Mr. BRUCE said, there was nothing remarkable in the construction of the permanent way of the Madras Railway. It was laid with the ordinary double-headed rail, fixed in cast-iron chairs, with compressed keys and trenails, on cross timber-sleepers. It was a form of construction well understood in England, but in his opinion it was not the most suitable for India. This communication might prove valuable in eliciting the opinion of Members, as to the best form of permanent way for that country. In his opinion there should be as few parts as possible, and where wooden sleepers were used, he preferred, in many cases, the contractor's rail fixed directly to the cross sleepers. It was a simple form of road, and was more easily laid, than when cast-iron chairs were employed. The use of wood sleepers in India was, however, generally disadvantageous. He had found great difficulty in obtaining in Madras the right sort of wood for sleepers. About twenty-eight different kinds of timber were introduced, with the qualities of which it was almost impossible for a European to be acquainted. The consequence was, many woods were purchased with the reputation of a high quality; and probably before it was ascertained which was the most durable, a stock of inferior timber had been purchased. In one case, in order to deceive as to the quality, a very poor description of wood was steeped in tanks for a fortnight, or three weeks, to change its colour, and to make it look like a totally different article. Unless a perfectly good wood could be procured, the sleepers would not last long, and then the renewals would form a great source of expense. Where wood was expensive, he therefore preferred using Greaves' ordinary cast-iron sleepers, if the ballast was suitable. Although the first cost of the permanent way might be increased £300 or £400 per mile by the use of cast-iron sleepers, he believed, after thirty, or forty years, the saving would be found to be in favour of the cast-iron road. The arrangements should also be made with a view to guard against speculation, as well as to obtain the simplest and the best mechanical construction, for in India and in other similar countries, the natives were apt to steal the ordinary fishing-plates and bolts.

Mr. HAWKSHAW, *V.P.*, remarked, that the result of his experience went to show, that wooden sleepers were not readily obtainable in India. He had found it necessary to send out cast-iron sleepers for about one hundred miles of railway, and had adopted Greaves' sleepers, which answered very well. He was also sending to India thirty thousand creosoted pine sleepers. If an unlimited time was allowed for the construction of the works, a sufficient number of sleepers, of good quality, might perhaps be obtained in the country; but in order to insure the completion of the works within a moderate time, it was essential to send some sleepers from England. Under these circumstances, he did not think it was

possible to determine, upon one system to be hereafter rigidly adopted; for materials must be sent out to get the lines finished, within the required time. Where compressed keys, as happened in India, were exposed for a considerable length of time, before being used, the virtue of the compression was lost, the keys swelled, and would not fit the chairs, without being pared down. He had latterly concluded, therefore, as a trial, to send out, instead of compressed keys, long oaken keys of wedge form, which could be driven from time to time, as shrinkage took place. He did not however wish to condemn the use of compressed keys. In this country he employed them extensively. Where circumstances admitted of their being taken care of, and applied at the right time, they made excellent fastenings.

In Russia, on the Riga and Dunaburg Railway, where the works had to be constructed for a limited sum, he had recommended the use of the contractor's rail, laid on cross sleepers. This description of road was extensively adopted in Prussia, and with a light traffic it was perfectly successful. But it was a road which, above all others, required great care in laying and maintaining; and it was unsuitable for the heavy traffic of railways in England.

Mr. VALENTINE could confirm the statement, that the compressed keys were not suitable for hot climates. In Portugal, on the Lisbon and Santarem Railway, the compressed keys did not answer. He had, therefore, adopted an oaken key, 10 inches long, slightly tapered, so that as the wood shrank from the heat, the keys could be driven up. This plan had succeeded perfectly.

Mr. P. M. PARSONS stated, with regard to the shrinkage of wooden keys, in a climate like that of India, that he would suggest a remedy which had been found effective in this country. This was to use an iron key, in connection with a wooden cushion, so cut that the end grain of the wood sustained the pressure of the key. By this arrangement the requisite elasticity was retained, while the security of the fastening was unaffected by the state of the atmosphere, as the greatest heat would not cause any perceptible shrinkage in wood end-ways of the grain. The tests to which this fastening had been subjected in this country, had proved perfectly satisfactory; the hot weather during the last two unusually hot summers, not having affected them in the slightest degree. These chairs and fastenings were laid on the East Kent Railway, the Great Northern, the South Western, and other lines. The satisfactory manner in which they had stood the heat in England, made him feel confident, that they would prove efficacious in India, and other warm climates.

Mr. ALLEN RANSOME said, in reference to the alleged pre-

mature expansion of the compressed fastenings, before reaching their destination, in hot climates, his belief was, that it was not so much the necessary consequence of any defect in the keys themselves, as the natural result of the manner in which the packages containing them were abused. Since the railways in India had been in course of construction, upwards of twenty millions of these compressed fastenings had been supplied, or sufficient to lay about 2,200 miles of railway. Until within the last few weeks, he had heard no cause of complaint, that ought to stand as a reasonable objection to these fastenings. In the Paper the compressed keys were favourably spoken of, and they were said to answer very well, when protected by the ballast from the white ant, whilst the uncompressed keys were stated to get loose. He was aware, that with the amount of dry heat to which the keys were subjected, under an Indian sun, with iron on both sides, even the compressed keys would have a tendency to shrink, before they were saturated with moisture. Hence, it had been suggested by Mr. Rendel, that the keys should be made somewhat larger for use in India, than was usual in England, so as to admit of a still greater degree of compression. Since that had been done, he had heard of no complaint. These fastenings, having been compressed into four-fifths of their original bulk, must certainly be safer, than those cut simply from ordinary timber, which could have no other tendency than to shrink. With regard to the treatment to which the keys were subjected abroad, he had been informed, that for months after delivery, many hundreds of casks of keys had been left exposed on the wharves to the heat of the sun; the consequence was, that the staves of the casks opened, and admitted the rain, until the keys were thoroughly saturated. That they should expand under these circumstances was not to be wondered at; in fact, it was exactly what they were intended to do. It was clear, that no damage arose from this cause on the voyage, as the casks had been delivered in good condition; whereas if there had been any expansion of the keys within the cask, the casks would inevitably have burst before delivery. He had been told, that on the opened portion of the Madras Railway, the amount of waste, or loss from premature expansion of the keys was inappreciable. But everything that was good might be spoiled, and the better the article the more easily, sometimes, was it injured.

Mr. C. H. GREGORY remarked, that in studying the form of construction of permanent way generally, and for foreign countries particularly, it was desirable to aim at obtaining the smallest number of pieces, simplicity of parts, and the avoidance, as far as possible, of complicated fittings. He thought the ordinary chair and sleeper road, as adopted in this country, was not the best suited for India; because the large number of parts were so many sources of de-

rangement,—the chair being liable to move upon the sleepers, and the keys to shift in the chairs. The keys were also injuriously affected by the peculiar action of tropical climates. The form of construction adopted in Germany, and other continental countries, and also extensively used in the United States, was, he considered, more simple, and, so far, preferable. It consisted of a single-headed rail, with a sufficiently broad flange to prevent the sleeper being cut into by the working of the rail. The great objection to this system had hitherto been the want of a perfect joint; but the application of the 'fish' or the bracket-joint, appeared, to a great extent, to supply that desideratum. This road was well suited for tropical climates, more particularly where the rail bed was cut on the sleeper by a machine. There was one form of permanent way, invented by Mr. W. B. Adams, which had been tried on some portion of the Eastern Counties line, that in his opinion merited the attention of those who had charge of the construction of railways in tropical climates. In this plan the old fashioned double-headed rail was bolted between two pieces of 'quartering,' which, in the case alluded to, was a sleeper cut in half lengthways. He believed that was a step in the right direction, and that such a form of permanent way would be found advantageous both in England and abroad.

Mr. SINCLAIR said, in allusion to Mr. W. B. Adams' system of enabling the double-headed rail to be used without chairs, by suspending it between longitudinal timbers, cut out to fit the form of the rail, that a length of 150 yards of this permanent way had been laid for six months on the main Cambridge line, at Stratford, where the ballast was bad and the traffic was great. In this case, the timber used was simply ordinary cross-sleepers cut down the middle. At the joints, there were brackets of angle iron, fastened to transverse sleepers. Two wrought-iron ties were also employed in each rail length of 21 feet. This arrangement made a good road, and there was a perceptible difference, in passing on to it, from the other portions of the line.

Mr. SAMUEL thought, most Engineers having experience of the maintenance of railways would admit, that the question of the renewal of wooden sleepers was one of great importance. An examination of the accounts of railway expenditure of the United Kingdom showed, that the average cost of renewal, irrespective of ordinary maintenance, amounted, on lines in this country, to £100 per mile per annum. Of this amount about 37 per cent. was expended for the renewal of rails, leaving 63 per cent. as the cost of renewing the substructure. To reduce this, attention had been directed to the use of cast iron, in place of timber sleepers, which had been proposed and tried in many different forms. It was not necessary for him to give a detailed description of the various

plans, as they were generally known to those interested in the subject. The practical defects of the existing systems had also been frequently pointed out. He would, therefore, simply state the results of his own experience in the matter, and explain what he believed would be considered an improvement, and a remedy for many acknowledged imperfections. He had found, that all rails in contact with metal chairs became, more or less, indented on the lower table. This took place to such an extent, that the double-headed rail, first introduced by Mr. Locke, M.P., President, could not be reversed; and thus the great advantage that form possessed over all others could not be realized. A recent examination of the rails on part of the Great Northern line, showed the indentations to be considerable. As a precautionary measure, to prevent the indentation at any one time from being sufficiently great to render the rail useless, it was a common practice at the stations of some of the metropolitan lines, where there was great traffic, to reverse the rails every few months. To prevent this injury, and to avoid the expense incurred in endeavouring to remedy it, in 1850 he introduced a trough-sleeper, of cast-iron, in which the rail was suspended between linings, or cushions of timber, so that the lower table was prevented from coming in contact with metal. An experimental length, which was laid with sleepers of this description nine years ago, on the main line of the Eastern Counties Railway, was now in excellent condition. On the South-Eastern and on the Midland Railways, sleepers on this principle had been in use for more than two years. In the latter case, they were laid near to the Derby Station, where they were subject to a traffic of five hundred and fifty engines, two thousand four hundred waggons, and one hundred and twenty carriages every twenty-four hours. He had recently introduced a cast-iron sleeper, which, it would be seen, from the samples exhibited, was in form a modification of the 'cup' sleeper, introduced by Mr. Greaves, and the 'trough' sleeper, and it had therefore been called the 'cup-trough' sleeper. The chair was entirely dispensed with, so that there were no projecting parts liable to fracture. This was of great importance, as a large proportion of the iron sleepers, with chairs cast upon them, which had been shipped to India, were found, on their arrival, to be broken and unfit for use. This form of sleeper was inexpensive in manufacture, and was applicable to any ordinary section of rail, without alteration of pattern. The maintenance of the way would be a simple operation, as there were dormer-holes in the sides of the sleepers, through which the ballast could be packed, with much greater facility than through holes at the top. For shipment, they could be stowed into one another, each sleeper not taking up more than one-third of its own

height when they were piled together. Accuracy in the gauge of the line and in the inclination of the rails was of the greatest importance. This could be effectually secured by using tie-rods, at intervals of six feet, passed through the neutral axis of the rails, with square washers, of unequal thickness, placed in the side channels of the rails. As to the commercial question, the first cost of a substructure on this system would amount to about £910 per mile of single way;¹ while that of an ordinary cross-sleeper and chair road, with sleepers at four shillings each and chairs at £4. 10s. per ton, would be £551. He contended that the timber sleepers would require to be renewed twice in twenty-one years. It was very natural, that there should be a difference of opinion as to their durability, as within his own experience he had known some sleepers to last only five years, while others were quite sound ten years after they were laid. It was, however, beyond all doubt, that even if the sleepers were rendered chemically durable, either by Mr. Bethell's process of creosoting, or by the well-known process of Dr. Boucherie, of both of which he had the highest opinion, the destruction of timber sleepers, from the incessant blows to which they were subjected, by the heavy traffic continually passing over them, rendered their duration, under the most favourable conditions, comparatively limited. When the time for the renewal arrived, the timber was valueless, while the iron sleeper retained, even if broken, two-thirds of its original value; but the probability was, that for all practical purposes, the iron sleepers would then be as good as when first laid down. The oxidation of cast iron would be trifling, if the sleepers whilst hot were immersed in boiled oil. He had taken up for examination cast-iron sleepers laid down eighteen years ago, on the Llanelly Railway, by Mr. Bid-dulph, and had found them quite as good, for use, as when new. The following detailed calculation of the comparative cost of the substructure, on the two systems, showed a saving of £1,058 per mile, of single way, in a period of twenty-one years, after allowing for interest on the original outlay, in both cases.

¹ Since the date of this discussion, tenders are stated to have been made by eminent firms, for the supply of the 'cup-trough' sleepers, with keys, tie-rods, and fastenings complete, at prices ranging from £600 to £710 per mile of single way; which prices were not much in excess of the first cost of the substructure of an ordinary transverse wooden sleeper and chair road at the present time.—
EDITOR.

COMPARATIVE COST OF THE SUBSTRUCTURE FOR A SINGLE LINE OF WAY, OF A 'CUP-TROUGH' SLEEPER ROAD, AND TIMBER CROSS-SLEEPER ROAD, FOR A PERIOD OF TWENTY-ONE YEARS.

'CUP-TROUGH' SLEEPER ROAD.

No.	T. C. Q.	£. s. d.	£. s. d.
3,520 'Cup-Trough' Sleepers	133 11 1 at 4 17 0	647 15 6	
7,040 Wood-linings or Keys	.. 0 0 3	88 0 0	
880 1-inch Tie-bars	5 18 0 „ 15 0 0	88 10 0	
3,520 Nuts	1 0 2 „ 25 0 0	25 12 6	
3,520 Washers	1 6 3 „ 15 0 0	20 1 3	
3,520 Clips to Sleepers	1 3 0 „ 15 0 0	17 5 0	
3,520 Bolts and Nuts to do.	0 19 0 „ 25 0 0	23 15 0	
			£ 910 19 3
Interest at 5% for 21 years			956 10 3
Wood-linings renewed once in that time			88 0 0
Interest at 5% for 10½ years			46 4 0
			£2,001 13 6
Deduct ⅔ value of metal			548 12 10
Total outlay for 21 years			£1,453 0 8

TIMBER CROSS-SLEEPER ROAD, RENEWED TWICE IN TWENTY-ONE YEARS.

No.	T. C. Q.	£. s. d.	£. s. d.
1,760 Timber Sleepers	.. at 0 4 0	352 0 0	
3,520 Chairs at 21½ lbs. each	33 8 0 „ 4 10 0	150 6 0	
3,520 Keys	Per thousand „ 5 10 0	20 10 6	
7,100 Treenails	Ditto „ 4 0 0	28 8 0	
			£ 551 4 6
Interest at 5% for 21 years			578 15 9
Cost of first renewal			551 4 6
Interest at 5% for 14 years			385 17 6
Cost of second renewal			551 4 6
Interest at 5% for 7 years			192 18 9
			£2,811 5 6
Deduct ⅔ value of metal			300 12 0
Total outlay for 21 years			2,510 13 6
Deduct total outlay of 'Cup-trough' Sleeper road			1,453 0 8
Balance in favour of iron road			£1,057 12 10

Mr. Samuel believed that the value of the double-headed rail had yet to be fully appreciated; and in India and other countries, where neither machinery nor labour existed for re-rolling the wrought-iron rails when worn out, it was peculiarly important to adopt that form, in preference to rails having only one wearing surface.

Mr. BETHELL said, the question arising out of this Paper, which was one of great importance, was whether it was desirable to construct the permanent way of railways in India, with creosoted wooden sleepers, or with cast-iron sleepers. It had been asserted,

that a wooden-sleeper road required to be renewed once in ten years, or twice in twenty, or twenty-one years. Upon that point Mr. Bethell joined issue, and he would say, that if wooden sleepers were properly creosoted, it would not be necessary to replace them in anything like that time. He would refer to the two places where the creosoted sleepers had been first used, to prove their durability, which had already extended to upwards of nineteen years. About seventeen miles of the railway from Manchester to Crewe were laid in 1840, by direction of Mr. R. Stephenson, M.P., with creosoted American fir sleepers, every one of which remained sound to the present day. Two years ago, on the line being relaid with heavier rails, the old creosoted sleepers, which had then been in wear upwards of sixteen years, were found to be in such a perfect condition, that they were used over again instead of new sleepers. On the Eastern Counties Railway, one thousand common Scotch fir creosoted sleepers were laid down in May, 1841, also by direction of Mr. Stephenson, on different parts of the line, in order to test the value of the process. The result of that experiment was, that nearly eight hundred of those sleepers were now as sound and as good as when first placed in the road. He exhibited a specimen of one of these sleepers in confirmation of this remark. The remaining two hundred had been removed, not on account of decay, but owing to breakages, and the wearing out which was occasioned by the chair sinking into the wood. He had lately been informed, by the Secretary of the East Indian Railway Company, that reports had been received from the Resident Engineers in India, stating that the sleepers on that line which had been properly creosoted were quite perfect, and there was every probability that they would remain so; whilst others, of triangular shape, which had not been so carefully prepared, already exhibited symptoms of decay. Since the original patent had expired, there had been a great deal of competition in the creosoting trade, and the consequence was, that in many cases the process of creosoting had not been effectually performed. Upon this point he would make one other remark. There was a general desire amongst Engineers to have sleepers which contained heart wood only, and all the young and sappy wood was required to be cut off. Now it was not possible to get heart wood to absorb the quantity of creosote oil that was necessary to preserve it thoroughly. He had more than once stated at the Institution, that the best timber for creosoting was young wood, which had a good deal of the alburnum, or sap wood upon it; because the pores of the wood were open, and would absorb a great quantity of the creosote oil. The effect of the process was, that after the lapse of years, and when the more volatile parts had evaporated, the oil solidified, and set into a solid, bituminous matter, like pitch, or asphalt, or like

an Egyptian mummy, from which he had taken the original idea of this process of preserving wood. A difference of opinion existed, whether it was desirable to use young wood, the pores of which would become thoroughly filled with this bituminous matter, or heart wood, into the pores of which only the thin and volatile portions of the oil, which were liable quickly to evaporate in a hot climate, would enter. At the present moment he was preparing a large quantity of sleepers for the East Indian Railway, by direction of Mr. Meadows Rendel. These sleepers were to absorb 10 lbs. of oil per cubic foot. Each sleeper was weighed previously to being placed in the creosoting cylinder, and again upon being taken out. The sleepers remained in the cylinder for twenty-four hours, under a pressure of 130 lbs. to the inch, in order to force that quantity of oil into the pores. He directed attention to pieces cut from these sleepers, one 5 feet from the end, in order to show how the wood had taken up the oil. Upon that subject he must repeat, what he had often said before, that Railway Companies did not pay so much attention to the quality of the wood to be used for sleepers, as that employed for houses and carriages. Timber intended to be converted into sleepers ought to be stacked and dried six, or eight months before being creosoted. But instead of enforcing such precautions, the contractors who offered to deliver the sleepers soonest obtained the contract. The timber was always kept in the water at Dantzic, and yet in the cases alluded to, it was imported and immediately sent to be creosoted, so that there was little chance of its being properly done. No one would think of building a house with deals just imported, before they had been stacked and seasoned, but sleepers were frequently used in that state. The durability of the creosoted sleepers having been, he thought, incontestably proved, the question simply resolved itself into the relative annual expense caused by the breakages, and the original cost of the substructure on the two systems, whether laid with creosoted wooden sleepers, or with cast-iron sleepers. His impression was, that the first cost of the latter would be found to exceed that of a line laid with creosoted wooden sleepers. He was not, however, in a position to state the cost of the iron road, but he could tell exactly the cost of the creosoted sleeper road. The creosoted sleepers now being supplied to the East Indian Railway Company were delivered to the ship in London at a cost of under eighteenpence per cubic foot. The sleepers varied in size, but on an average they were 10 feet long, and 10 inches by 5 inches in section, or half square, so that there would be $3\frac{1}{2}$ cubic feet of timber in each sleeper. The freight to Calcutta amounted to from 25s. to 28s. per ton, bringing up the cost of each sleeper delivered at Calcutta to about seven shillings and threepence.

The cost of the materials, for the substructure of one mile of railway, delivered at Calcutta, might be thus stated :—

			£.	s.	d.
1,760	creosoted sleepers	at 7s. 3d. each	.	638	0 0
40	tons of cast-iron chairs	at £7. 10s. per ton	.	300	0 0
3,250	keys	at £5 per thousand	.	17	12 0
3½	tons of spikes	at £17. 10s. per ton	.	61	5 0
			<hr/>		
			£1,016 17 0		

With regard to harbour work, piles containing a large proportion of young wood became, when submitted to the creosoting process, saturated to a depth of 2 or 3 inches all round, so that no marine worm could reach the heart of the pile. When piles were cut into after being creosoted, so as to expose the heart wood, naturally the worms would attack it; but their ravages would not extend to the creosoted portion, as the poisonous nature of that material completely stopped them. It had been proved, that Kyanizing, with corrosive sublimate, had no effect in resisting the worm. When the poisonous corrosive sublimate became combined with the sap of the wood, it formed a substance which was no longer poisonous, and could be eaten by the worms with impunity. That, however, was not the case with the combination of the oil of creosote and the albuminous, or sappy portion of the wood, as the substance thus produced still remained a deadly poison, and could not be eaten by any worm, or insect.

Mr. HAWKSHAW, *V.P.*, could not subscribe to the principle, that in order to get good creosoted sleepers, wood of the lowest quality, closely approaching to the nature of sponge, must be selected; though, no doubt, such wood would absorb the largest quantity of oil. He had full belief in the value of the process of creosoting, and he was using it extensively, at the present time, both for sleepers for India and for this country, and also for timber to be employed in marine works. He adopted the process, because he thought it the best of the kind; but he had not such faith in it, as to have arrived at the conclusion, that young timber, full of sap, might be used in preference to good heart timber. He had always found the best results, when the greatest care was taken in the selection of the timber. There was some timber still in existence, St. John's yellow pine, which he laid down twenty years ago, part of which was Kyanized, but some portion was wholly unprepared; yet that timber had been equally durable in both cases. The Kyanized timber was merely steeped, and wood so treated was not impregnated to the depth of more than the tenth of an inch. He attributed the duration of that timber, mainly, to the care bestowed in its selection. This fact went to

prove, that if pains were taken to secure the best quality of timber, great reliance might be placed upon it, and a good result might almost be insured.

Mr. SINCLAIR produced several specimens of creosoted, Burnettized, and unprepared sleepers, all taken from the same district of the Eastern Counties Railway, and all of which had been in the ground about eighteen years. He did not mean to say, that these sleepers were laid side by side, but they were all within a few miles of each other, and were exposed to precisely similar conditions, as to ballast, &c. It would be noticed that all the specimens were in an equally good state of preservation. It was true that they had all been laid in particularly good ballast, which was never perfectly dry, but in which the sleeper was always wet. He had taken great pains to ascertain the truth of these facts, before stating them, and he felt assured of their correctness. His object was not to depreciate either the creosoting, or the Burnettizing processes, both of which, particularly the latter, he thought very highly of as preservatives, but to show that much more extended experience was required, before an opinion could be formed of their comparative merits, and their relative superiority over unprepared timber. He also called attention to some specimens of unprepared Scotch fir sleepers, which had been laid in the old road of the Eastern Counties line, between Stratford and Romford, not very far from those before alluded to, and which had been in the road two, or three years longer, or upwards of twenty-one years. There were many thousands of these sleepers still in the road in excellent preservation. As far as he was able to ascertain, the proportion of decayed and damaged sleepers was nearly the same in all cases. Of course, he did not mean to say, that the unprepared sleepers would, in ordinary cases, last so long as those which had been prepared; but he believed it was possible to have Scotch fir sleepers remain sound for twenty years without preparation.

In reference to the ravages of the sea-worm, the conclusion he had arrived at, from his experience at the Lowestoft Harbour, was that creosoting the piles was an effectual preservative. It was true that some of the timber piles, in that harbour, had been seriously injured, and in several instances ruined; but that occurred in places where the creosoted portions had been cut through, in order to permit the braces to be fastened to the piles; or it might have been owing to the timber not having been properly creosoted in the first instance. In some cases the worm had got in, and hollowed out the piles almost like pipes. Those piles which had not been cut were quite sound, and had no appearance of having been attacked by the worms.

Mr. BIDDER, *V.P.*, agreed in the statement relative to the piles
[1858-59. N.S.] 2 F

at Lowestoft Harbour. That work was hurriedly constructed, and probably much green timber, which could not be properly creosoted, had been used. In some cases, where the piles had been undisturbed, they stood very well; but wherever the surface of the wood had been cut away, and access was obtained to the heart wood, the worm attacked it. With regard to the sleepers alluded to, he could state from his own knowledge, that Sir W. Burnett's process was not applied at all, on that portion of the Northern and Eastern Railway, which he had constructed twenty years ago. He was the more positive on this point, because he had great difficulty in persuading the Directors to allow any preservative process to be tried. It was also a fact, that, whatever the quality of the ballast in which they were laid, the old sleepers had been relaid three, or four times, once within the last five, or six years, whilst the creosoted sleepers were still in the same state as when first laid.

Mr. SINCLAIR explained that the Burnettized sleeper was taken from about two hundred others, similarly prepared, which had been laid opposite the church at Roydon. Their appearance was very different from the sleepers in that vicinity generally.

Mr. BIDDER, *V.P.*, was positive the Burnettized sleepers were not laid at the same time that the creosoted sleepers were put down. But leaving that matter, he would turn to the subject of the Paper. He had long thought that the right principle had not been adopted for the permanent way of railways in India. Quality should be the first consideration, as the freight and land carriage of heavy articles increased the expense enormously. In this view he believed, that rails weighing 60 lbs. to the yard, to which an extra hammering had been given, would answer well for a line where high speeds were not required, and would be attended with economy. The comparative cost of a wooden-sleeper road and of a cast-iron-sleeper road would, in all cases, depend upon circumstances. For Egypt and other similar localities, Greaves' cast-iron sleeper was preferable to creosoted, or other wooden sleepers, and was best adapted to the soil and climate. There was no ballast, in the ordinary acceptation of the term, only a little silt, and it would be difficult to get a foundation for an ordinary sleeper; whereas by burying Greaves' cast-iron sleepers a sufficient depth in the ground, a firm bearing was obtained. He could not but express surprise, that a modification of Greaves' sleeper should be introduced with a patent attached to it. Although there might be no legal limit to patents, yet he thought there ought to be some moral limit to them. People ought not to be entitled to take out a patent for a simple modification of a mechanical contrivance. A vast amount of information was derived from the knowledge and experience of those who had gone before, and the

existing generation ought to be ready and willing to contribute to the general stock of professional knowledge and practical skill, without trammelling every trifling modification with a patent right. He was induced to make this remark because there were many obstructive, but still in his belief unsound patents, connected particularly with the permanent way of railways, which were held by Engineers, who, he thought, as professional men having to judge of the merits of various systems, and their applicability under different circumstances, should not be commercially interested in any of these articles.

Mr. GREAVES had made a calculation of the cost per mile of single way, when surface-packed, cast-iron sleepers, weighing 80 lbs. each, laid 3 feet apart, were used, and when ordinary creosoted sleepers, placed at the same intervals, were employed. He found that the cost of the substructure, on the former system, amounted to £726, and on the latter to £770; the weight of the materials being 146 tons and 155 tons respectively. But, inasmuch as the rails had a greater length of bearing, at each support, on the first plan, he considered a lighter rail might be adopted, say 65 lbs. instead of 75 lbs. per yard. Under these conditions, the gross cost per mile of single line would be £1,441 and £1,595 respectively; the total weight of the materials being 248 tons in the one case and 273 tons in the other. With respect to the durability of the sleepers on the Manchester and Crewe line, he thought that was hardly a fair case to cite, for not one per cent. of the lines in England were laid in such good ballast—fine sand—and if any rain fell, it drained off very rapidly.

Mr. BETHELL said, timber sleepers lasted longer in wet ballast, dry situations being the worst for their preservation. On the Eastern Counties line, the creosoted sleepers, one thousand in number, previously alluded to, were laid in five different positions—some being in wet and others in dry situations; but the result was the same in all cases.

Mr. BRUNLEES stated, in reference to the duration of sleepers, that, in 1840, when he was the Resident Engineer on the Bolton and Preston Railway, Mr. Adie, who was the Principal Engineer, laid the greater part of that line on longitudinal sleepers. The timber used was yellow pine, which was kept boiling in a saturated solution of arsenic, for two hours, under a pressure, put on by a force pump, of 150 lbs. to the square inch. The cost of the process, including the tank and the pumps, was about twopence per cubic foot. In 1853, a considerable portion of the line was relaid with new rails, when it was found, that many of the longitudinals had split at the ends. This was partly owing to the light rail used, 52 lbs. per yard, and partly to the unequal packing under the sleepers. The ends were cut off, and

the whole parts of the timber were converted into cross sleepers. These sleepers, with a length of $6\frac{1}{2}$ miles of the original longitudinal timbers, on which a new and heavier rail had been laid, were now as sound as when first laid down. The whole of the timber was well seasoned and had been carefully selected, at Liverpool. This, together with the fact of the sleepers being laid in thoroughly well-drained ballast, had no doubt materially assisted the conservative powers of the arsenic.

Mr. EDWARD BLYTH thought it had been overlooked, in the remarks which had been made, as to the relative applicability of hard and soft woods for creosoting, that the process would not alter the character of the wood. In his opinion good, sound, larch was preferable to Scotch fir creosoted, and he believed sleepers of the former timber would make a better roadway. On the North British Railway, it had been necessary to remove a number of Scotch fir sleepers, on account of the spikes having lost their hold, owing to the oscillation of the trains. On curves the train pressed uniformly without oscillation, but upon straight lines the oscillation was very considerable.

Mr. DAVID STEVENSON had used creosoted timber, in marine works, to a considerable extent. Where the outer, or creosoted portion was from any cause removed, the timber was readily attacked by the worm. He was so impressed with this fact, that he invariably had the timber creosoted after it was cut for the work, and in no case ought timber to be cut after it was creosoted. Until quite lately, he was under the impression, that there was no instance of the worm attacking wood that was blackened by creosote, as he had seen numerous specimens in which the creosoted portion of the timber was not touched. Recently he had received a specimen of Memel timber, from Scrabster Harbour, in Caithness-shire, which undoubtedly proved, that the blackened, or creosoted outer surface of the timber was attacked by the worm. It was the first case of the kind that had come under his observation, and it might be of importance to state it. He had reason several years previously to remark, that the ravages of the worm at that place were more rapid than he had ever witnessed before. The timber had been placed in position in November, 1857. It had been creosoted after it was cut for the work, and it was specified that it should receive 10 lbs. of oil per cubic foot. Careful inspection, after the timber was creosoted, seemed to show, that it was apparently properly prepared. The ends and outer coating of the timber were believed to have been thoroughly impregnated. On the pile being cut, it was found that creosote had penetrated into the timber 14 inches, or 15 inches from the end, and fully 1 inch from the sides. The worm had not entered the timber at an end which had been cross cut, and

was not creosoted afterwards, or at a damaged part of the outer surface, but from the creosoted side, and the ravages of the worm were very distinct in the blackened wood. Mr. Stevenson hoped the remarks he had made would not be regarded as unfavourable to the process of creosoting. He considered it a valuable preservative of timber, and he quite agreed that the process, in many situations, added considerably to the duration of the timber. But that, he apprehended, was not the only question with which they, as Engineers, had to deal. There were some places where the ravages of the worm were much greater than in others. He believed that creosoted timber, when exposed to the worm, would last, in many cases, for six, or eight years, and in others the process might be regarded as a specific. The only new fact he desired to draw attention to was, that the blackened, or creosoted portion of the timber was actually eaten by the worm, a circumstance that had never before come under his notice.

Mr. MICHAEL SCOTT remarked, that the discoloration of the wood did not, necessarily, indicate that it had been properly creosoted. Indeed it might be the reverse. It was possible to have a dark colour, for a considerable depth, and yet the timber would be open, he believed, to the attack of the worm. It would be desirable to ascertain, whether, in the instance brought forward, the wood was sound previous to being creosoted. He had known many instances, in which the timber had been attacked, before it was creosoted. There was hardly a log from Memel, which had been long in the water, that was not, more, or less, affected by one, or other of the worms.

Mr. A. M. RENDEL mentioned, that he also had found the worm in the piles and timbers at the end of the pier at Leith. That timber was creosoted under the direction of the late Mr. Rendel, in the most careful manner, and was built into the pier about eight years since. He was sorry to say, he was now compelled to commence its repair. From the duration of unprepared timber at the same place, he believed that the process of creosoting might be said to more than double the life of the timber. The creosoted sleepers originally sent out to India were triangular in section, and from this cause, and perhaps from their not being thoroughly impregnated, they had not quite confirmed all the statements that had been made. But those now forwarded were rectangular, and as they received a minimum of 9 lbs., and an average of 11 lbs. of creosote per foot, he expected a better result.

Mr. ROBERT RAWLINSON mentioned, that during the time he was connected with the Bridgewater Trust, the best yellow pine was used for the decks of steamers, above the boilers, as it was found to stand better than the red pine.

Mr. T. E. HARRISON remarked, that the entrance gates of the Monkwearmouth docks at Sunderland, which had been constructed of yellow pine creosoted twenty years ago by Mr. Brunel, were quite sound; but portions of Kyanized timber used in the same works had been attacked by the worm to a considerable extent.

Mr. ABERNETHY said, his experience in marine works, particularly during the last four years, both on the east and the west coasts of Great Britain, induced him to believe that thoroughly creosoted timber perfectly resisted the ravages of the worm, which made no impression upon it. At the same time, he quite agreed in the opinion, that the quality of the timber should receive careful consideration. The fact which had been stated, in reference to Scrabster Harbour, was very important, and it was advisable that the quality of the creosote oil used in that instance, as well as the quality of the wood itself, should be carefully investigated; for if these matters were not properly attended to, it could hardly be expected that the timber would be able to withstand the attacks of the worm.

Mr. HENRY MAUDSLAY said, the beneficial effects of the process of creosoting seemed to be generally admitted, but such a variety of opinions had been advanced, as to the results obtained in different cases, the depth to which the liquid might be expected to enter the wood, and the unequal period of duration of the timber so acted upon, that he thought it would be interesting, if an account was given of the most successful method of creosoting, as now adopted.

He believed a Paper was read at the Institution¹, some years ago, describing the process then in use; but he imagined that some improvements might have been made in the interval, as it was evident from the very different results which had been spoken to, that the same, or the best-known method, could not have been practised in all cases. A difference of opinion also appeared to prevail, as to whether sappy timber, or that which had been desiccated, was the best adapted for taking the creosote oil. Information upon that point, and upon the best method of desiccating the timber, would likewise be valuable. It had been stated, that porous timber was the best, because it absorbed more liquid than when the timber was hard, and that some engineers inserted in their specifications a clause to the effect, that it should absorb a certain defined quantity of creosote oil as a minimum. If that was the case, then dried timber would surely absorb more liquid than that in which the pores were already filled with water. He therefore suggested, that the tank in which the timber was placed might first be filled with high-pressure steam, and then a current

¹ *Vide Minutes of Proceedings, Inst. C. E.*, vol. xii., p. 206.

of hot air be driven through it, and pumped out before the liquid was admitted. This plan had been found to be very beneficial for other sorts of pickling, which was really what was wanted in the act of creosoting timber.

Capt. W. S. MOORSOM was surprised to hear that granite had been used for blocks, upon the Madras Railway. From the general configuration of the country, he had been led to believe it was not a description of granite that could be depended upon, and partook rather of the character of soft gneiss, than of granite. He agreed in the opinion, that the characteristics of a locality must have a great deal to do in deciding the description of permanent way to be adopted. For example, in Egypt there was a peculiarly light ballast, except in the desert, and there were seldom, if ever, any heavy rains to disturb it. No timber grew in that part of the country, and therefore the iron supports adopted there seemed judicious. He also concurred, to a great extent, in what had been said as to, the desirableness of selecting that form which, while being simple in itself, had the fewest number of parts; but he did not, on that account, concur in the conclusion, that the system which had been adverted to as having been tried on the Eastern Counties, the double-headed rail bolted between longitudinal timbers, was the best for tropical climates. In countries where there were immense jungles, there was great risk of the easily removable portions of a permanent way being taken out and stolen by the natives, and in this respect he thought that model of permanent way objectionable. The point to which he wished more particularly to allude was, that most of those who had spoken on this subject did not lay sufficient stress upon the importance of utilizing, as far as possible, the resources of the country in which the works were being carried on. So many elaborate opinions had been advanced upon matters wholly unconnected with the tropics, that he thought it would be useful to bring back the discussion to the subject of the construction of railways in those countries. He believed, that under proper arrangements, there was no necessity to prepare the permanent way timber in this country and to send it out to great distances. Those countries would supply all the timber that was required for railway purposes; and the Ceylon Railway, the line of which he had laid out for Government, came under this category. He had no hesitation in saying, that the resources of that island, with reference to the supply of railway material, might be made available to a much greater extent than had yet been done. There were forests of almost interminable extent; and the cultivated land appeared only in little patches here and there, amid hundreds of square miles of forest. It would, therefore, occur to Engineers, that those forests must abound in timber of a quality adapted for railway purposes.

He had personally inspected eighteen different samples, of which nine at least were superior woods for railway sleepers, in situations where they would be exposed to extreme variations of atmosphere and weather. The 'cohambe' was a wood containing a bitter oil, which rendered it impervious to the attacks of any insect. There were two other woods, the 'theet kha' and the 'mee,' the former possessing "great durability, and both were known to be impervious to the attacks of the teredo. The 'weberiyē' was used for marine works, but would not stand exposure to the sun. The 'mendoran' was used in the works of jetties round the coast. The 'dambe' was an excellent wood for the masts and spars of ships, the trees growing to a height of from eighty feet to ninety feet without any branch; and they also formed the most magnificent scaffolding-poles he had ever seen. These various descriptions of timber were offered to him by three native headmen, who employed elephants for the transport of the timber, and contracts were also offered by four European gentlemen, some of whom went from this country as engineers, and likewise by contractors and merchants on the Malabar Coast and at Colombo. He had understood upon inquiry, that there were immense quantities of teak, which could be delivered at the port for 40 rupees per ton. With regard to the cost of carriage, timber was carried up mountains 3,000 feet or 4,000 feet above the level of the sea, for fivepence per ton per mile, and the down-country carriage was threepence-halfpenny per ton per mile; and for an average of ten, or fifteen miles, the carriage was sixpence per ton per mile. The average load of a hackory, or 'bandy,' was twenty-one cwt. down country, and fifteen cwt. up country. There were thirty-one different descriptions of wood offered to him from Madras, thirteen of which had been proved to be excellent wood for sleepers.

The drainage of railways in tropical climates was a matter of the utmost importance. The soil was mostly of a character that, with a little care, would enable this to be done; but the sleepers must be looked upon as lying in a dry soil, and the ballast was liable to be carried away by the heavy periodical rains. On the Ceylon Railway, he had estimated that there should be as many as forty culverts per mile, with the view of keeping the line and works dry. The ballast was excellent, in fact, superior to any he had seen in this country, with the exception of that used on the West Cornwall Railway, which was what was called 'mine sand.' In his opinion, the reason why the resources of India and other tropical countries had not been more used for railway purposes, was owing to the harassing supervision of the Government (so-called) Engineers. He thought that supervision ought to be confined to the auditing of the expenditure; and that those persons

who had no practical acquaintance with the subject should not be allowed to determine the weight of the rails, the nature of the bearings, and every other point in detail. Such a system, both in principle and in practice, was highly reprehensible, as it cramped the genius and energy of the practical Engineers sent out from this country, led to the serious delays which had been notorious in the execution of Indian railways, and induced an expenditure much beyond that which a better system would require.

Mr. W. BRIDGES ADAMS remarked, through the Secretary, that there were three classes of materials of which permanent way might be constructed—wrought iron, cast iron, and timber. Wrought iron appeared to be the most desirable, effecting a saving in weight, bulk, and the amount of ballast, while free from brittleness, or decay. Of cast iron, a good and permanent way might be made; but it must be in heavy masses, to prevent breakage, and involved great cost in freight. With timber, a good way might also be made; but it was objected, that it was subject to be destroyed by rot and by vermin. Creosote, effectively used, prevented timber from rotting, and deterred vermin. But it was not generally known, that creosote could only be made to penetrate effectively into very soft wood. Into highly resinous, or very hard wood, it would only enter skin deep. These classes of wood resisted ordinary rot, but they would not resist all kinds of vermin. Creosote was, in truth, only a contrivance to give to soft wood the chemical durability of good timber. There was another difficulty with timber. It required, in modern practice, with heavy engines, to be applied with considerable surface-bearing, and with very stiff rails to distribute the load, and prevent it from being crushed in detail. It was for this reason that the single-headed rails used on cross timbers, on American and other lines, were found inefficient, and difficult to keep in repair. It was to the lightness of former engines and trains, that the durability of rails, for seventeen years, on the South Western Railway, was to be attributed. It was to the weight of the engines that the crushing of rail-tables in the chairs, and the crushing of chairs into sleepers, was to be attributed; that rails, formerly reversible, had ceased to be so, and that the weight of the intermediate chairs has been increased from 16 lbs. to 42 lbs. It was the weight of the engines, added to want of stiffness in the rails, that caused bridge rails to sink into longitudinal timbers, and forming grooves, wore them out mechanically, by crushing. It was the almost impossibility of keeping rails fast in chairs, under such loads, that had caused the vibration and damage which would ultimately lead to the disuse of the double-headed rail, if no remedy were provided.

Mr. Adams had devised three remedies, enabling the double-headed rail to be used without chairs; one, suspending it upon

lateral angle brackets of cast-iron, wrought-iron, or wood, upon cross sleepers, saving the lower table from all damage and the rail from crystallization, and with a saving in first cost of upwards of £50 per mile. Another suspending it between a pair of wrought angle-irons; and the third between a pair of longitudinal timbers. The scantling was applied on each side of the rail, to the channels of which it was contoured, each piece of timber being 5 inches wide by 4 inches deep, the rail and timbers being all bolted together by a flat bolt of bar iron, 1 inch by $\frac{1}{4}$ of an inch, and two washers and keys, 3 feet apart. The joints of the rails were connected, by brackets of angle-iron, to a cross tie of timber. As upon this system, only a very thin vertical web was required, the rail might be increased in depth, giving much greater vertical strength. In this mode, the rail and longitudinals might be reversed, without separating them, by merely taking out the joint bolts and turning the rail upside down, or end for end. A sample of that laid down on the Eastern Counties was exhibited. The ordinary rail with two unequal heads was used, and the longitudinals were formed of the ordinary cross sleepers, cut down the middle, and formed to the shape of the channel by a machine. The practical result was an economy of three sleepers out of eight, saving the whole of the chairs, and one-half the ballast. If intended for export, the saving in freight was equal to 148 tons per single mile, supposing the whole material to be sent from England as at present. The mechanical result was a good and easy road, with little trouble in maintenance. Short lengths had been laid on the main Cambridge line for upwards of six months, and on the North London for upwards of two years; in the latter case the rails, having been worn out on the upper table, had been reversed. When the timber bolts were taken out, it was found that the timber was firmly cemented to the rails, showing that there was no looseness of parts, and they could not be separated without force. The small scantling of timber facilitated low cost, and also the process of creosoting. Moreover, the holes being bored previous to creosoting, would greatly facilitate the entrance of the oil, and insure a thorough saturation. This system was about to be applied on the Pennsylvanian Railway, in the United States. The wrought-iron way had been tried on three different lines—the Great Northern, the London and North Western, and the North London. On the Great Northern, it was taken up at the end of two years and a quarter, the heads of the rails having been worn down under the heavy coal traffic and shunting, and no spare rails existed to replace them. The head of the rail, in this case, was only 2 inches wide. On examination, when taken up, no loose bolts were found; no wear of the connecting joints; all had been absolutely unmoved, and with the exception of a few of the faulty rails, was quite fit to go

down again. For the London and North Western, 5 miles were prepared, the breadth of rail-head being $2\frac{1}{4}$ inches. Only one mile was laid down on the main up line between Harrow and Pinner. A portion of this was laid in blowing Woburn sand, another portion on naked flint nodules, and a third portion on the worn ballast of the line. It carried the whole traffic of the line for six months, and was then taken up. Mr. Adams was not aware that any reason had ever been assigned for taking it up. On careful examination, after it was re-stacked, no defect of any kind was found; the bolts had all been tight, all the joints and connections firm, and the rails were as perfect as when laid down. In these samples, the depth of rail was 7 inches, and the breadth of continuous bearing on the ballast $13\frac{1}{4}$ inches. The specimen on the North London was composed of the ordinary double-headed rail, weighing 75 lbs. to the yard, and two angle-irons each 28 lbs. per yard. The total width of bearing was $9\frac{1}{2}$ inches. It was found sufficient to carry the whole traffic of the North London line, with upwards of sixty trains per day, without any sinking. There was no doubt that 170 tons of wrought iron per mile, including rails and angle-irons, would form a competent road, involving light freight, small bulk, easy packing, and absence of breakage, with less outlay than the ordinary cross sleeper road. Materials for 20 miles of similar wrought-iron way had been forwarded to India. All the fastenings were thoroughly secure and out of the reach of pilferers. Less ballast was required than on the wooden side-bearer system, the angle of stability was even greater, and there were no wooden keys for the vermin to attack. It had been proved, experimentally, that the application of longitudinal timbers, bolted laterally to the rails, as above described, added one half additional to the vertical strength, and materially augmented the lateral stiffness.

Mr. LOCKE, M.P., President, said, in closing the discussion, the great diversity of opinion that prevailed upon this subject could not fail to be noticed. Every one appeared to think his own plan the best, and naturally preferred to be guided by his own experience, rather than by that of others. As to the question of the durability of timber, whether prepared or not, and if prepared, then by what process, few persons were able to furnish reliable data, founded on their own observation, as far back as twenty, or thirty years. It had been remarked, that the life of a timber sleeper might be estimated at an average of ten years, but to this it had been replied, that there were still in use many thousands of sleepers which had been laid twenty years. He was afraid the Members could not now be informed of the exact quality and character of that timber, or of the nature of the preservative processes, if any, to which it had been subjected. But

practical facts, such as had been elicited by this Paper, were valuable in themselves, and the Minutes of Proceedings of the Institution, as embodying a variety of opinions upon this and other questions, would continue to furnish the best sources of information upon those facts which it was desirable to collect. He doubted whether the question could ever be solved, or whether there could be universal agreement, as to what was the best system of permanent way, to be used under all conditions. When the defect of any plan was made evident, after a fair trial, the object should be to devise something better. That was a safe mode of effecting progress in mechanical science, and he should be sorry to see a stop put to it.

April 12, 1859.

JOSEPH LOCKE, M.P., President,
in the Chair.

THE discussion upon Mr. M^rMaster's Paper, No. 994, "On the Permanent Way of the Madras Railway," occupied the whole evening, to the exclusion of any other subject.

CURTIS'S AXLE BOXES.

After the meeting, Mr. Curtis explained a system of axle boxes, in which, by centrifugal action, the oil was constantly thrown over the upper side of the axle, and descending slowly upon the axle was returned again to the oil chamber. As soon as it had passed the axle, a piece of thin porous flannel, placed at the bottom of the oil chamber, was found in practice to answer as a filter to receive the parts of the metal, or other residuum, resulting from the working of the boxes. These boxes were now at work on eight railways in England, and on one in France. They had been in use for upwards of eighteen months; in some cases they had run for two months without any fresh oil being applied; but the ordinary practice was to introduce about a wine-glass full of oil to each box once a week.