majesty's Government has found it necessary to erect a new and more commodious Custom-house; and the harbour improvements now in progress include not only the deepening of the water on the bar, but greatly extended wharf and quay accommodation. The Scinde Railway will communicate directly with these wharves and landing places, and a great improvement in the system of loading and discharging cargoes has already been introduced, and is daily making rapid strides.

Hitherto all commercial communication with the upper districts has been carried on by native boats on the Indus, or by cafilahs of camels. No roads worthy of the name exist. Until the opening of the Scinde Railway these river boats were accustomed to stop at Khettie, a river station at one of the mouths of the Indus, (Plate 10.), and there discharge their cargoes into native sea-going craft, which conveyed the greater part to the port of Bombay,

¹ There are no exact returns of the sea trade for 1853-54.

² This return is for eleven months only.

³ The trade of 1862-63 has amounted to £3,500,000 in the nine months, and is estimated at £5,000,000 for the whole year.

only a comparatively small portion reaching Kurrachee. The import trade had to struggle with the same impediments, increased by the slow progress made in 'tracking' the boats up the Indus, against an average current of 3 miles, or $3\frac{1}{2}$ miles per hour, and a portage at Sukkur of $1\frac{1}{2}$ mile. During the prevalence of the south-west monsoon, lasting from May to September inclusive, even this wretched and dilatory system was suspended, paralysing commerce and creating an indescribable amount of expense, inconvenience, and irregularity. The formation of the Scinde Railway, and the improvement of the port of Kurrachee, have met all these obstacles, and will open up a magnificent field for commercial enterprise, introducing civilisation, with all its attendant benefits, to a district inhabited by millions of human beings hitherto shut out from its influences.

On the 29th of April, 1858, the works of the Scinde Railway were commenced by Sir Bartle Frere, K.C.B., then the highly-respected Commissioner of Scinde, who wheeled the first barrow-load of earth into an embankment in the neighbourhood of Kurrachee. The contract for the execution of the whole of the works was originally let to Messrs. James and Edwin Bray; but in June, 1859, the line was taken over by the Company, and the works then remaining to be completed were executed departmentally by the Engineers, Inspectors, and other officers of the Company. Without entering into a statement of the causes of Messrs. Bray's relinquishing the works, which at present form a subject of legal reference, it will suffice to say, that when the Company's Engineers took possession of them, they had to encounter difficulties which were not due entirely to the peculiarities of the country. There was a great dearth of the ordinary railway plant: irregularity in the payment of the native labourers of all classes had driven many away, and had caused an unnatural and serious rise in the rate of wages. To meet this position of affairs, and to secure the economical execution of the works, a fair tariff of wages, at a reduction of fully 25 per cent. upon those which were paid by Messrs. Bray, was published by the Company's Engineers, and daily payments were guaranteed. This had the effect of drawing a considerable number of labourers to the undertaking.

The Province of Scinde contains but a sparse population, which is principally located on the low-lying alluvial land on the banks of the river, where the rich earth yields ample returns with a minimum amount of labour. The Scindee, born and bred on these plains, is naturally indolent and devoid of muscular power; at the same time he is not deficient in talent, easily acquiring a knowledge of account-keeping and writing. The natives of the neighbouring state of Cutch are a much superior race. Cutch sends carpenters, masons, smiths, and skilled handicraftsmen to the whole

of the northern portion of the Bombay Presidency ; and from thence came a large majority of the skilled workmen employed on the Scinde Railway. From the hill tribes of Beloochistan and Affghanistan were obtained a hardy race of labourers ; men of great stature and personal strength, but wholly ignorant of the use of other tools than the powrah, (a large kind of hoe,) and a basket in which to carry the loosened earth. Half-wild and unaccustomed to the restraints of a more civilised state, these men required much tact, and at the same time a strong arm, to keep them in order. To secure and maintain discipline amongst such a body of men, it was found advisable to organise a regular railway police force, consisting of about 80 men. Police stations were erected at intervals along the line. To facilitate the administration of justice the Government appointed a special magistrate, whose duty it was to move up and down the line, and to hear any cases which might be brought before him. To these wise precautions may be attributed the fact, that few outrages of a serious character occurred, the majority of cases being petty thefts and attempts at imposition. This facility for obtaining justice, and the rapidity with which punishment followed crime, were highly appreciated both by the Europeans and the natives.

In districts like Scinde, where the population is scanty, and it becomes necessary to depend upon distant provinces for the supply of labour, it is obviously wise policy to offer every inducement, not only to secure, but to maintain such a supply. A higher rate of wages than ordinary may, in the first instance, draw together large bodies of men, but other arrangements are absolutely essential for establishing contentment and permanence. Hardy as these Beloochees and hill tribes were, and unaccustomed to anything approaching luxury, they appreciated highly such attentions to their feeding, shelter, and health, as policy no less than humanity suggested. When it is borne in mind, that the course of the line of railway lay at a considerable distance from existing towns, or villages, only passing through the small village of Jemedar-ke-Landi, and leaving the important towns of Tatta and Jerruck at distances of 10 miles and 17 miles respectively,—it will be seen, that a difficulty arose in obtaining food for the large masses of men congregated at the various heavy portions of the works. This was met by the Company licensing a number of bunians, or native provision merchants, to establish themselves at various points along the line ; their scales of charges being regulated by a nerrick, or list of prices, settled by the nearest kardhar, under the orders of the railway magistrate. To supply the workmen with wholesome water for drinking was equally imperative. When this precaution was not observed, the men were under the necessity of using such water as was most easily accessible, and as it was

generally of very bad quality, the results were cholera and fever of a bad type. A regular system of water carts and bullocks was first organised, and as the railway progressed, water trains were dispatched from the Mulleer, the Indus, and the Bahrn, to meet the daily requirements of the men. It was remarked, that a supply of wholesome water was always followed by the disappearance of the diseases above-mentioned, and more particularly of fever. To protect the men from another source of fever, mat huts were erected, which sheltered them from the heavy dews, and rendered them more comfortable and contented. To afford medical aid in cases of sickness, or of accident, permanent hospitals were erected at Kurrachee and Kotree, under the charge of the civil surgeons of these stations; and in addition, two temporary hospital buildings were erected at Joong Shaie and Doraji Gore, under the charge of a resident apothecary. These arrangements were very successful in preserving the health of the employés of the Company, both European and native, and in cases of accident, they were doubtless the means of preserving many lives.

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

The departmental execution of the works gave the Engineers and other officers engaged, favourable opportunities of becoming acquainted with the capabilities of the various classes of natives, as well as of ascertaining the cost of each description of work. When work of any kind was executed by day labour, it was found that its economical execution entirely depended upon the energy and honesty of the muccadam, or native overseer; but these good qualities were so rare, that it became necessary to resort to the

piece-work system. It was with some difficulty that this was established as a rule; but by degrees opposition was overcome, and the earthwork, masonry, and ballasting, were let to small gangs, with considerable advantage to the Company, while the labourer himself, excited to more vigorous and diligent exertion, earned higher wages than by the day-work system.

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

Alluvial earth excavated from side trenches and placed in embankment, the average distance of conveying it being 22 yards	10 annas per 100 cubic feet, or 4·09 pence per cubic yard.
Firmly set gravel, or soft shaly material	12 annas per 100 feet, or 4·9 pence per cubic yard.
Rockwork requiring bars, but no powder for blasting	1s. 9d. per cubic yard.
Hard rock requiring blasting,—the powder, drills, and other tools being found by the Company	2s. 0d. „ „
Ballast, consisting of small stones, or gravel, gathered in the neighbouring jungle, selected and placed <i>in situ</i>	1s. 0d. „ „
Ballast of broken stone	1s. 10d. „ „

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

Description of Work.	Quantity.	Average Cost.
EARTHWORK.		
Embankments cubic yds.	1,831,916	0 0 11½
Cuttings (a large portion consisting of rock of different degrees of hardness)	432,705	0 1 6¾
Diversion of roads and streams	212,532	0 0 8½
Ballasting	408,596	0 1 6
Pitching slopes sup. yds.	1,745	0 2 0
PERMANENT WAY.		
Leading and laying lineal yds.	193,600	0 6 0
FENCE WALLING „	338,700	0 3 0
MASONRY.		
Concrete cubic yds.	10,756	0 4 6
Dry rubble „	2,526	0 3 0
Common ditto „	17,434	0 12 0
Coursed ditto, with rubble backing	352	0 15 0
Coursed ditto „	32,550	1 0 0
Block in course „	15,192	1 11 6
Ashlar cubic feet	87,806	0 1 7½

The geological character of the district traversed by the Scinde

Railway demands a few remarks. The aspect of the country generally is barren in the extreme, but in some places there is sufficient soil to repay cultivation. Situated in what is termed the rainless zone, the average quantity of rain is very small. The annual rainfall from 1855 to 1860 is given in the following Table:—

RAIN MEASURED at the OBSERVATORY of the EUROPEAN HOSPITAL, KURRACHEE, from the 1st September, 1855, to the 31st August, 1860.

Year.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.	Total.
1855	0·15	0·00	0·00	0·00	..	..	..	..	..	..	..	..	0·15
1856	0·00	0·00	0·00	0·00	1·62	0·59	0·00	0·00	0·00	0·04	0·11	0·25	2·61
1857	0·38	0·00	0·00	0·00	0·41	1·13	0·00	0·00	0·00	0·00	0·29	4·34	6·55
1858	0·57	0·00	0·00	0·27	0·00	0·00	0·00	0·00	0·00	0·03	4·94	0·09	5·90
1859	1·08	0·00	0·02	0·20	0·00	0·00	0·02	0·00	0·00	0·00	4·90	0·00	6·22
1860	0·00	0·00	0·00	0·00	1·09	0·00	0·00	0·00	1·22	0·00	0·00	0·52	2·83
													Average.
													4·82

Kurrachee, 31st August, 1860.

(Signed)

C. RICHTERN,
Observer.

The rain is looked for about the 20th of July. Except during the rainy season, the river beds are dry, but in them water can generally be obtained, by sinking to depths varying from 5 feet to 30 feet. All the water procured from these wells is, however, more or less saline. The following analysis of several samples was made at the Government laboratory, Bombay, and will show to what extent this property prevails:—

TABLE 1.

The Numbers indicate parts in 10,000 of Water.

	A	B	C	D	E	F
Specific gravity . .	1000·72	1000·54	1000·44	1000·75	1001·10	1000·69
Carbonate of lime . .	1·160	1·328	1·252	1·720	1·011	1·136
" magnesia . .	·908	·757	·621	·247	1·151	1·120
Lime	·241	·333	·161	·611	·257	·289
Magnesia	·210	·113	·187	·269	·037	·135
Chlorine	{ 2·281 ·825 }	1·598	1·731	2·281	{ 2·689 1·473 }	2·130
Chloride of sodium .	4·445	2·485	2·185	Not tried.	Not tried.	Not tried.
Silica & oxide of iron	·100	·310	·386	·756	Not tried.	Not tried.
Sulphuric acid . .	·334	·601	·479	·851	·741	·896

TABLE 2.
SOLID CONSTITUENTS IN WATER marked B, in 10,000 parts.

Chloride of sodium	2·485
Sulphate of lime	·809
Chloride of magnesium	·115
Sulphate of magnesia	·188
Carbonate of lime	1·328
„ „ magnesia	·757
Silica and oxide of iron	·310
Total	5·992
Total solids by evaporation	5·490

TABLE 3.

	WATERS AT KURRACHEE, (selected).				
	21	22	23	24	25
	Bed of Lyaree River.	Campwater, Company's well, near Government Gardens.	Well on the Bunder Road, in front of Messrs. Warwick and Waller's premises.	Well on the Bunder Road, near Muchee Meanee.	Well in the Rutton Tank.
	H	H	H	H	H
Date of Collection	June, 1859	June, 1859	June, 1859	June, 1859	June, 1859
Specific gravity at 60° Fah.	1000·4	1000·9	1006·6	1037·8	1001·4
Chloride of sodium	2·35	8·12	58·20	423·75	9·41
„ „ magnesium	·02	—	—	—	—
„ „ calcium	·66	—	—	—	—
Sulphate of soda	—	·78	4·34	43·73	2·02
„ „ magnesia	—	·05	6·61	76·85	·02
„ „ lime	·53	·69	·44	12·04	·45
Nitrate of magnesia	—	—	—	—	—
„ „ lime	—	—	—	—	—
Carbonate of magnesia	·04	·38	1·09	2·91	·95
„ „ lime	·55	·96	2·37	2·37	1·26
Silica	(X)	(X)	(X)	(X)	(X)
Organic matter in solution	—	—	—	—	—
„ „ „ suspended	—	—	—	—	—
Total solids.	4·15	10·98	73·05	561·65	14·11
Gaseous contents	—	—	—	—	—

Samples Nos. 21 to 25 were selected from nineteen specimens taken from all the wells and tanks in use at Kurrachee. The difference in the quality of the water is extreme. Nos. 21, 22, and 25 are fair drinkable waters. In No. 23 salt is present in enor-

mous quantity, the water being a strong brine, twice as salt as sea water. The purest water was obtained from the River Indus at Kotree, and from wells in the bed of the Mulleer.

In the neighbourhood of Kurrachee, the principal features of the country are low hills, varying from 150 feet to 200 feet in height, and consisting of a coarse-grained arenaceous rock, of a dirty yellow colour, abounding with fossils. Most of these hills are capped with conglomerate, more or less disintegrated on the surface, the pebbles composing it being water-worn, and the majority derived from the nummulitic limestone of the Halla range of hills, which extend from Cape Monze, in a north-easterly direction, to the west of Mithun-Kote on the Indus. All the hills lying north of the Indus to the foot of the Halla range, of which they are spurs, exhibit the effect of considerable volcanic disturbance, and the drainage of the country passes through the fissures thus formed. One of the most remarkable of these is at Dhurwat, where, during the rains, the water of the Bahrūn occasionally rises 70 feet, rushing through the pass with overwhelming force. The Kheytriani hills are composed of pale arenaceous limestone, containing but few nummulites. This rock is easily worked, and is an admirable building stone, hardening with exposure. It was from quarries opened in this neighbourhood, that most of the stone was obtained for the masonry of the central district of the line. Near the Rhodh River there are many small hills, of conical shape, composed of calcined clays of various colours, and also large collections of nodular masses of flint. In the aluminous clay beds, veins of foliated gypsum abound. In the plains lying between these hills the soil is alluvial, and in many places it is covered with boulders of nummulitic limestone and conglomerate. The following Table, taken from a letter addressed to Sir R. I. Murchison by Captain N. Vicary, of the Hon. East India Company's service,¹ will serve to give a general idea of the relative position of the formations existing in Scinde :—

1. Conglomerate.	7. Pale arenaceous limestone,
2. Clays and sandstone.	with Hyponyees, Nummu-
3. Upper bone-bed.	lites, and Charoidea.
4. Sandstone; fossils rare.	8. Nummulitic limestone of the
5. Lower bone-bed.	Halla Range.
6. Coarse arenaceo-calcareous rock	9. Black slates, thickness un-
with <i>Cytherea exoleta</i> and <i>exa-</i>	known.
<i>rata</i> ; <i>Spatangi</i> ; no Nummu-	
lites.	

The fact that indications of considerable volcanic disturbance

¹ Vide "The Quarterly Journal of the Geological Society of London." Vol. iii. p. 335. London, 1847.

are visible among the ranges of hills lying to the north-east of the line of railway has been already noticed. At 3 o'clock in the morning of Tuesday the 9th of April, 1861, a rather smart shock of an earthquake was felt at Kurrachee, and at several places along the line, which occasioned some cracks in the walls of the Author's house in Kurrachee; and those observed shortly after, in some of the masonry of the bridges along the line, may be referred to the same cause. It is, therefore, suggested that, to guard against the consequences of such an event, hoop-iron bondings should be introduced into the walls of future buildings. This would be attended with but small extra cost, and it is submitted that such a precaution on other lines of railway in India may not be unadvisable. The natives of Scinde and Cutch possess legends of the occurrence of violent earthquakes; and though there is no authority for it, the utter prostration of the extensive buildings of Brahminabad, 60 miles east of Hyderabad, may lead to the inference, that an earthquake completed the ruin of that once important city.

The distance between Kurrachee and Kotree traversed by the Scinde Railway is 108 miles 10 chains. Of this distance 32 miles 50 chains are level, and the remaining 75 miles 40 chains are on inclines more or less favourable, 1 in 200 being the ruling gradient, as will be seen by the following classified abstract of the gradients:—

From	To	Length.	
		Miles.	Chains.
	1 in 200	10	27
1 in 200	1 ,, 300	22	33
1 ,, 300	1 ,, 400	15	67
1 ,, 400	1 ,, 500	5	5
1 ,, 500	1 ,, 600	3	48
1 ,, 600	1 ,, 700	6	63
1 ,, 700	1 ,, 800	3	10
1 ,, 800	1 ,, 900	3	8
1 ,, 900	1 ,, 1,000	1	0
	1 ,, 1,056	2	31
	1 ,, 1,100	0	68
	1 ,, 1,402	1	0
	1 ,, 1,760		
Total length of gradients		75	40

The total length of straight line being 74 miles 22 chains, the length of the line on curves is, therefore, 33 miles 68 chains, the sharpest curve having a radius of 43 chains for a distance of 76 chains, as will be seen by the following Table:—

Radius from	To radius	Length.	
Chains.	Chains.	Miles.	Chains.
	43	0	76
57	100	9	15
115	200	22	50
240	320	1	7
Total length of curves .		33	68

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

The earthworks generally are executed to accommodate a single line of railway; but all the bridges, culverts, and stone viaducts are constructed to carry a double line. In the cases of the wrought-iron viaducts, the stone piers are adapted to support girders for a double way, while those required for a single line alone are erected. The only portion of double line yet made, is that between the workshops at Ghizree Junction and the terminus at the Bunder Head, a distance of 3 miles 15 chains. In order to accommodate the traffic coming to Kurrachee from the districts called the Eastern Delta of the Indus, during the south-west monsoon, a short branch, $3\frac{1}{2}$ miles in length, has been constructed, leaving the main line near the workshops, and terminating in an embankment and a timber pier at Ghizree, alongside which native boats discharge their cargoes. The permanent way consists of the ordinary double-headed rail, weighing 65 lbs. per yard, fixed by compressed wooden keys in chairs, each weighing 22 lbs. The joints are fished in the usual way, the fish plates being secured by four bolts, each 1 inch in diameter. The whole is laid on transverse wooden sleepers, at intervals of 3 feet, except at the joints, where the sleepers are only 2 feet apart. The dimensions of the sleepers are:—length, 10 feet; breadth, 10 inches; depth, 5 inches. A large proportion of the sleepers is of red and white pine creosoted, sent from England. To complete the requisite quantity, a contract was entered into with a native merchant at Lahore, for the supply of sleepers of deodar timber, (*Cedrus deodara*), which grows upon the slopes of the Himalayas, where it attains great size. Several logs sent down to Kotree for the use of the railway measured 5 feet in diameter at the butt, and a calculation of the taper upon the log gave a result of 150 feet as the height of the tree. The trees are felled, and cross-cut into convenient lengths, for rolling to the bottom of the ravines, on the banks of which they grow. The private mark of each proprietor is cut on every log he has felled. These logs remain at the bottom of the ravines until the rains, when they are carried by the torrents into the River

Indus, where they are watched for, selected according to the marks, rafted, and floated to their destination. This rough treatment wastes much of the timber; many of the logs are split, and the ends of all are damaged; while the shortness of the pieces, which vary from 20 feet to 33 feet in length, diminishes their value. Owing to the deficiency of rain in the season of 1859-60, only a small quantity of this timber could be got down. The native merchant thus failed to complete his contract; and a quantity of Australian blue and white gum, and native red eyne sleepers was, therefore, purchased. These were objectionable, on account of their great weight, and the ease with which they were split by the driving of the spikes. The respective cost of each, when delivered in Kurrachee or Kotree, was:—

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

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

excellent ballast on the Scinde Railway, consisting chiefly of broken stone or clean gravel, assists in preserving the sleepers from the white ant.

The cost of creosoting sleepers in India varies with the description of timber submitted to the operation. In 1854 Mr. Turnbull, Chief Engineer of the East Indian Line, gave the following summary of the details of the cost supplied in a former portion of his Report¹:—sâl, $6\frac{1}{2}d.$; teak, 1s.; soondry, 1s. $5\frac{1}{2}d.$; and sissoo, 2s. $1\frac{1}{2}d.$ per sleeper. He further states, in the same Report, that one thousand sleepers of fir wood, prepared by Sir W. Burnett's process with chloride of zinc, were landed and stacked in Calcutta, where they remained for two years. On being examined at the end of this period, they were all found to be sound, and in as perfect a condition as when they were landed. This statement led the Author to recommend the adoption of Sir W. Burnett's process, and a complete apparatus was shipped from England. The vessel was, unfortunately, lost on the passage; and considerable delay occurred in replacing the apparatus, so that the majority of the deodar sleepers were submitted to the sulphate of copper process. The cost of the Burnettising process at Kotree is $5\frac{1}{2}d.$ per sleeper, which contrasts favourably with the cost of creosoting.

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

Red eyne	56 $\frac{1}{4}$ lbs. per cubic foot.
Jarrah (Australian mahogany)	52 $\frac{1}{4}$ " " "
Common jungle teak	34 $\frac{1}{2}$ " " "
Moulmein teak	33 $\frac{3}{4}$ " " "
Deodar	31 $\frac{1}{2}$ " " "
Yellow pine	24 $\frac{3}{4}$ " " "

Neither eyne nor jarrah timber will float in sea water before it is thoroughly dried. Red eyne is obtained from the forests of Guzerat, and costs in log, delivered in Kurrachee, about 1s. 6d. per cubic foot. It is not, however, very plentiful. As a pile it

¹ Vide "Selections from the Records of the Madras Government. Report of the Railway Department for 1854," page 238.
[1862-63. N.S.]

drives remarkably well, hardly requiring either ringing or shoeing in ordinary ground. It is reported to be impervious to the attacks of the white ant; but of this the Author has no positive proof. The Moulmein, or Rangoon teak, judging from the quality of the best the Railway Company could procure, is inferior to the southern, or Malabar teak, which, however, is scarce and expensive. The cost of Moulmein teak in log, delivered in Kurrachee, varies from £15 to £18 per load. The jarrah is a fine Australian timber, and is obtainable in logs of large scantling and length. If not well seasoned before being submitted to the dry climate of Scinde, it cracks and rends seriously, but not so if it is allowed to season for twelve months before being shipped. Its cost in Kurrachee is about 1s. 6d. per cubic foot. The deodar timber, the qualities of which have been before adverted to, costs at Kotree in log about 1s. 1d. per cubic foot.

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

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

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

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

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

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

The electric telegraph, with two lines of wires, is laid along the Scinde Railway. The wires are carried upon posts of deodar timber, fixed in cast-iron sockets. The block system of working the trains is adopted. Needle-speaking instruments are used for conveying the information required between the several stations and passing-places. On the Continent of Europe there exists but little difficulty in obtaining suitable and intelligent clerks for working the telegraph signals; but in India the case is widely different. There, for the sake of economy, the staff of telegraph clerks is formed and recruited from the class of half-castes and more intelligent natives, very often lads of fourteen or fifteen years of age. It is true they have to pass a preliminary examination as to their capabilities in writing and reading English; but the Author's experience of men who have passed this examination is, that they

are often deficient in the important point of understanding the messages they transmit or receive. This becomes a more serious matter when the signalman, a native, is trusting to the verbal instructions he receives from the telegraph clerk, who, in several instances on the Scinde Line, holds the combined offices of telegraph clerk and station master, a system which, for many obvious reasons, is to be deprecated. Greater security would be obtained by the separation of the train-signalling machine from the conversing telegraph, and also by the introduction of permanent train-signals, which would speak to the eye, and could not be liable to misinterpretation. Native clerks are too apt to occupy the speaking-machine, and at the same time to amuse themselves with a conversation, to the exclusion or the delay of important messages.

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

The line of the Scinde Railway, as will be seen by the map, (Plate 12,) crosses the natural drainage of a great extent of country, thus rendering necessary a large provision for waterway. The rains in Scinde are very partial, and as there are no records of rainfall which throw much light upon the subject, and no existing bridges, a careful examination of old flood marks was the only guide as to the requirements. Fixing the spans of the bridges at the large rivers and nullahs was comparatively easy. It was in crossing wide, flat plains, such as that at Pipri, that the question was surrounded with difficulties. This plain is nearly 5 miles wide. A certain number of culverts was originally built, and in addition, large catch-water drains were cut, with a view of conducting the rain water to the Guggur River, the natural and main drain of the valley. In 1861, when the rain was very heavy for about six hours in this locality, the drains were found insufficient to carry off the water in the time, and the embankment of the railway, which ponded up the water, was soon breached in many places. To remedy this, it was considered a waste of money to erect more culverts; but the plan was adopted of lowering the line to the surface, laying it, in fact, in a ditch 16 feet wide and 2 feet deep, just large enough to receive the ballast, and allowing the water to flow over the line. This plan was severely tested in the unusually heavy rains of 1862, when the water passed over the rails to the depth, in some places, of 9 inches, without either damaging the line, or stopping the traffic. In districts like Scinde, where the

rainfall is so partial, and of such short duration, but at the same time so heavy, it is submitted that this mode of crossing a large, flat plain is the safest and most economical.

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

The haulage of materials constitutes an important item in the cost of the construction of railway works everywhere, and especially in India. The following facts will assist in forming calculations on this head. About 5,500 tons of permanent-way materials were required at Loyach, one of the stations on the line, and were conveyed by native boats from Kurrachee to Soondah, a point upon the River Indus where there was a convenient landing place. It was necessary to form a road for carts between Loyach and Soondah, through the jungle, a distance of $12\frac{1}{2}$ miles, and the following were the details of the cost of the whole proceeding:—

Freight from Kurrachee to Soondah by native craft, including cost of loading and discharging cargo	8s. 6d. per ton.
Loading and unloading the native carts	0s. 6d. „
Haulage $12\frac{1}{2}$ miles, at 1s. per ton per mile	12s. 6d. „
The cost of forming and maintaining the road for twelve months was £323.13s.6d., equal on the above-mentioned quantity of materials to	1s. 2 $\frac{1}{4}$ d. „

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

Number.	Size of Opening.	Number of Openings.
46	2 feet 6 inches	191
2	3 feet	2
2	6 feet	2
113	8 feet 6 inches	329
5	10 feet	9
18	12 feet	53
2	15 feet	2

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

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

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

1	"	"	3	"	"	30	"
2	"	"	10	"	"	40	"
2	"	"	4	"	"	45	"

The large stone viaduct across the Bahrur River is 1,728 feet in length. Its greatest height, measuring from the bed of the river to the rails, is 31 feet 6 inches, and its average height is 25 feet 6 inches. The superficial measurement of the bridged area is 44,064 square feet. It consists of thirty-two arches, each 45 feet span, and having a rise of 10 feet 6 inches. This was the heaviest piece of masonry upon the line, and the time required for its completion was the measure of that for the opening for public traffic. The quantities of the different classes of work in this viaduct, and the average cost of each kind, (full details of which are given in the Appendix, page 475,) are as follows :—

	Quantity.	Cost.
		s. d.
Excavation of foundations	20,513 cubic yards	0 9½ per cubic yd.
Concrete	6,814 "	4 0½ "
Common rubble	4,455 "	11 9½ "
Coursed rubble	7,233 "	20 0½ "
Block in course	5,244 "	31 6 "
Ashlar	29,000 cubic feet	1 3 per cubic foot.
Broken stone for backing and filling in between the spandrels	2,650 cubic yards	
Ballast	3,780 "	

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

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

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

With regard to the Mulleer Viaduct, the most extensive of this class, the Author would merely observe, that the foundations and general construction were of an interesting character, on which he abstains from enlarging, as he finds that Mr. J. E. Hartley, (M. Inst. C.E.), who was the Resident Engineer during its construction, is engaged in writing a special Paper upon it. From the experience acquired by the Author from these examples of Warren's girders, he is compelled to report unfavourably of them, when contrasted with plate girders. There is an amount of vibration, both laterally and vertically, caused by passing trains, which had the effect of breaking, or of loosening the bolts fixing the longitudinal timber stringers to the cross girders. To such an extent did this occur, that it was found necessary to appoint one, two, or three native workmen at each viaduct, according to its length, whose duty it was to inspect and repair these breakages, or loosenings, after the passage of each train. The cost of this was so serious, that it was found advisable to take up the original rails, and although it raised the line and interfered slightly with the gradients, to lay the ordinary permanent way upon transverse sleepers. This has had the effect of diminishing the evil, but not of removing it entirely. The arrangement of the timber platform

over these viaducts the Author considers highly objectionable, inasmuch as, while loading the bridges, it adds nothing to the lateral stiffness, nor does it distribute the load over the whole area, as might have been the case. It is submitted that two layers of planking, each $3\frac{1}{2}$ inches thick, laid diagonally, and crossed, upon which the ordinary permanent way could have been laid, would have been a better arrangement,—stiffening the bridge laterally, and distributing the load more uniformly. The sliding blocks upon which each girder is laid, for the purpose of meeting the effects of contraction and expansion caused by changes of temperature, were not found to work well. In several cases the large ashlar stones upon which the bed plates were fixed, were drawn out of their places, before the blocks would slide. It is considered that the roller system, as originally specified, would have been a better arrangement. The impossibility of getting at all the surfaces of the ironwork, to scrape and repaint them, is likewise a serious objection; for while there is no great amount of rain annually in Scinde, there are heavy dews for months together, which cause a rapid oxidisation of unprotected wrought iron. The large viaduct across the Chinnee Creek, of ten spans, each of 100 feet, for a double line, has not yet been erected, but the ironwork is already complete, and delivered at Kurrachee. The girders are of plate iron, of elliptic form in elevation.

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

The railway system, which thirty years ago was in its infancy, and struggling into public notice, has now arrived at gigantic proportions, and has not only spread its network over the land of its birth, but is extending, with rapid strides, over the vast continents of the world. During the early years of railway con-

structions, and while the works connected with them lay in civilised countries, the professional Engineer was surrounded by all the appliances of modern science, and had the command of skilled and unskilled labour, which rendered his duties comparatively easy. But the extension of railway communications into wild and uncivilised countries, demands from the Engineers, Agents, and Contractors engaged, the exercise of more than ordinary observation, self-discipline, and energy. This remark applies to all grades of the employés of a foreign Railway Company, from the Chief Engineer and Agent, to the lowest European Inspector. Each European employé almost necessarily occupies an isolated position as regards his fellow-countrymen. He is surrounded by natives, with whose language and habits he is but imperfectly acquainted. Yet upon the obtaining and securing the services and good-will of these natives, the progress and success of the work intrusted to his charge wholly depend. Great tact and temper are, therefore, absolutely necessary. It is flattering to know, that the natives of India place unbounded faith in the truthfulness and justice of a Briton, and when this high position is not weakened, or lost, by the improper acts of the individual, it is a most powerful instrument for good. Kind, considerate, just, and withal firm treatment secures willing service; while an opposite course is followed not by retaliation, perhaps not even by remonstrance, but by the native quietly moving off in search of more humane treatment elsewhere. In carrying out the works of the Scinde Railway there was no lack of examples confirming the above opinion, as to the effect of the European's general treatment of the natives, upon the number and character of those whom he could attract to the works. Again, the Engineer or Inspector situated as above-described, at a distance from head-quarters, meets with cases of emergency, when fertility of resource and self-reliance are most invaluable qualities; while at all times, and wherever he may be placed, energy of character and perseverance, combined with temperance, will alone render him a valuable officer. It becomes then the wise policy of all foreign Railway Companies, and of all Contractors for their works, to exercise the greatest strictness, in ascertaining that the agents sent out from this country at immense cost, are not only proficient in the practical details of their profession, but that they are also possessed of gentlemanly feelings and habits, which alone will command the respect of the uncivilised native, attracting him to the work, reducing its cost, and converting the Railway Engineer into a pioneer of civilisation and a missionary of science.

The Author has pleasure in acknowledging, that he is greatly indebted to the following gentlemen, members of the Engineering

staff of the Scinde Railway, for much valuable assistance in collecting and recording the data from which the cost of the various works given in this Paper is calculated:—Mr. W. T. Warren, Mr. Henry Stone, Mr. Thomas Warren, Mr. J. E. Hartley, and Mr. J. Pinder.

The Paper is illustrated by a plan and section of the line, and by a chart of Kurrachee Harbour, from which Plates 11 and 12 have been compiled, as well as by an elevation, plan, and sections of the Bahrun Viaduct, and details of the mode of forming the masonry piers for the iron girder viaducts.

[APPENDIX.

APPENDIX.

BAHRUN VIADUCT.

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

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

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

For this sum $8\frac{1}{2}$ cubic yards were excavated, thus costing :

Per cubic yard	ANNAS 5·14
About an equal number were excavated by the two modes, therefore add as above	4·36
	<u>9·50</u>

which, divided by 2, gives as the average cost per cubic yard	R.	A.	P.
Add for tools	0	4	9
	0	0	5
Average cost of excavation, } or $9\frac{1}{2}d.$ per cubic yard . }	0	5	2

COST OF CONCRETE.

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

For 100 Cubic Feet of Concrete.

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

Or, 4s. 0½d. per cubic yard.

COST OF ASHLAR MASONRY, PER 100 CUBIC FEET.

Quarrying	7	4	0	
Earthwork in baring quarry	1	0	0	
Dressing	30	0	0	
Water for men	0	8	0	
Maistry	0	8	0	
Smithwork—labour	1	3	0	
Haulage	3	0	0	40 7 0
Setting	12	0	0	
Water for mortar	0	12	0	
Lime	1	0	0	
Sand	0	4	0	
Maistry	0	6	0	
Tools and contingencies	4	11	0	
Total				Rs. 62 8 0

Or, 1s. 3d. per cubic foot.

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

Quarrying	6	4	0	
Dressing	25	0	0	
Earthwork in baring quarry	2	0	0	
Water for men	0	11	0	
Smithwork—labour	0	10	0	
Maistry	0	10	0	
Haulage	3	0	0	35 3 0
Setting	11	8	0	
Water for mortar	0	14	0	
Sand	0	8	0	
Lime	1	8	0	
Maistry	1	0	0	
Tools, coal, templates, &c.	4	3	0	
Total				Rs. 57 12 0

Or, £1. 11s. 6d. per cubic yard.

COURSED RUBBLE, PER 100 CUBIC FEET.

	R.	A.	P.	
Quarrying	6	0	3	
Earthwork in baring quarry	1	0	0	
Dressing	12	8	0	
Water for men	0	6	0	
Maistry	0	8	0	R. A. P.
Smithwork—labour	0	8	0	
	<hr/>			20 14 3
Haulage	2	4	0	
Setting	10	8	0	
Water for mortar	0	14	0	
Lime	1	8	0	
Sand	0	8	0	
Maistry	0	4	0	
	<hr/>			15 14 0
Total	<hr/>			Rs. 36 12 3

Or, £1. 0s. 0 $\frac{3}{4}$ d. nearly, per cubic yard.

COMMON RUBBLE, PER 100 CUBIC FEET.

Quarrying	3	6	0	
Smithwork—labour	0	8	0	
Water for men	0	6	0	
	<hr/>			4 4 0
Haulage	2	2	0	
Setting	10	0	0	
Lime	1	12	0	
Sand	0	8	0	
Maistry	0	8	0	
Water for mortar	0	14	0	
Tools and contingencies	1	10	6	
	<hr/>			17 6 6
Total	<hr/>			Rs. 21 10 6

Or 11s. 9 $\frac{3}{4}$ d. per cubic yard.

CENTERING.

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

Iron in one set of centres 36 cwt.

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

Total for one centre Rs. 2,623 0 0

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

Total Rs. 33,396 0 0

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

18,336 0 0

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

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

TOTAL COST OF THE BAHRUN VIADUCT.

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

COST OF MASONRY AT KURRACHEE.

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

ASHLAR.

	R.	A.	P.
Two good men will prepare 8 cubic feet per day for 20 annas $\times 12\frac{1}{2}$, or for 100 cubic feet	15	10	0
Two good men will set in general work 20 cubic feet per day for 20 annas, making for 100 cubic feet	6	4	0
To labour, including coolies', nowgunnies', smiths', and maistrys' pay	15	4	0
Cost of contractor's part	Rs. 37	2	0
Add for quarrying stone, exclusive of powder, &c., for 100 cubic feet	4	0	0
Ditto for delivery of stone, if 5 miles lead, and supposing each cart to contain 7 cubic feet, at 12 annas per cart load, or for 100 cubic feet	10	11	5
Ditto for lime delivered on the works	2	12	0
Ditto for sand „ „ „	1	4	0
Ditto for water „ „ „	0	12	0
Total for 100 cubic feet	Rs. 56	9	5
£1. 10s. 6 $\frac{3}{4}$ d. per yard, Or about 1s. 4 $\frac{1}{4}$ d. per cubic foot.			

BLOCK IN COURSE.

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

	R.	A.	P.
Brought forward	27	2	8
Add for stone in quarry, exclusive of powder, &c., per 100 cubic feet	4	0	0
Ditto for delivery of stone, if 5 miles lead, and supposing each cart to contain 7 cubic feet, at 12 annas per cart load, per 100 cubic feet . .	10	11	5
Ditto for sand per ditto	1	8	0
Ditto for water per ditto	0	14	0
Ditto for lime delivered upon the work . . per ditto	3	0	0
Total for 100 cubic feet	Rs. 47	4	1
Or £1. 5s. 6½d. per yard.			

COURSED RUBBLE.

Two good men will prepare 20 cubic feet per day, at 10 annas per day for each man, making for 100 cubic feet	6	4	0
Two good men will set in general work 30 cubic feet per day, at 10 annas each man per day, making for 100 cubic feet	4	2	8
To labour, including coolies', nowgunnies', smiths', bullocks', and maistris' pay	10	8	0
Cost of contractor's part	Rs. 20	14	8
Add for stone in quarry, exclusive of powder, &c., per 100 cubic feet .	3	8	0
Ditto for delivery of stone, if 5 miles lead, and supposing each cart to contain 7 cubic feet, at 12 annas per cart load, per 100 cubic feet . .	10	11	5
Ditto for sand per ditto	1	8	0
Ditto for water per ditto	0	14	0
Ditto for lime delivered upon the work . . per ditto	2	12	0
Total for 100 cubic feet	Rs. 40	4	1
Or £1. 1s. 8½d. per yard.			

A SUPERIOR CLASS OF RUBBLE.

Two good men will prepare and set 40 cubic feet per day, at 10 annas per day for each man, making for 100 cubic feet	3	2	0
To labour, including coolies', nowgunnies', smiths', bullocks', and maistris' pay	8	0	0
Cost of contractor's part	11	2	0
Add for stone in quarry, exclusive of powder, &c., per 100 cubic feet	3	8	0
Ditto for delivery of stone, if 5 miles lead, and supposing each cart to contain 7 cubic feet per 100 cubic feet	10	11	5
Ditto for sand per ditto	1	10	0
Ditto for water per ditto	1	0	0
Ditto for lime delivered upon the work, per ditto	3	0	0
Total for 100 cubic feet	Rs. 30	15	5
Or 16s. 8d. per yard.			

[Mr. W. P. ANDREW,