DESCRIPTION OF THE LINE AND WORKS OF THE SCINDE RAILWAY.

BY

JOHN BRUNTON, M. INST. C.E., F.G.S.

EDITED BY

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HONORARY SECRETARY:

AND

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WITH AN ABSTRACT OF THE DISCUSSION UPON THE PAPER.

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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.

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

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

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 Hydrabad 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 1.) Three distinct capitals were originally raised, under the following titles:—1, The Scinde Railway; 2, The Indus Steam Flotilla; and 3, The Punjaub Railway. 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;[2] 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 3,) 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 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° 47′ 21″ and long. 66° 58' 15", and is not only the natural port of Scinde, but also of the Punjaub and of Central Asia. The plan, (Plate 2,) 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

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[2] 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.

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 2,) 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	138,176	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 necessaries, spices, fruit, oilman's stores, and wearing apparel.

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.

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*
1854-55	604,000	629,000	1,233,000
1855-56	628,913	604,440	1,233,353**
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***

* There are no exact returns of the sea trade for 1853-54.
** This return is for eleven months only.
*** 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.

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 1,), and there discharge their cargoes into native sea-going craft, which conveyed the greater part to the port of Bombay, only a comparatively small portion reaching Kurrachee. The import trade had to struggle with the same impediments, increased by the slow progress made in 'tracking' the boats up the Indus, against an average current of 3 miles, or 3½ miles per hour, and a portage at Sukkur of 1½ 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 Bahrun, 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 muccadum, or ganger, whose orders they cheerfully obey, and to whom each man pays a stipulated small percentage from each rupee earned by him. It is through the muccadum, 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 muccadum, 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 49 pence per cubic yard.
Rockwork requiring bars, but no powder for blasting	1*s*. 9*d*. per cubic yard.
Hard rock requiring blasting, the powder, drills, and other tools being found by the Company	2*s*. 0*d*. per cubic yard.
Ballast, consisting of small stones, or gravel, gathered in the neighbouring jungle, selected and placed in situ	1*s*. 0*d*. per cubic yard.
Ballast of broken stone	1*s*. 0*d*. per cubic yard.

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		
			£.	s.	d.
EARTHWORK.					
Embankments	cubic yds.	1,831,916	0	0	11½
Cuttings (a large portion consisting of rock) of different degrees of hardness	cubic yds.	432,705	0	1	6¾
Diversion of roads and streams	cubic yds.	212,532	0	0	8½
Ballasting	408,596	cubic yds.	0	1	6
Pitching slopes	sup. yds.	1,745		2	0
PERMANENT WAY.					
Leading and laying	lineal yds.	193,600	0	6	0
Fence Walling	lineal yds	338,700	0	3	0
MASONRY.					
Concrete.	cubic yds.	10,756	0	4	6
Dry rubble	cubic yds.	2,526	0	3	0
Common rubble	cubic yds.	17,434	0	12	0
Coursed rubble, with rubble backing	cubic yds.	352	0	15	0
Coursed rubble	cubic yds.	32,550	1	0	0
Block in course	cubic yds.	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 rain-fall 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	4:82 Average.
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	0.00	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	
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	1001.1	1000.69
Carbonate of lime	1.160	1.328	1.252	7.720	1.011	1.136
Carbonate of magnesia	0.908	0.757	0.621	0.247	1.151	1.120
Lime	0.241	0.333	0.161	0.611	0.257	0.289
Magnesia	0.210	0.113	0.187	0.269	0.037	0.135
Chlorine	2.281	1.598	1.731	2.281	2.689	2.130
	0.825				1.473	
Chloride of sodium	4.445	2.485	2.185	Not tried.	Not tried.	Not tried.
Silica & oxide of iron	0.100	0.310	0.386	0.756	Not tried.	Not tried.
Sulphuric acid	0.334	0.601	0.479	0.851		

TABLE 2.	
SOLID CONSTITUENTS IN WATER marked B, in 10,000 parts.	
Chloride of sodium	2.485
Sulphate of lime	0.809
Chloride of magnesium	0.115
Sulphate of magnesia	0.188
Carbonate of lime	1.328
Carbonate of magnesia	0.757
Silica and oxide of iron	0.310
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	58.2	428.75	9.41
Chloride of magnesium	0.02	-	-	-	-
Chloride of calcium	0.66	-	-	-	-
Sulphate of soda.	-	0.78	4.34	43.73	2.02
Sulphate of magnesia	-	0.05	6.61	76.85	0.02
Sulphate of lime	0.53	0.69	0.44	12.04	0.45
Nitrate of magnesia	-	-	-	-	-
Nitrate of lime	-	-	-	-	-
Carbonate of magnesia	0.04	0.38	1.09	2.91	0.95
Carbonate of lime	0.55	0.96	2.37	2.37	1.26
Silica	(X)	(X)	(X)	(X)	(X)
Organic matter in solution	-	-	-	-	-
Organic matter in 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 enormous 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 Bahrun 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,[3] will serve to give a general idea of the relative position of the formations existing in Scinde:—

1. Conglomerate.
2. Clays and sandstone.
3. Upper bone-bed.
4. Sandstone; fossils rare.
5. Lower bone-bed.
6. Coarse arenaceo-calcareous rock with *Cythorea exoleta* and exarata; Spatangi; no Nummulites.
7. Pale arenaceous limestone, with Hypponyces, Nummulites, and Charoides.
8. Nummulitic limestone of the Halla Range.
9. Black slates, thickness unknown.

The fact that indications of considerable volcanic disturbance 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

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

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 Hydrabad, 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 in 300	22	33
1 in 300	1 in 400	15	67
1 in 400	1 in 500	5	5
1 in 500	1 in 600	3	48
1 in 600	1 in 700	6	63
1 in 800	1 in 900	3	10
1 in 900	1 in 1,000	3	8
	1 in 1,056	1	0
	1 in 1,100	2	31
	1 in 1,402	0	68
	1 in 1,760	1	0
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, 3½ 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. 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 Report[4]:—sâl, 6½*d.*; teak, 1*s.*; soondry, 1*s.* 5½*d.*; and sissoo, 2*s.* 1½*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,

[4] Vide "Selections from the Records of the Madras Government. Report of the Railway Department for 1854," Page 238.

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 5½*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	56¼ lbs. per cubic foot.
Jarrah (Australian mahogany)	52¼ lbs. per cubic foot.
Common jungle teak	34½ lbs. per cubic foot.
Moulmein teak	33¾ lbs. per cubic foot.
Deodar	31½ lbs. per cubic foot.
Yellow pine	24¾ lbs. per cubic foot.

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 1*s*. 6*d*. per cubic foot. It is not, however, very plentiful. As a pile it drives remarkably well, hardly requiring either ringing or shoeing in ordinary ground. It is reported to be impervious to the attacks of the white ant; but of this the Author has no positive proof. The Moulmein, or Rangoon teak, judging from the quality of the best the Railway Company could procure, is inferior to the southern, or Malabar teak, which, however, is scarce and expensive. The cost of Moulmein teak in log, delivered in Kurrachee, varies from £15 to £18 per load. The jarrah is a fine Australian timber, and is obtainable in logs of large scantling and length. If not well seasoned before being submitted to the dry climate of 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 1*s*. 6*d*. per cubic foot. The deodar timber, the qualities of .which have been before adverted to, costs at Kotree in log about 1*s*. 1*d*. 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 10 inches, and at the top 15 inches. Its average cost was 3*s*. 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 2*s*. 4½*d*. 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 Dutch 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 8*s*.
> First year from date of indentures, per mensem 30 rupees £3
> Second year from date of indentures, per mensem 40 rupees £4
> Third year from date of indentures, per mensem 50 rupees £5
> Fourth year from date of indentures, per mensem 60 rupees £6
> Fifth year from date of indentures, per mensem 80 rupees £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 natter 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 3,) 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 Bahrun. 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 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 8*s*. 6*d*. per ton.
>
> Loading and unloading the native carts 0*s*. 6*d*. per ton.
>
> Haulage 12½ miles, at 1*s*. per ton per mile. 12*s*. 6*d*.

> The cost of forming and maintaining the road for twelve months was £323.13*s*. 6*d*., equal on the above-mentioned quantity of materials to 1*s*. 2¼*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 carded 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 inverts 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 bridge, containing 3 arches, each of 30 feet span.
> 2 bridges, containing 10 arches, each of 40 feet span.
> 2 bridges, containing 4 arches, each of 45 feet span.

The large stone viaduct across the Bahrun River is 1,728 feet in length. Its greatest height, measuring from the bed of the river to the rails, is 31 feet 6 inches, and its average height is 25 feet 6 inches. The superficial measurement of the bridged area is 44,064 square feet. It consists of thirty-two arches, each 45 feet span, and having a rise of

10 feet 6 inches. This was the heaviest piece of masonry upon the line, and the time required for its completion was the measure of that for the opening for public traffic. The quantities of the different classes of work in this viaduct, and the average cost of each kind, (full details of which are given in the Appendix) are as follows:—

	Quantity.	Cost.	
		s.	*d.*
Excavation of foundations	20,513 cubic yards	0	9¼ per cubic yd.
Concrete	6,814 per cubic yd.	0	0¾ per cubic yd.
Common rubble	4,455 per cubic yd.	11	9¾ per cubic yd.
Coursed rubble	7,233 per cubic yd.	20	0¾ per cubic yd.
Block in course	5,244 per cubic yd.	31	6 per cubic yd.
Ashlar	29,000 cubic feet	1	3 per cubic foot.
Broken stone for backing and filling in between the spandrils	2,650 cubic yards		
Ballast.	3,780 cubic yards		

The total cost of this viaduct was £27,185. 12*s*. 10*d*. The cost per lineal foot of viaduct was £15. 148. 7d., and per square foot of bridged area 12*s*. 4*d*. 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.
The Guggur	3 spans.
The Dorbagi	2 spans.
The Runnpittiani	6 spans.
The Loyach	8 spans.
The Rhodh	3 spans.
Total	43 spans

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 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 constructions, 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 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 2 and 3 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.

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
		Rs.	2 10

For this sum 8 cubic yards were excavated, thus costing:

	ANNAS			
Per cubic yard.	5.14			
About an equal number were excavated by the two modes, therefore add as above.	4.36			
	9.50			
which, divided by 2, gives as the average		R.	A.	P
cost per cubic yard		0	4	9
Add for tools		0	0	5
Average cost of excavation, or 9¼ *d*. per cubic yard		0	5	2

COST OF CONCRETE.

				R.	A.	P
Lime per maund of 80 lbs.				0	3	2
Sand per 100 cubic feet				0	12	0
Stone per 100 cubic feet:						
	R.	A.	P			
Quarrying	1	0	0			
Breaking	1	0	0			
Hauling	2	12	0			
Water per 100 cubic feet				4	12	0
				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 cubic feet, at	4	12	0	per 100 cubic feet	1	9	4
Sand 50 cubic feet, at	0	12	0	per 100 cubic feet	0	6	0
Water					1	4	8
Mixing and depositing in place					2	12	0
Total					6	4	12
Or, per cubic yard					1	14	0
Add for tools					0	2	6
Total					2	0	6

Or, 4*s*. 0¾ *d*. per cubic yard.

COST OF ASHLAR MASONRY, PER 100 CUBIC FEET.

	R.	A.	P	R.	A.	P.
Quarrying	7	4	0			
Earthwork in baring quarry	1	0	0			
Dressing.	30	0	0			
Water for men	0	8	0			
Smithwork-labour	0	8	0			
Maistry	1	3	0			
				40	7	0
Haulage	3	0	0			
Setting	12	0	0			
Water for mortar	0	12	0			
Lime	1	0	0			
Sand	0	4	0			
Maistry	0	6	0			
Tools and contingencies	4	11	0			
				22	1	0
Total				Rs. 62	8	0

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

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

	R.	A.	P
Quarrying	6	4	0
Dressing	25	0	0
Earthwork in baring quarry	2	0	0
Water for men	0	11	0

	R.	A.	P.	R.	A.	P.
Smithwork-labour	0	10	0			
Maistry	0	10	0	R.	A.	P.
				35	3	0
Haulage	3	0	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	3	R.	A.	P.
				22	9	0
Total				57	12	0

Or, £1. 11*s*. 6*d*. 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			
Smithwork-labour	0	8	0			
				R.	A.	P.
				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	R.	A.	P.
				15	14	0
Total				Rs. 36	12	3

Or, £1. 0s. 0¾d. 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	R.	A.	P.
				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	R.	A.	P.
				17	6	6
Total				Rs. 21	10	6

Or 11*s*. 9¾ *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 Rs	1910	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

	R.	A.	P.
Cost of the 12 sets was, therefore	31,476	0	0
Fixing and removing in 32 arches	1920	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 Koonee 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 arches	1,255	0	0
Koonee Bridge arches	418	5	4
Total	Rs. 15,060	0	0

TOTAL COST OF THE BAHRUN VIADUCT.

	R.	A.	P.
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	12*s*	10*d*

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 x 12½, or for 100 cubic feet	15	10	0
Two good men will set in general work 20 cubic feet per day for 20 annas, making for 100 cubic feet	6	4	0
To 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
Add 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
Add for lime delivered on the works	2	12	0
Add for sand	1	4	0

Add for water	0	12	0
Total for 100 cubic feet	Rs. 56	9	5

£1. 10*s*. 6¾*d*. per yard,
Or about 1*s*. 4¼*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
Add for stone in quarry, exclusive of powder, &c., per 100 cubic feet.	4	0	0
Add 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
Add for sand per 100 cubic feet	1	8	0
Add for water	0	14	0
Ditto for lime delivered upon the work	3	0	0
Total for 100 cubic feet	Rs. 47	4	1

Or £1. 5*s*. 6¼*d*. 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 maistrys' 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
Add 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
Add for sand	1	8	0
Add for water	0	14	0
Add for lime delivered upon the work	2	12	0
Total for 100 cubic feet Or £1. 1*s*. 8¼*d*. per yard.	Rs. 40	4	1

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 maistrys' 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
Add for delivery of stone, if 5 miles lead, and supposing each cart to contain 7 cubic feet	10	11	5
Add for sand per 100 cubic feet.	1	10	0
Add for water per 100 cubic feet.	1	0	0

Add for lime delivered upon the work, per 100 cubic feet.		3	0	0
Total for 100 cubic feet	Rs.	30	15	5
Or 16*s*. 8*d*. per yard.				

Mr. W. P. ANDREW,

Mr. W. P. ANDREW,—Chairman of the Scinde Railway Company,—observed, that on the map of India, (Plate 1,) this railway appeared to be a very small undertaking; yet in actual length it would be found to compare advantageously with some of the leading railways in England. For instance, it was about the same length, 108 miles, as the Great Western, from London to Bath, and very nearly equal to that of the London and Birmingham Railway, which was 113 miles, while the Scinde Railway was more than twice the length of the London and Brighton line. It was not, however, from its dimensions, but from its relation to other parts of India, that this line derived its great national and commercial importance. The immediate object for its construction was to meet the two great difficulties of the Indus, the creek navigation and the ocean swell of the open sea. All the serious accidents that had been attended with loss had occurred, either in the short navigation of the open sea, or in the creeks of the delta. By the last mail he had received a letter, stating that another company, (not in connection with the Scinde,) which proposed to establish a through navigation between the Punjaub and Kurrachee, had had three of their vessels seriously injured, the back of one being reported to have been broken, in the creek navigation. So alive had the natives been to the advantages gained by the Scinde Railway, and so much did they appreciate the regularity and certainty of railway communication, that the native craft which was formerly in the habit of coming to Khettie in the delta, as the port of trans-shipment, both for Bombay and Kurrachee, did not now come below Kotree, where the goods were trans-shipped and conveyed by railway to Kurrachee. In a letter received that day, it was stated that there was a length of two miles of native boats collected at Kotree, the upper terminus—which in itself was sufficient evidence to show the dangers of the sea and creek navigation by steamers and by native country craft, and to demonstrate the necessity for such a work as the Scinde Railway. The Agent of the Company further stated, that not a single native boat had gone below Kotree for the last two months. The immediate object contemplated by the Scinde Railway,—to relieve the commerce of the country from its two great dangers, had thus been accomplished by substituting a railway of 108 miles, for the creek navigation of 230 miles. Moreover in a political and military point of view, it was of the greatest importance to be able to move troops from Kurrachee to Kotree in a few hours, instead of losing a week in conveying them up the creeks.

Looking at the map of Upper India (Plate 1), towards the north, a branch line would be observed on the right bank of the River Indus. That was the proposed line from Sukkur, *viâ* Shikarpoor and, Jacobabad, to the Bolan Pass; the surveys had been partially executed, and it was found that the line could be easily and cheaply constructed. Its political importance was great; and a large portion of the traffic of Central Asia came down that Pass on its way to Kurrachee, and was subject to great difficulties and delays. Higher up was Moultan, the lower terminus of the Punjaub Railway: that line extended to Lahore and Umritsir, and from thence proceeded the Delhi Railway, which would form a junction with the East Indian Railway at Delhi. The traffic between Moultan and Kotree was now most imperfectly carried on by means of a large fleet of steamers, which he trusted would speedily be superseded by a railway. India would then have one of the longest continuous lines in the world, from Kurrachee to Calcutta, a distance of upwards of 2,200 miles, forming a great steam arch connecting the Arabian Sea with the Bay of Bengal. This would give the greatest protection to the empire of India, by affording the most effectual means of quelling disturbances, either within or without the frontier. It would, moreover, powerfully develop the enormous resources of the interior of the country, bringing to the port of shipment that produce of its plains which was so urgently required in England. The capabilities of India were but little understood. The discrepancies of conflicting authorities might, however, be accounted for when it was considered, that India was a country of vast extent, being as large as the whole of Europe without Russia, that it possessed every variety of soil and climate, and that, from the different elevations of the plateau, its products necessarily varied.

With regard to the cost of the Scinde Railway, he thought that it would slightly exceed the average cost of railways in India, which he believed to be about £15,000 per mile. But there were peculiarities in the case of the Scinde Railway which would, in a great measure, account for this excess. In the first place, there was considerable difficulty in procuring from England freight for the materials, for at the time the concession was granted, Kurrachee was scarcely known, and it became necessary to investigate and to publish the capabilities of the port. In the second place, the Scinde Railway comprised, in proportion to its length, a more than usually large number of such works, as piers, wharves, &c., which did not ordinarily belong to railways. Then there were difficulties when the materials arrived in India; the Company having even to provide their own boats for unloading the vessels, and as there was a deficiency of labour, labourers had to be imported from Cutch and Central Asia, and from the confines of China and Persia. All these obstacles were overcome, however, by the energy and perseverance of the Author of the Paper, and the Engineering staff under him, and Sir Bartle Frere, the then Commissioner in Scinde, and the present Governor of Bombay, had borne testimony to the admirable manner in which the affairs of the Company were conducted.

There was one important engineering point on which it was desirable to elicit an opinion, that was the best material for sleepers in India. In Scinde the soil was hard and stony; many of the cuttings were through rock, and the embankments consisted, in great part, of stone. The kind of sleeper which would answer there would probably be ill adapted for the railways in the Punjaub. On the Scinde line, the sleepers had been prepared in a variety of ways, but they had all apparently retained their original size and form, thus presenting, as he understood, a great contrast to the wooden sleepers employed in almost every other part of India. On those lines, the sleepers had, irrespective of the attacks of the white ant and notwithstanding every precaution, become desiccated and had almost entirely disappeared, from the effect of natural decay. From his own acquaintance with India and with the habits of the white ant, in

1846, he had ventured to predict that the apprehension of the ravages of that insect upon railway sleepers was exaggerated. The results had proved as he had predicted, that whatever was liable to sudden concussion, or vibration, would never be much affected by the ant, as it always worked under a covered way, and whenever that covered way was disturbed, it invariably retired. As in the Punjaub there was a great difficulty in procuring wooden sleepers, the Company had, upon the recommendation of Mr. Bidder, (Past-President Inst. C.E.,) sent out several miles of iron sleepers. As they were only being now put down, it was impossible at present to give an opinion as to their adaptability.

He desired also to call attention to another engineering point connected with the Scinde Railway, which was perfectly novel to him. From some cause or other, the waterway appeared to be insufficient to allow the drainage of the country to pass beneath the line, and the Engineer had adopted the expedient of allowing, on a part of the line, the water to flow over, instead of under it. The water appeared to glide over slowly, and the ballast being heavy stone, the line was not injured, nor had the traffic been interrupted by this peculiar mode of treatment.

From the days of Sir Henry Pottinger[5] and Sir Charles Napier[6] to the present time, the attention of Indian statesmen had been directed to the political and strategic, as well as to the commercial importance of Kurrachee. A good port capable of admitting at all hours and seasons ships of large burden, was indispensable to the success of the combined system of rail and river for the valley of the Indus, intended to be carried out by the Scinde and the Punjaub Railways, in conjunction with the Indus Flotilla. Such was to be found in Kurrachee, the most western port of India, and the only land-locked harbour between Bombay and the Persian Gulf. It was perfectly safe and easy of access for large ships, by day and night, and even during the monsoons. According to Commodore Young of the Indian Navy,[7]—who, as far back as 1854, took the steam frigate Queen' twice into Kurrachee in the night time, during the south-west monsoon,—it, though a bar harbour, had sufficient depth of water, even in its existing state, for ships of from 17 feet to 18 feet draught, at high water of ordinary tides. At high spring-tides, the depth was from 20 feet to 21 feet, and at times, even 22½ feet. In this view, Commodore Young was confirmed by Commodore Rennie,[8] of the Indian Navy, who, during the preparations for the late expedition to the Persian Gulf, was constantly in and out of the harbour with troops, and became convinced, that there was frequently more water on the bar than was shown by the port register. As a proof of this, the 'Bussorah Merchant,' a large vessel drawing 20½ feet of water, passed the bar when the register showed 21 feet. To that able and excellent officer, Captain C. D. Campbell, I.N.,

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[5] Vide Letter from Sir H. Pottinger to Mr. W. P. Andrew, in "The Scinde Railway, and its Relations to the Euphrates Valley and other Routes to India.' London, 1856.

[6] Vide "The Indus and its Provinces." By W. P. Andrew. London, 1857.

[7] Vide "The Indus and its Provinces." By W. P. Andrew. London, 1857.

[8] Vide ibid.

belonged the credit of having been the first to take, on his own responsibility, a large armed steamer into the harbour of Kurrachee.

From the Ganges to the Oxus, whoever wished to communicate with any place beyond the sea, must pass through Kurrachee, which thus occupied a position scarcely less favourable to commerce than Alexandria. The port was protected from the sea and from bad weather, by Manora Point, a bluff rocky headland projecting south-eastward from the mainland, and leaving a space of about 2 miles between the extreme point and the coast to the east. The harbour was spacious, extending about 5 miles northward from Manora Point, and about the same distance from the town, on the eastern shore, to the extreme western point.

To be the nearest point to Europe of all the British possessions in India was important in many respects, but more especially with reference to the Euphrates Valley route; and every remark relative to the direct communication of Kurrachee with Suez was equally, if not more, applicable to that with Bussorah, as materially reducing the sea voyage from India. When the proposed telegraphic communication should be established with Europe, whether by the Persian Gulf, as advocated by him, or the Red Sea, or, as it ought to be, by both routes, the advantage would be great, of being the medium of disseminating the political and commercial intelligence of Europe to the most distant parts of India, and giving in exchange the most recent events there, and also in Central Asia. Until lately beyond the pale of the electric chain, which already spanned the eastern empire, Kurrachee was destined, ere long, to become the chief seat of the telegraph in India, and from its geographical position, it must become the European port of India. It was (Plate 4) 205 miles nearer than Bombay to Aden; and for three months in the year, during the prevalence of the south-west monsoon, it was virtually 735 miles nearer.

Nearly ten years ago, Sir Bartle Frere, the present Governor of Bombay, remarked,[9] "it might be premature to dwell on the certainty of this port (Kurrachee) becoming, ere long, the channel of a direct steam communication with Aden. But compare the length of the run hither from Aden with the length of the run to Bombay; and consider that the passage from Bombay to Aden is, for three months in the year, in the teeth of the south-west monsoon; that on the line from this to Aden, the south-west monsoon does not blow with violence, and is, in fact, not more than a steady trade-wind, equally favourable for the run to, or from Aden, the result of a consideration of these circumstances can hardly be other than a conviction, that a direct steam communication will be established at no distant period, and from the large number of passengers between the Punjaub and England, to whom it is of importance to avoid the delays and

[9] Vide "The Scinde Railway, and its Relations to the Euphrates Valley and other Routes to India." By W. P. Andrew. London, 1856.

expenses of going round by Bombay, there can be little doubt but that it would prove a good passenger line."

Mention was made in the Paper of the extensive works carried on by Government for the improvement of the harbour. Mr. Andrew could further state, that the Scinde Railway Company had sent out from England more than one hundred ships, and that no accident had occurred to any of them either in entering, or on leaving the port.

Mr. BRUCE said, it appeared from the statement of the Chairman of the Scinde Railway, that the cost of the line might be estimated at rather more than £15,000 per mile, and the average prices of the different descriptions of work were given in the Paper; but there was another necessary element in the consideration of the case, the price of labour, by which alone it was possible to judge whether the work was cheap, or dear. The price of earth-work was stated to be 11½*d*. per cubic yard, and that of block in course 31*s*. 6*d*. per cubic yard. Now he hoped he should not be considered as stepping beyond proper criticism in saying, that he thought those prices were too high, under almost any ordinary circumstances. The cost of the line was, in his opinion, much too high for a poor country,—for although India was extensive, still the people were poor,—and if railways were to be widely extended in that country, some means must be found of making them at a cheaper rate. He thought it probable, that those railways which had been the pioneers, had borne the brunt, and that it would be found possible now to introduce a better system, by which future lines could be laid down at less cost.

The Author had alluded to the difficulties in which he was placed, by the Contractor not being able to carry out his engagements, he being in consequence, compelled, to undertake the management, and to conduct the works himself. The question whether works should be carried out through the medium of Contractors, or not, had often been mooted at the Institution. Although Mr. Bruce himself had set an opposite example, in dispensing with a Contractor in India, he quite agreed with the Author, that the proper system, which should not be deviated from without good reason, was to let the work to a large Contractor, capable of thoroughly executing it, and thus to relieve the Engineer, to a great extent, of the burden of detail. There was nothing like division of labour when properly carried out, and where it was possible to submit work to a fair amount of competition, so as to secure fair prices for the Company.

There were some points of a general character in the Paper, which he thought called for remark. The Author stated, that the price of labour was fixed by the magistrate. Mr. Bruce's experience in such matters was, that the less recourse was had to the magistrate the better, and that the Engineer should fix the prices for everything. The magistrates had too much power, and though they exercised it efficiently in their own work, still it was a mistake to require of them more than to render the protection ordinarily and everywhere expected from magistrates. The Author had followed a system, which was very wise, that of endeavouring to train young people in India for the different trades, but the pay allowed them appeared to be high. From £3 to £8 per month was large pay for a youth learning his business. As to the sleepers, the Author stated that a large proportion of those which had been sent from this country were of creosoted red and white pine, and that they had generally failed. Mr. Bruce had been in the habit of sending out red pine, but as a general rule, he preferred using cast-iron sleepers in India; and he had no doubt it would be found, that those sent out upon Mr. Bidder's recommendation would be efficient and last well. It was, however, quite certain, that if wooden sleepers were sent out, they must be of the best kinds of wood; it was useless to trust to creosote for making good the deficiencies of the timber itself.

With regard to the question of water-way, he thought it would have been a better, a surer, and in the end, a more efficient and economical course, to have provided proper openings for carrying the water under, or through, than to allow it to run over the railway. Although there might be circumstances in this particular case of which he was not fully aware, which might justify the course adopted by the Author, he thought it was not a desirable system, or one which it would be safe to follow to any extent.

Mr. Bruce cordially agreed with the remark at the end of the Paper, as to the necessity of taking care to send to a foreign country, men who were not only good mechanics, but also of good character. The main element for consideration in the men to be sent out, of whatever grade, should be character, because the natives looked up so much to Europeans, that if they were not men of steadiness and honesty, they obtained very little power, or control in India. That was a point which could not be too much insisted on in carrying out works of this description, in countries far removed from head-quarters.

Mr. G. BERKLEY remarked, that in a Paper submitted to the Institution in 1860, by his Brother, (the late Mr. James Berkley,) it was stated, that the prices paid in Western India for block in course, varied from 16*s*. to £1. 15*s*. per yard.[10] It was, therefore, evident that circumstances varied considerably, and that it was extremely difficult to fix upon any average by which to compare prices in two districts, where the conditions might be entirely different. In the same Paper, the price of earthwork was stated to be much lower than in the present case; but it should be remembered, that the lead was only a quarter of a mile, whereas on the Scinde Railway it might have been longer, and thus the prices might be a fair representation of the circumstances under which the Author had been working.

He would refer to the subject of the improvement of the port of Kurrachee, merely with the view of drawing attention to what appeared to be one of the most important objects in these undertakings, the means adopted for loading and shipping goods at the termini of the various railways. On the Scinde Railway the appreciation of its importance was

[10] Vide Minutes of Proceedings Inst. C.E., vol. xix., p. 609.

demonstrated by the early consideration it met with, and by the execution of efficient works at the seaboard terminus. At Bombay there was a first-rate harbour, and although, for many years past, several plans had been suggested, he had not yet heard of any practical step having been taken towards effecting the improvement so much required. Station accommodation at the Bombay Terminus of the Great Indian Peninsula Railway was also a subject the consideration of which had occupied much time.

With regard to creosoted sleepers, he had found them liable to split when they arrived in India, and there was also an objection to them as cargo, on account of their inflammability and their liability to injure other goods. The same objection applied to carrying creosote itself.

He agreed with the remarks, as to the importance of sending out agents and work-people of good character: this was, however, a matter of considerable difficulty. The great desideratum was to find old heads on young shoulders; men prompt and practical, and at the same time, of tact and temper. The Engineers and others who had gone to India had, as a body, very creditably represented their countrymen; but it would be extreme good fortune always to obtain men with these remarkable characteristics combined.

Mr. W. A. BROOKS observed, that Kurrachee was, with the exception of Bombay, the only good harbour on the western coast of Hindostan. With reference to the statement in the Paper, that an improvement had taken place in the depth over the bar at Kurrachee since the Keamaree Pier had been carried out, it appeared from the chart, (Plate 2,) that the greatest available depth was only 15 feet, at low water of spring tides a depth which did not warrant the statement that any improvement had taken place; because the survey made in 1848-49 by Mr. Fenner, a master in the Indian Navy, and marine surveyor, gave the same depth, (15 feet,) which added to the 9 feet rise of tide, made 24 feet, as shown on the chart. In 1853 it was recorded, that the high water depth was 23 feet. In 1856, the late Mr. Walker reported, that at low water of spring tides the depth was from 9 feet to 12 feet; but in a Paper of Directions for approaching Kurrachee, dated January, 1860, the depth on the bar at high water of spring tides was stated to be, S.W. monsoon, between May and September, from 22 feet to 23½ feet.[11]

It was important to recollect, that at present the harbour of Kurrachee was almost a pure tidal receptacle, and that, therefore, any works which diminished that receptacle for the tide must have the effect of greatly injuring the harbour. Formerly, a large volume of the floods of the Indus passed into the harbour by the Lyaree Channel, but little came down now. He was desirous of directing the attention of the meeting to the contraction of the tidal flow presented by the works projected by the late Mr. Walker,

[11] Vide "The Engineer's Journal," July 1, 1861. Vol. iv., p. 132. Calcutta, 1861.

and now in progress; because there was, in his opinion, great danger that a noble harbour might be ruined. It was part of Mr. Walker's design to extend from Manora Point, a pier, on the eastern side of which, a shoal would most certainly be deposited, precisely similar to that now existing on the eastern side of the point. The construction of the pier, as proposed, must be followed by a proportionate extension of sand under the lee side, during the prevailing set of the current along the coast; the bar would be merely shifted a little farther out, and would overlap the Keamaree Pier, just as the bank, in its natural condition, overlapped it at present. This would always render it difficult for ships to enter the harbour when the wind was from the west-ward. It must be evident, that vessels trying to weather Keamaree Pier head, would be in constant danger either of falling upon it, or of being driven to leeward of the harbour.

In the Calcutta Engineers' Journal' for July and October 1861[12], there appeared an able Paper on Kurrachee Harbour, by Lieutenant A. D. Taylor of the Hydrographical Department of the Indian Navy, in which he recommended a pier to be made from the shore at Clifton, and, after passing over the Oyster Rocks, to terminate abreast of Manora Point, leaving a capacious entrance between the pier head and the point. Mr. Brooks stated, that he had given much attention to this subject, and that he considered Lieutenant Taylor's plan to be better adapted to improve the mouth of Kurrachee Harbour, and to augment the tidal receptacle, than the present works. Moreover, if the eastern pier were made to extend rather beyond Manora Point, the set of the prevailing current would be against its inner, or harbour face, and would act beneficially in maintaining good water on the bar.

Mr. PARKES said, that he had made the survey of the harbour of Kurrachee, and had assisted the late Mr. Walker in the design, but the work was being carried out entirely under the Public Works Department of the Bombay Government. He would however mention one fact to show the incorrectness of Mr. Brooks's conclusions. At the end of Manora Point the water was about 9 feet deep, in which depth the waves broke. In breaking, they lifted the sand from this shallow bottom, and rolled it forward into the stiller water immediately under the lee of the point. If the pier were carried out, its extremity would stand in a depth of 24 feet, and the waves would not break. There would, therefore, be no tendency to lift the sand, and, consequently, no tendency to form a bar there. He had been informed, that the groyne, which he believed had lately been completed along the Keamaree Spit, on the opposite side to the entrance, had already produced considerable effect upon the bar. The bar was in a transition state at present, and, therefore, all he could now say was, that the sand had been considerably moved. The navigable channel being circuitous would not, in its existing position, be much affected by the increased scour, but the top of the bar had been lowered to a great extent, and when the increased scour caused by the groyne had gone on a little longer, the bar would, no doubt, be reduced to a much greater extent, and a more direct and

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[12] Vide "The Engineer's Journal," vol. iv., pp. 132 and 186. Calcutta, 1861.

much deeper navigable channel would be formed. The immediate effect, though as yet incomplete, was very encouraging. Mr. Brooks had alluded to the importance of maintaining the tidal space within the harbour, but he had omitted to mention the fact, that by Mr. Walker's designs, probably about one-fifth would be added to the original area; the water covering the whole of the space to the eastward of the Napier Mole would be brought through the harbour, instead of escaping, as it now did, through Chinnee Creek. Mr. Parkes thought these few particulars might be interesting in connection with the sea terminus of the Scinde Railway, now under discussion, but he objected to having imported into it any abstract questions of the principles of harbour engineering, as applied to this particular case, to which the subject of the Paper was entirely foreign.

Mr. BROOKS observed, that he had not only offered an opinion, but he had also given the reasons upon which that opinion was based. Mr. Brooks desired to reply to the remarks relative to Kurrachee Harbour, but it was intimated that it was advisable to restrict the discussion to the Scinde Railway, which was the main subject of the paper.

Mr. G. P. BIDDER, Past-President, said, his observations upon the engineering questions would be confined to a few points. With respect to the plan adopted for the passage of the flood water over the Scinde Railway, he quite concurred in the views of the Author, which he believed to be practically and commercially right. It was easy to say, that it would have been more perfect to have constructed archways for the passage of the flood water, but the question was, at what cost could it have been done, and at present, there was no information, there were no facts, upon which to determine the extent of archway required. The only fact before the Meeting was, that the floods to be provided for were exceptional and local; the Engineer would thus be in the dilemma, either of having to construct an amount of archway altogether unnecessary, or such an amount as would be insufficient, and the effect of the inundation would be occasionally to stop the railway. He believed the smallest estimate of the cost for the provision of such an extent of archway as would be required, was about £70,000; and this enormous expense would be incurred merely to obviate the chance of two, or three stoppages of the line, in the course of eight, or ten years. He thought, that on such a railway as the one under discussion, it was better to save the outlay of £70,000, and put up with the occasional stoppage of the line. Perfection might be obtained at too high a cost. As to sleepers, that was still a question to be solved for India.

He had recommended cast-iron sleepers, on account of their success in other places. The Company were in a difficulty: the Contractors had failed to supply the wooden sleepers, and the employment of cast-iron sleepers was the only remedy that presented itself. Whether they would prove the best, or whether any other form of sleeper would be better, had still to be ascertained.

Mr. Brooks had raised an important and interesting question. Looking, on the one hand at the vast extent of India, and its prodigious population, and on the other, at the very few effective ports, and comparing it with Great Britain, with only a fifth of the population, but with ports on every part of the coast, the importance of the question was at once evident; in fact, he believed that no outlay, however large, would be misapplied which would tend towards perfecting the ports of India. Mr. Brooks had correctly stated, that the only two good ports were Bombay and Kurrachee; Madras was no port at all, and Calcutta was as bad as it could be; yet those were, at present, the only outlets for the vast trade of India.

The question to which he wished to direct attention was far more important than that of the engineering, or of the ports. It was as to the mode in which Indian railways were, in future, to be carried out and worked, and he believed that on that question would depend the future extension and success of railways in India. There was one great satisfaction in looking at the map of India, that the lines at present executed and in progress were in the right direction. The lines from Calcutta and Kurrachee, meeting at Delhi, with their eventual connection at Bombay, must be the permanent backbone of the railway system in that country; and if that system were completed, and if nothing more remained to be done, it would be unnecessary for him now to advert to the peculiar conditions which attached to the construction of Indian railways, and the difficulties under which they had been carried out. When the railways in India were projected, three financial systems were open for consideration. First, their being carried out by private enterprise; that broke down at once, because the capitalists of England were disinclined to take them up on their own account. Secondly, the method of subvention, which never was, he believed, seriously entertained. Thirdly, there was the system of guarantee, which had been ultimately adopted. Before further adverting to that system, he would remark, with a view to prevent misconstruction of what he was about to say, that he had no strictures to make upon the mode in which it had been administered, whatever imperfections might attach to the system itself. That it had been carried out with any degree of success was, he believed, greatly owing to the endeavours of all parties to make it work. Every one had gone, more or less, beyond strict routine, otherwise the railway system in India must long ago have collapsed. At present the railways in India were entirely carried out on a system, by which the Government guaranteed a certain rate of interest upon the outlay. The result was that the Government was liable for the interest on all the outlay, so that, in fact, they had to look to the receipts of the railways for the repayment of the liabilities thus incurred. The Government, therefore, felt it necessary to overlook the whole of this outlay, and for that purpose there was established a system of supervision, permeating into the greatest minutiæ. The consequence was, that all individual energy and all independent activity were restrained; and, as he said before, unless the authorities, particularly the official directors, so far as his experience went, had applied themselves very much to the oiling of the machinery, he thought it must very soon have stopped altogether. He trusted, therefore, that his remarks would be taken as applied to the system, and not to individuals, or to bodies of individuals, for he was bound to say that India was a field which brought out, in every respect, and in a most peculiar manner, the energies of the Anglo- Saxon race.

The whole political system of England, from the beginning of the establishment of her rule in India to the present time, had been, theoretically, the worst possible; and that glorious empire had been established by the individual energy of those who represented this country in India. This remark applied peculiarly to those who had been connected with the railways of India. The amount of work which the Directors, particularly the Chairmen, had gone through, was prodigious; the amount of correspondence was marvellous, and that they should have had the patience to drag through it, was, he was bound to say, perfectly astonishing. The question arose, whether it was desirable that the system should be changed, and whether so much yet remained to be done in India as to make it desirable that the reconsideration of the system of making and working railways in India should be seriously entertained. With regard to the extension of railways in India, the backbone of the system was still far from being completed; the line from Umritsir to Delhi, a length of 300 miles, remained yet to be accomplished. If the Indus had been a deep, quiet canal, the carrying of the railway system along that valley might for some years have been postponed; but the Indus was perhaps the worst specimen of inland navigation that could be conceived, and, as the Author had stated, the channels of navigation were 570 miles in length, as against 470 miles of direct route. Mr. Bidder had very carefully considered the question of the Indus Flotilla, and he was every day more satisfied, that the necessity of occupying the valley of the Indus with a railway was becoming more urgent. Even in regard, therefore, to that backbone, there were about a thousand miles of railway yet to be constructed. The question then arose as to the best mode in which it could be carried out, and the best system of working it, when completed.

He had already stated that the Government of India was liable for a given rate of interest upon the whole outlay for the railways; there was, therefore, a distinct interest in the receipts, and the same minute supervision was exercised in the working as in the construction of the lines. Before any comparatively unimportant step could be taken in the Punjaub, sanction had to be obtained from the Lieutenant-Governor of the Province, which he could not grant without reference to the Governor-General of India; and, in a similar way, the Commissioner of Scinde was powerless without the sanction of the Governor of Bombay. Then again requisitions, for manufactured railway material and for workmen, sanctioned by the officials he had referred to, had to be reviewed, commented upon, and indorsed by the Secretary of State for India in Council in London, before the most urgent want could be supplied. As regarded the construction, he was satisfied that the necessary restrictions which the system imposed caused a waste of time to the extent of 25 per cent., and at least an equal waste of money. But in the working the results would, he believed, be far more serious. How was it possible to work a railway efficiently, economically, and energetically, to develop the traffic, and adequately to meet the ever-varying demands of the public for accommodation, when a new foreman could not be appointed, nor his salary be fixed, without the manager undertaking a large amount of correspondence, involving duplicates and references to perhaps two or more jurisdictions, and a necessary delay of months. Take such a case as the London and North-Western Railway, and he asked could such a system be worked at all, if a correspondence begun in England had to be concluded in Calcutta, and passed through the Government Departments, before practical effect could be given to it. These departments, he fully admitted, were most anxious to do what was right and proper,—desirous even to go out of their way to give facilities; but still that channel must be gone through, and the result of such a system, whatever its effects might be upon the original construction, would be felt, in his opinion, much more seriously afterwards in the management and in the traffic arrangements.

To return to what he considered the system ought to be, and on which he spoke with some decision, from the experience he had had of its satisfactory working in another quarter. First, with regard to the construction of the railways, he thought that the Government should receive tenders from companies of capitalists for the completion and equipment of a line of railway, for example, between two given points, for a definite sum of money, and stating the amount of subvention they required from the Government, to be paid in cash, or by an equivalent. The character of the line as regarded materials, workmanship, and accommodation, being defined, the maximum rates of fares, the regulations connected with the public service, such as conveyance of troops, &c., being fixed, the total capital, the amount of subvention, and the approval of the railway by the Government on the completion of the same, being provided and stipulated for, the construction and the working should be left entirely to the management of the Company, who should take, as a first charge upon the net revenue, interest upon their portion of the capital up to an agreed amount, say 5 per cent., and the surplus revenue afterwards to be divided in agreed proportions between them and the Government. By so doing, all the energy of independent management would be brought to bear, and that management would work with the same responsibility and limitation as in this country. He believed that, upon that system alone, the full advantages of railway communication in India, or in any other country, would be realised.

He would, for the sake of illustration, assume a case, that of a railway up the Indus Valley, 500 miles in length, and that the reasonable cost, including equipment, was £10,000 per mile, or that a capital of £5,000,000 would be required. Of this he would suppose the Government to furnish £5,000 per mile, or two and a half millions of capital, either in cash, or by an equivalent guarantee; and as the Company would have to find the balance, and to satisfy the Government that the bargain had been efficiently carried out, there would be every possible responsibility thrown upon the executive, that all the money would be economically and judiciously applied. Then the working, subject to conditions with the Government similar to those he had indicated, should be conducted entirely by the Company, who should rely upon the receipts of the railway alone for a percentage upon their capital up to, say, 5 per cent.; and after that the net receipts should be divided, say two-thirds to the Government and one-third to the Company, as an inducement to the latter still farther to develop the traffic, and to work economically. This arrangement of course implied a proper audit of accounts for the satisfaction of the Government. He believed that it would be to the advantage of Government to apply this system of working to railways already opened for traffic, and to those now under construction; for instance, the lines from Kurrachee to Delhi, a length of from 600 to 700 miles, exclusive of the Indus Valley. For the privilege of working these lines, Government might receive, by tender, a contribution from a Company of say three or three and a half millions sterling, which would be more than adequate for the subvention of the Indus Valley line, which if carried out would complete a system of 1,100 miles, or thereabouts, from Kurrachee to Delhi, with a preferential capital of about five and a half millions sterling, with a preferential interest of 5 per cent., and a further contingent advantage from surplus net receipts. He was certain that the Government would get more profit under that system than under the present one, of taking the whole of the profits to meet the liabilities they had incurred, and they would have that contribution to apply to the extensions which might be made to this great backbone of railways throughout India; because though it was a poor country, mile for mile, yet when it was considered that there was one mile of railway in England for every 3,000 inhabitants, as against one mile of railway in India for every 50,000 inhabitants, it would at once be seen that, in India, the necessity for branches and extensions would grow in importance every year.

Looking to the rapid rate of increase of the trade of India, exhibited by the growth of the traffic on the Scinde Railway, in the face of the greatest possible hindrances to the transit of goods from the interior, he had the strongest possible conviction, that the application of individual skill and energy would realise a fair return upon all the capital which might be contributed, either by Government or by private capitalists, and concurrently, incalculable advantages would result to the trade of India generally.

He did not think that it was necessary to enlarge his observations on this subject. He had pointed out what occurred to him as the rational system to adopt, a system which, he believed, might be made to work very practically. It was the system on which the Norwegian Trunk Railway was carried out. Parties in England contributed one-half the capital, and the Government the other half. The English contractors took 5 per cent. preference, and the Norwegian Government took 4 per cent., and the surplus was equally divided. That system had been carried out without any difficulty, or contention whatever. He did not mean to say that those exact terms would apply to India; but a system which admitted of independent energy, and obviated the necessity of state interference in construction, and a restriction in all the arrangements by which alone railways could be effectually carried out, would, in his opinion, be found advantageous to that great empire, and economical to the Government.

Mr. J. BRUNTON, in reply, said an objection had been made, that the Paper did not contain a list of the prices of labour. Now it was expressly stated, that he abolished the day-work system almost entirely, and established a system of piece-work, because he was convinced that it was the only means by which he could get the work done at the lowest possible price. Had he given a list of the daily wages paid to the labourers, it would have led to erroneous conclusions, because some were paid 4 annas, and others 5 annas or 6 annas per day, and at those wages they did little, or no work. He did not think the prices of day-labour furnished so good a criterion as the price at which, for instance, a cubic yard of earthwork was excavated and carried a certain distance; it was the same with regard to masonry. With respect to the observations about the magistrates fixing the prices of labour, that was a misapprehension. The magistrates were only called upon to fix the prices at which the provision dealers should sell their flour and other articles for the consumption of the labourers on the works; they did not interfere in any way with the prices of labour. As to the amount of £3 per month paid to the apprentices for the first year, he had a great deal of correspondence in India upon that very subject, before those prices were fixed. He maintained it was absolutely necessary for the European boy in India, particularly if separated from his parents, or taken away from his guardians, that he should receive a pay that would enable him to keep himself independent of and superior to the natives. The amount of £3 per month would not, in India, be considered a high rate of pay to keep a youth of 15 or 16 years of age in a respectable position; and it was only respectable lads of good character that were admitted as apprentices in the Company's workshops. He was not surprised that £16,000 per mile should have been considered a high rate of cost. It would be so, undoubtedly, for a line of railway running through a very flat country, which was the character of the districts through which most of the lines of railway in India were carried; but a glance at the section of the line between Kurrachee and Kotree would convince any Engineer that it was not an easy one. There was a considerable amount of earthwork upon it; and the earthworks were not of the soft character usually found in alluvial plains. The majority of the excavations were through hard rock, requiring gunpowder; many of the embankments were formed from side cuttings in rock, as no softer material could be obtained, and the embankments were built up with the stone so quarried from the side cuttings. That, coupled with the fact that the line crossed the natural drainage of an extensive hilly district, and required large viaducts and many culverts and bridges, would account for the increased cost per mile. But, as the Chairman of the Company had remarked, the Scinde Railway might be considered as rather exceptional, because, for a short length, it had two expensive termini, and there had been a heavy charge upon the capital of the Company for wharves and other works for the accommodation of the flotilla at Kotree, where from 3,000 feet to 4,000 feet of wharves had been constructed.

Since the reading of the Paper, he had received a communication from General Goodwyn, of the Bengal Engineers, with regard to the Burnettising process of saturating sleepers with chloride of zinc. That gentleman had paid great attention to the subject in India, and had made the following report to the Government:—

"I have the honour to report, for the information of the Board, that I have this morning been engaged in the examination of the timbers, bamboos, and other articles that were subjected by me, in 1846, to immersion in chloride of zinc; the following is the result:—

"II. The hair and woollen articles from the arsenal appear to have been uninfluenced by the solution, and have rotted, whilst some portions of canvas have been attacked by white ants, though slightly. The greater part of the canvas is sound and untouched; the twine and small rope are sound and good; whilst all wooden articles have been entirely preserved—such as the handles of brushes, sieve rims, and fusees.

"III. The whole of the sâl timbers of various scantlings are quite sound, free from rot, or white ant; whilst one piece that has been buried in a fungus pit five years is as sound as on the day it was put in. The bamboos, a perishable material, are sound and strong in every way.

"IV. These timbers had been indiscriminately piled up in an open shed, where white ants abound, and exposed to alternate heat and moisture, where other timber has been destroyed in less time.

"V. The deal Memel, and even oak timbers, that were received from England in the same year, saturated by Mr.'s process, have all been attacked by white ants, some completely eaten. They were stacked in the same way, and in a similar shed.

"VI. The solution that my timbers were soaked in was chloride of zinc; the process patented by Sir William Burnett. It was the refuse liquid from the galvanic batteries in use at the Mint for refining of silver.

"VII. Major Baker and Mr. Turnbull, the senior Engineer of the Railway Department, were with me, (in fact, it was to show them that I scrutinised the whole), and they were satisfied of the efficacy of the process. I consider this to be so satisfactory, as to be worthy of communication to Government.

"I have, &c.
(Signed) H. GOODWYN.

"Fort William, "27th September, 1852."

General Goodwyn further stated, in a letter received that day, that since the above report was written he had been confirmed in the opinions he had expressed. This was of great importance; for if the native timber could be preserved by so simple a process as that of immersion in chloride of zinc, more of the woods of India could be used in future for sleepers. Mr. Brunton's experience did not extend over a sufficient time to enable him to form a conclusive judgment upon its preservative qualities; but he had applied it on his own line to sleepers, and to cills and door-frames, and hitherto the timber so prepared had not been attacked by white ants.

With regard to the water-way, and the novel mode he had adopted of lowering the line of railway from the low embankment on to the surface of the country, and laying the rails flush with the surface, he observed that he had done this almost from necessity; for the only alternative was the very expensive one of constructing a continuous series of culverts over the whole distance. Then it was to be remarked, that the rains in Scinde were different from the rains in other parts of India; Scinde, in that respect, must not be judged by the lower parts of Bengal, or Bombay. In Scinde the average fall of rain was about 5 inches, which, was very small; but it fell heavily, and in a short period, seldom extending over more than three days, for four, or five hours each day. Though the water passed slowly over the line, the traffic need not be stopped; and, in fact, it was not stopped during the last rainy season, although the water was 9 inches deep over the rails; after the water had passed away, which it did in the course of a few hours, the railway remained in as perfect condition as before. In cases of this kind, only good broken stone ballast should be used.