Discussion.

Mr. R. RAWLINSON, C.B., asked if Dr. Siemens could say anything as to the probability of the introduction of steel and the abolition of iron sleepers. Iron had apparently been used in almost all the cases referred to in the Paper, but he had no doubt that Dr. Siemens, who knew so much, particularly of modern improvements, would say that iron would soon be a past manufacture. Mr. Rawlinson.

Dr. SIEMENS said he was hardly bold enough to make such an assertion; at the same time he believed that steel was on the whole preferable for the new application. While continental nations had been giving great attention to the introduction of metal permanent way, England had remained perhaps too partial to timber as the material to be employed. It was true that English engineers would now have the advantage of the experience already gained, and when turning their minds to the subject they would soon perceive not only the advantage of the metal system, but the most practical mode of carrying it into effect. Iron should be strong enough for the purpose, because each portion of an iron cross sleeper was apparently not strained beyond its capability of resistance; still he apprehended that homogeneity was of great importance, because where the fastening held, the metal was strained to a very considerable extent—an extent which could hardly be determined *à priori*, and in all such cases steel yielded before it fractured under compressive strains. Then again, he believed that the introduction of steel sleepers would be of great advantage to the manufacturer, even though he should not realise large profits from the actual operation. It was well known that in Germany, where iron and steel sleepers had been largely introduced, the manufacturer was glad to supply them at a comparatively low cost, because he could go on with the manufacture without waiting for specifications. It was always the same thing, and whenever he had no other work on hand he could turn to rolling sleepers; moreover, although a good metal should be employed, it was not necessary to use entire ingots, but considering the short length of a sleeper, odds and ends of the material could be utilised to a considerable extent. Therefore he had no doubt that, for the two reasons he had mentioned, the comparatively low price at which sleepers could be supplied, and their great permanency when once laid down, iron or rather steel permanent way would soon be very largely, if not universally, introduced into this country. Dr. Siemens.

Mr. d'Avigdor. Mr. E. H. D'AVIGDOR ventured to make one observation bearing upon the question of Belgian girders—a subject of which he knew something, because he had made those girders himself. He took the liberty of challenging the statement in the Paper that in any girders made of Belgian iron the breaking strain transversely was only one-third of the breaking strain longitudinally. Some exhaustive experiments had recently been made in London by eminent persons on various Belgian girders, and such a result as had been mentioned in the Paper had never been even approached. The longitudinal breaking strain, as the Author had remarked, varied from 20 to 22 tons, but the transverse breaking point had never been anything like so low as one-third, or even as one-half, and only in one case was it two-thirds.

Mr. Cowper. Mr. E. A. COWPER wished to direct the attention of the members particularly to the fact that English engineers were so far behind their neighbours in the use of steel sleepers. The advantage of good steel rails and sleepers was now pretty well acknowledged. As the Author had stated, about 200,000 tons of iron and steel sleepers were at work in Germany, and some of them had been laid twenty years, others twelve and fifteen years; so that the experience that had been gained in that country was very great. The Author had pointed out the defects in certain constructions. It would be seen that on the Continent many experiments had been tried with different forms of construction, some of which certainly did not commend themselves to general acceptance. Experiments had been tried in different directions; if any form failed, another was tried; and after gradually simplifying the arrangement, a section had been attained which appeared to be generally approved. He referred to the sleepers on the Bergisch-Märkisch Railway, of which a great quantity had been made. He had thought that after the excellent Paper and discussion at the Düsseldorf meeting of the Iron and Steel Institute, last year,[1] the attention of English engineers would have been given to the subject more closely than it had been. He had on several occasions expressed his opinion that in a few years the public would be travelling over steel sleepers. He hoped the shareholders and the directors would take the subject into consideration as well as the engineers. Mr. Webb's sleeper, with riveted jaws, had been laid for some months on the London and North

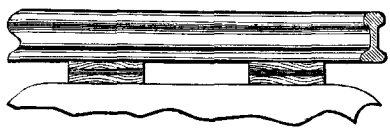
[1] *Vide* "On the results obtained with various systems of iron permanent way in Prussia," by E. Grüttefien. The Journal of the Iron and Steel Institute, 1880, p. 488.

Western line, and he hoped that other lines would follow suit. Mr. Cowper.
He thought that the sleepers should be made of steel, not of iron, steel being more tough and springy, as well as much stronger, and they could be made much lighter. The end should be turned down, so as to give resistance to motion, and this could be done easily and cheaply. At the German Steel Works, last year, he saw sleepers rolled for the Bergisch-Märkisch Railway, in lengths of 60 or 70 feet. As the metal emerged from the rolls, lengths were sawn off, which were carried forward, the holes punched, the ends slit and turned down, and the sleepers set to a slight curve, to give the inclination to the rails. The whole punching and bending was done for about 1½*d*. He agreed with Dr. Siemens that many odd scraps might be used up for the jaws and the chairs with a view to economy. He had long considered the use of steel for sleepers. Large sums of money now spent for wooden sleepers might be saved, and a double demand for steel would be made upon the steel works, the sleepers weighing quite as much as the rails. It was true that sleepers would last a long time when once made; but then all the lines would have to be supplied with them from the first, because the wood would be gradually displaced. Looking at the fact that 200,000 tons of iron sleepers had been laid in Germany, and were working for the most part successfully and economically, he thought English engineers would be very much to blame if they did not benefit themselves and the public by the use of steel sleepers within a very few years.

Mr. JAMES LIVESEY said that the subject was becoming of great Mr. Livesey.
importance, and the experience of those who had been for many years engaged in connection with it might be of some value to the Institution. Twenty years ago his attention had been directed to the subject of iron permanent way; and, before recommending any particular class of iron permanent way, he resolved to make some exhaustive experiments on the North London Railway, with a view of testing the various ideas he had upon the subject. At that time he entertained the opinion that an elastic permanent way would be a great improvement, and he resolved to test, not only the question of elasticity, but other questions in relation to iron permanent way. Having obtained permission to make his experiments, he had a large quantity of sleepers cast, and his first experiment was with a cast-iron bowl sleeper of an oval form. The rail was fastened to the sleeper by means of an iron key, the rail being bedded on the body of the sleeper, iron to iron. He then put down a length of road with wooden blocks interposed between the rail and sleeper; then a length with pieces of india-

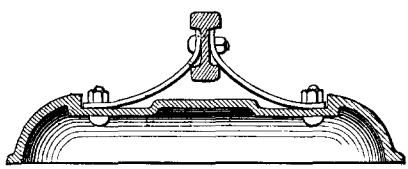
Mr. Livesey. rubber ¼ inch thick interposed between two blocks of wood; then he had india-rubber placed between the timber about ½ inch thick (Fig. 30); and beyond that he had a length put in with rails

FIG. 30.



secured on steel springs (Fig. 31). He had watched the experiment with great interest for a long time, and it was difficult to discover which road gave the best results. The first road seemed to stand the best; but it was for a long time difficult to discover very much difference. After some months, however, when bad weather came on, it was found that the sleepers that had any degree of elasticity

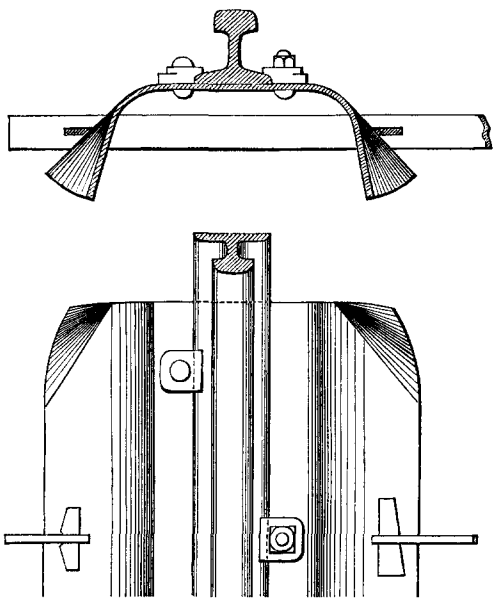
FIG. 31.



gave a great deal of trouble—even those with the small piece of india-rubber. The little motion that the sleepers had rendered frequent repairs necessary. The road on steel springs seemed to promise well at first; but when wet weather came the sleepers were so lively in the ground, and the repairs so great, that this part of the road had to be taken up. The result of his experiments was that he abandoned altogether the idea of adopting an elastic sleeper or putting in an elastic medium, except, perhaps, a wooden block between the rail and the sleeper. These sleepers stood the heavy traffic of the main line of the North London Railway, giving no indication of weakness in any other point. The system had been examined by many engineers, and the result was that upwards of 200,000 tons of similar sleepers had been laid in various parts of the world, giving, he believed, great satisfaction, and their use was being largely extended. Soon after making the experiments he wished to try the result of a wrought-iron sleeper, and obtained permission to make experiments on the Great Eastern Railway. The Author had stated that from 1855 to 1878 no wrought-iron permanent way had been tried in the country.

During that period, however, Mr. Livesey had been making many experiments with wrought-iron sleepers, especially on the Great Eastern Railway. The sleeper was a simple plate, bent in the form of a saddle, and strengthened by a tie-bar passing through (Fig. 32). It made an exceedingly easy road to travel over; and he found that $\frac{1}{4}$-inch plate was sufficient to stand all the main line traffic of the Great Eastern Railway. Some interest was taken in that form of sleeper by engineers; and about 16,000 tons had been Mr. Livesey.

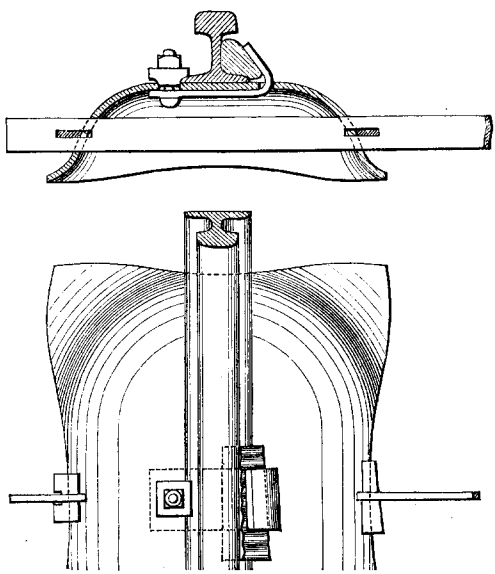
FIG. 32.



made during the last ten years. He believed the only point of trouble with them was that the hook-bolt on the inside clip of the rail had not a sufficient bearing surface; but the outside clips, which were riveted down, had given no trouble. He had been anxious to obtain, if possible, a stronger form of sleeper, because, if anything, that form of sleeper was a little too elastic. For some time he tried to get the manufacturers to make a bowl form of sleeper out of a rectangular plate (Fig. 33). Being so made it would be exceedingly strong. There was no waste in its manufacture, and the flat corners of the sleeper gave more bearing surface, besides having the advantage of the greatest depth of ballast being on those corners, and the sleeper was thereby anchored

Mr. Livesey. down in the ballast. A great many sleepers of that pattern had been made, and were now laid on many railways in various parts of the kingdom. The illustration by the Author (Fig. 27) simply showed a jaw riveted to the sleeper, and a corrugated iron key; but one objection to that arrangement was that the gauge could not be adjusted. In the bowl form of sleeper which he had just described the gauge could be adjusted by the back-stop, the bolt-hole in which was placed eccentrically, so that by turning it in one direction the gauge was made a little wider, or in the other

FIG. 33.

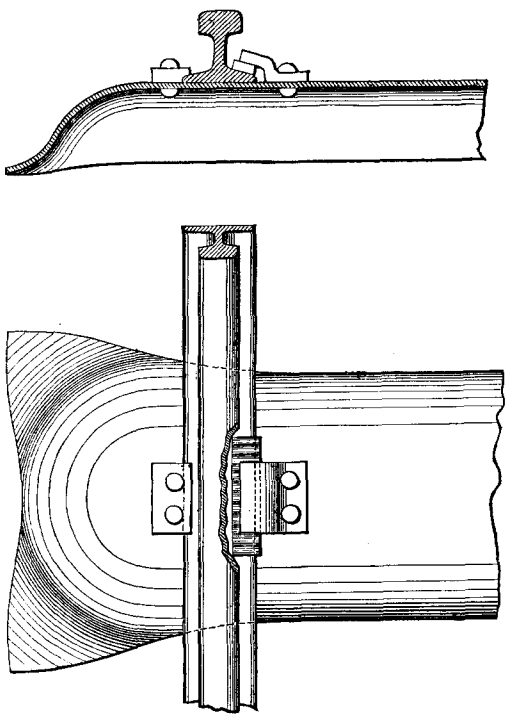


direction a little narrower. That arrangement of sleeper also was giving great satisfaction. The Author had stated that there was no necessity for turning down the ends of the sleeper. Mr. Livesey had recently been in Belgium and Germany, where he had seen thousands of sleepers on various lines, and in every instance the ends had been turned down, showing that experience abroad at any rate was in favour of that method being adopted. He had seen a long time ago that this was a necessity. When Mr. Barningham and he were making experiments on the Great Eastern Railway, the platelayers used to say that the great trouble with the open-ended transverse sleeper was that the road got so much out of form that it was a "floating" line. He then saw

the necessity of turning down the ends of the sleepers, and adopted that method. On the South-Western Railway open-ended sleepers were tried, and they were found not to give satisfaction. They moved sideways. Mr. Livesey.

Considering the different kinds of ballast on various lines and under so many varying conditions, it required only a little discernment to see that a sleeper with closed ends became almost a

FIG. 34.



necessity. With wet, sloppy ballast and on curves an open-ended sleeper opposed little lateral resistance, and was what platelayers so aptly called a "sliding or floating" permanent way. The few experimental lengths of road tried in this country, and under favourable conditions of ballast, curves, &c., afforded very little guidance. Experience became valuable after many years of trial in different countries under varying conditions.

The Author of the Paper had indicated the best kind of ballast to be employed. It was certainly more easy to say what was the

Mr. Livesey. best ballast than to procure it. In the neighbourhood of Middlesbrough, where the Author had conducted his experiments excellent ballast could be procured without difficulty; but since an engineer had to deal with various physical conditions in all parts of the world, he must be prepared to adapt his designs thereto. In the Argentine provinces there were hundreds of miles of railway where neither broken slag, broken stones, nor gravel of any description could be had, but ballast consisting of black soil only. At certain seasons of the year, the rainfall was very heavy, and at others there was a continuance of dry, hot weather for months. It had been found that the cast-iron bowl sleeper answered admirably, and met the peculiar conditions in a singular manner. The bowl of the sleeper held a good body of soil ballast, which became hardened and was not easily washed away. Gradually the soil under the sleeper was consolidated, until a kind of pyramid was formed under each sleeper. When the heavy rains set in, the ballast in the centre of the road and around the sleepers was often washed away, but the earth was so indurated under the sleepers that very little disturbance followed. A timber-sleepered line had been impassable, when the iron sleepers stood firmly on their pyramidal beds, though the earth around had been washed away; thus showing that the form of sleeper played an important function. A flat sleeper, for instance, might do well in favourable ballast; but his experience was, that a sleeper holding a good body of ballast met such varying conditions, as had been alluded to, better than any other.

Speaking from experience extending over many years and on railways with which he had long been connected as engineer, he found that the girder-class of road was far too rigid and severe, and if with a sufficient amount of bearing area (other conditions being equal) it was more expensive than the transverse or bowl system, both of which, if properly constructed, had given excellent results. The determination as to whether a transverse or a bowl system should be adopted, depended in a great measure on the gauge of the line. For equal effective bearing areas, the cost of the two systems was about the same, with the 3-feet or metre gauge; but for a wider gauge, the transverse system was more costly. For a gauge of 5 feet 6 inches, the difference was considerable. With a bowl sleeper the extra cost was simply the additional length of tie-bar, which amounted to a mere trifle; but with the transverse sleeper, it came to the cost of so much of the entire sleeper.

Next to the form, and equal in importance, was the rail-fastening.

Since iron sleepers were intended generally for countries where there was little skilled labour, it was important to have as few loose pieces as possible, and those of a simple kind. The bulk of the cast-iron sleepers he had so largely adopted and introduced, were of deep bowl form, and oval, so as to obtain a long bearing for the rail. The key was of cast iron and was corrugated or serrated on one of its faces, fitting into corresponding corrugations in the jaw of the sleeper, which was made of steel, cast firmly into the body of the sleeper, and was elastic enough to allow the corrugations to pass each other. The key was driven in and out in the usual manner by a platelayer's hammer, and when driven, no vibration of the road could shake it out. The road was held to gauge by a tie-bar with a single cotter to each sleeper, which could not be wrongly placed. Mr. Livesey.

It had been found that large surfaces were necessary for the outside edges of the flat-bottomed rail to bear against. The comparatively sharp edge of a Vignoles rail made, in four or six years, a perceptible indent in the outside jaws against which the rail abutted. This action went on increasing, and the result was that keys became loose and the gauge of the line deranged. It was, therefore, important to have all bearing and wearing surfaces as large as possible. He had also discovered that, on wrought-iron sleepers, it was especially important to have the parts forming the rail fastenings rigidly and immovably secured to the sleeper. If any part had the least chance of motion or vibration, however slight, destructive wear set in. A well-riveted abutment, or back-stop, on the outside edge of the rail, offering considerable wearing surfaces, and a riveted elastic key-jaw on the inside would last as long as the sleeper itself. This arrangement of rail-fastening was shown by the Author of the Paper at Fig. 27. The only loose part was a corrugated iron key, which, when driven, could not shake loose.

It was a great advantage not to have any loose parts to fit into the sleeper on the ground. All parts should be rigidly and permanently secured at the works, and form an integral part of the sleeper. The sleepers could then at once be placed in position on the ground, the rail inserted, and by simply driving in an iron key, the road would be permanently laid. Such a road could be laid by unskilled labourers.

The strong form of the transverse sleeper with bowl-formed ends, and the bowl-sleeper itself, allowed a very light plate to be used, either of iron or steel, which effected a very considerable saving in weight. For securing the rail-fastenings to wrought-

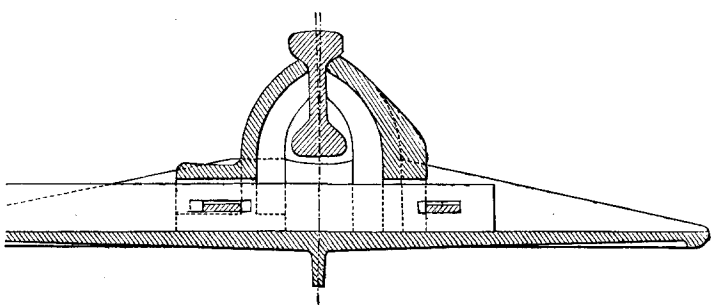
Mr. Livesey. iron sleepers, it was important to have strong washer-plates under the head of either rivets or bolts. He found, where fastenings had been employed that could vibrate in the least degree, that in the course of years the plate was gradually worn through; and often these points of weakness did not develop to any serious degree for a number of years. He had seen examples that had been in the ground eleven years, and found the sleeper practically as good as new, with the exception of one or two weak points, which had the effect of rendering the sleeper prematurely useless.

He could not agree with the Author of the Paper, either as to the form of sleeper which he recommends, or as to the mode of securing the rail. The grounds of objection to the open-ended sleeper had already been given, but the effect of bending the sleeper so as to dip towards the centre of the road was, in his opinion, to lead the water in that direction instead of towards the outside of the road. For climates where long-continued and scorching heat was followed by extreme moisture, a wooden key for securing the rail was objectionable; for not only did it shrink, but wear was constantly going on. Even in the damp climate of England, it was well known what trouble the wooden keys gave on railways. With the ordinary cast-iron chair, the keys working loose and dropping out here and there was not of vital importance; but when the permanent security of the chair itself depended upon a wooden key, which had to answer the double purpose of securing the rail to the chair, and the chair to the sleeper, the arrangement did not seem to offer that reliable security which ought to be looked for in a sleeper, which the Author of the Paper said ought to last thirty years. He had pointed out the destructive effects produced by motion of the parts on wrought-iron sleepers. Now the Author admitted that a few of the keys on his experimental length had come loose. If this was so with an experience of only three years, during three wet winters and three remarkably wet summers, what would be the result of an exposure of many months under a tropical sun? The elasticity of the jaw was an advantage to a certain extent, but, in his opinion, the range of elasticity was not sufficient to meet the shrinking and wear of a wooden key. For many years he had employed the elasticity of a steel key-jaw and other elastic arrangements in connection with a corrugated or serrated iron key; but even with this, consequent on the wear that took place, the keys occasionally required to be tightened up. The Author had been at great pains to collect information from foreign engineers, which together with the opinions expressed by English engineers would be found of some value, as it would

enable engineers to avoid errors and weak points that could only be discovered after long experience. Mr. Livesey.

Mr. BRADFORD LESLIE remarked that in India the high cost and rapid decay of timber had long ago compelled engineers to have recourse to iron for sleepers. The renewals of timber were not less than 10 per cent. per annum, while the renewals of iron did not exceed 1 per cent. His experience was chiefly with cast iron, but as it had been said that within twelve months wrought iron would be a thing of the past, he feared cast iron would be considered as already quite out of date. Yet there was something to be said in favour of cast iron: in the first place, it was cheap; and in countries like England and her dependencies, where the double-headed rail requiring lateral support was in use, the vertical jaw for this purpose was more easily provided in a casting than in any description of wrought-iron or steel sleeper. Another advantage of cast-iron sleepers in India, where there were no rolling mills, was that cast scrap was more valuable than steel or iron scrap. Scrap-sleepers were recast on the spot, but wrought- Mr. Leslie.

FIG. 35.

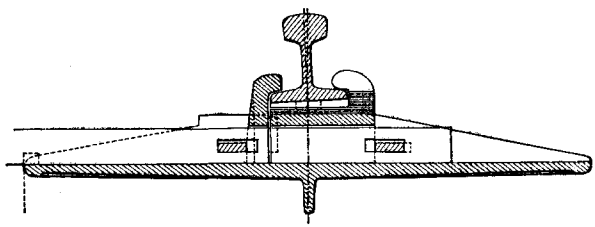


iron or steel scrap had to be sent across the sea to be worked up again. He had further to observe that, in adopting any form of channel bar as a transverse sleeper, there must necessarily be a great waste of material in the centre, even with the 4 feet $8\frac{1}{2}$ inches gauge, and where, as in India, the standard gauge was 5 feet 6 inches, such a section would be inapplicable. He had found that where sand or loam was available for ballast, Greaves's old-fashioned surface-packed pot-sleeper made an excellent road. With a hollow bearing, however, of any description, it was more difficult to get a good "top" on the road and to keep it, than with a flat bearing; and for use on broken stone ballast for renewals promiscuously with timber sleepers, a cast-iron sleeper, called the Denham-Olpherts sleeper (Fig. 35), was used, consisting of a pair of

Mr. Leslie. flat plates, with stiffening ribs on the upper sides and external fixed jaws. A wrought-iron tie-bar passed through the fixed jaws, and by means of cotters at the back of the jaws connected the plates together and regulated the gauge. An internal loose jaw slid between the stiffening ribs of each plate, and was pressed firmly against the rail by a taper key passing through a hole in the loose jaw, and a corresponding hole in the tie-bar. By this arrangement the rail was suspended and firmly gripped between the jaws.

The East Indian Railway was originally laid with transverse timber sleepers, and these cast-iron plates (Fig. 36) had been used

FIG. 36.



instead of timber for ordinary renewals, so that there were commonly three or four timber sleepers and as many cast-iron sleepers in the same length of rail. Whether used in this way or continuously, they made an excellent road for heavy and high-speed traffic; and excepting in the case of a few defective castings there were no breakages. The weight of the plates was 100 lbs. each. The cost of the complete sleeper with all fastenings, including the chair for support of the double-headed rail (which the Author's sleeper did not provide), delivered at the East India Railway, was 9*s.* 10*d.*

Mr. Blair. Mr. JAMES M. BLAIR presumed the numerous types of longitudinal sleeper described in the Paper as having been tried in this country, had been mentioned as a matter of interest to engineers, but not as examples to be copied. The transverse sleeper, undoubtedly, had a great deal of merit, and he thought that the Author's system was about the best of any. It was a singular circumstance that the first longitudinal sleeper, Mr. Barlow's, was one of the best, and the same remark he thought applied to the transverse sleepers. The first of them, Mr. Le Crenier's, in 1860, the only one not illustrated, was very much of the same model as the Author's, which, however, had certain improvements. Mr. Blair made the sleepers that were laid on Mr. Le Crenier's system in Portugal. There was a wrought-iron plate following the rim or section of a transverse timber sleeper, somewhat as

shown in Fig. 28, but the tilt of the rail was impressed into the sleeper in the same operation as bending the plate. The Author's system had an improved fastening for the rail, and an improved section for the transverse sleeper, but the plan of following the section of the wooden system seemed to be almost the same. He thought the Author had carried them far enough in the direction in which he had gone. In some instances the transverse sleeper was impracticable on account of extra cost of transport or manufacture, especially in the case of broad-gauge railways. It might be suitable for the ordinary gauge, but for broad-gauge lines there was an extra element of expense. Many other systems had been adopted. There was the cast-iron pot sleeper with a tie-bar, which had served its purpose very well. With regard to the question of steel or iron, he was glad to notice in the Paper some remarks as to the liability to corrosion. That was one point which for a long time had prevented engineers from adopting wrought-iron or steel sleepers. It had been proved that there was very little liability to corrosion in an iron permanent way where there was an existing traffic; but where the line was at rest corrosion would soon take place. Where traffic existed, the corrosion was almost nil. That was a point in favour of thin plates of iron or steel for permanent way. It was a good many years since wrought-iron plates $\frac{1}{4}$-inch thick had been used. They had been thoroughly tested, and did not fail on account of corrosion. Many other plans had been tried, and he thought that Mr. Livesey's was about as good as any brought before the meeting. Steel, however, was no doubt an advance. He considered that $\frac{1}{4}$-inch plate of iron was ample. Many hundreds of miles had been made of $\frac{3}{16}$-inch plates, and he had made steel plates less than $\frac{1}{8}$ inch thick. They had been tested with heavy engines, and had been found quite fit to stand the heaviest traffic. Steel plates $\frac{1}{16}$ inch would be ample, if they were not liable to corrosion. With regard to some transverse sleepers, such as shown by Mr. Livesey, there was an objection to them on account of their getting rigid in the centre, so that when the pressure came on the rails the ballast was depressed under them, and the transverse sleeper rode on a ridge in the centre. With the ordinary pot sleeper, either wrought iron or cast iron, there was not so much liability to this occurring, he thought, as in the case of the transverse sleeper.

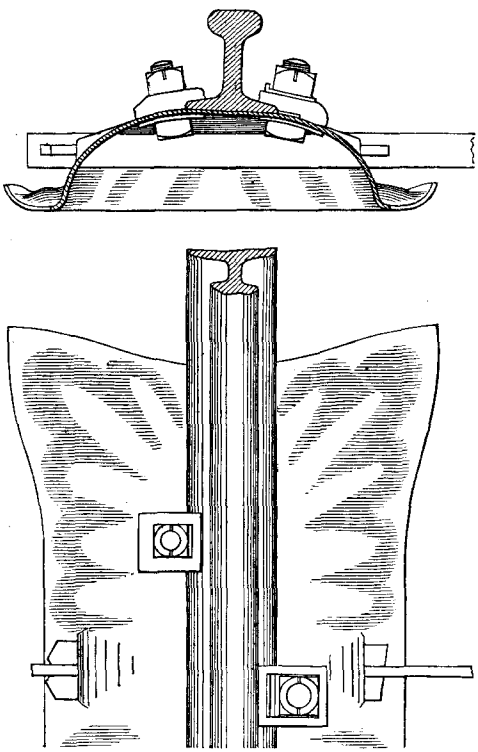
Mr. Blair.

It might be assumed that engineers of the present day generally felt assured that steel was the metal of the future, and was destined largely to replace cast and wrought iron in structures where strength and lightness were essential. He believed it was

Mr. Blair. a metal peculiarly adapted for the permanent way sleeper-chairs of railways. On this account he submitted some forms of embossed steel sleepers. It had been found that the corrugated form imparted considerable extra strength, and in point of manufacture afforded a ready way to dispose of the metal, and thus avoid the severe strain to which the plate was subjected in making the plain form of bowl sleeper.

The sleepers (Fig. 37) of $\frac{3}{16}$-inch steel plate, were the form adopted by the Oude and Rohilkund Railway Company, a railway

Fig. 37.



which had shown the lowest cost for maintenance of any in India. These sleepers had been tested by pressure to 25 tons without retaining any permanent set. Some hundreds of miles had now been laid, many of which had been down for six or seven years, and had continued to give the most satisfactory results.

The rail clips were fastened by a bolt and nut. This, he con-

sidered, was better than a plain rivet, insomuch as the point of the bolt was intended to be riveted over the nut, thus effectually preventing the nut from coming off; but, in case of slacking, it could be more easily tightened than a simple rivet. For the sleepers adopted by the Oude and Rohilkund Railway Company the bolts were of steel, with steel lock-nuts, and having one of Sterne's locking-washers under the nut. There was also a 3-inch square washer between the head of the bolt and the under side of the sleeper. This rail-fastening had answered well, and gave no trouble. Mr. Blair.

He thought that what was sometimes described as the chattering of the fastenings in new sleeper-chairs, could be obviated at little cost by introducing a thin layer of felt, or other fibrous material, or even sheet lead, between the rail and the sleeper. Wood cushions had been used for this purpose, but he did not know if what he now suggested had been tried.

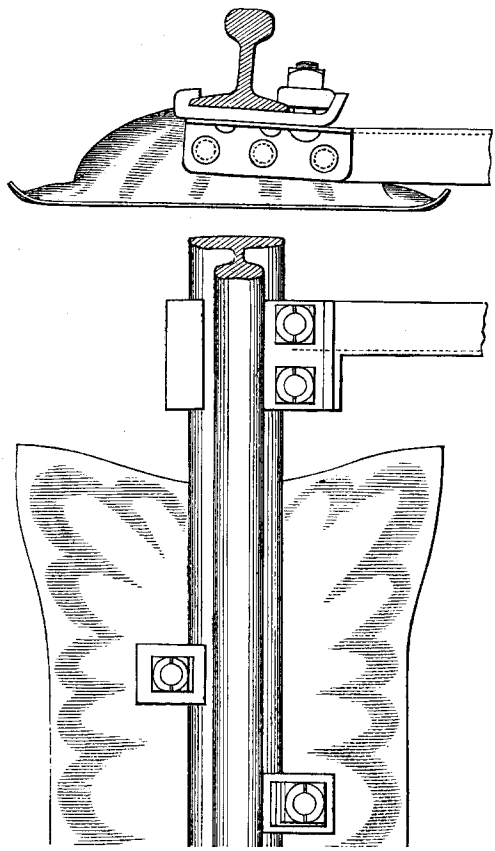
The embossed steel sleepers, made of plates $\frac{3}{32}$-inch thick, were not thought strong enough to carry the tie-bar through the sleepers; an independent tie-bar had therefore been adopted, of angle or other suitable section, with proper fastenings to the rail, and so formed as effectively to hold them, both as to tilt and gauge, the sleeper chairs serving only to support the railway on the ballast (Fig. 38). By this arrangement a better tie was obtained, bearing directly on the rails, which were thus more easily held rigidly in position.

A short piece of railway of this description, with sleepers $\frac{3}{32}$-inch thick, had been laid some time ago in Clutha Iron Works. The sleepers were laid on iron plates, so that their action could be well observed. A powerful locomotive engine, weighing 45 to 50 tons, was passed over them several times slowly; it was also made to rest with the driving-wheels directly over the sleeper chairs; and was run across them at such speed as could be attained in about 100 yards, without visibly affecting them in any way. In addition to this, a $\frac{1}{2}$-inch plate was placed under one of the sleepers, thereby partially suspending those on each side and bringing greater stress on the elevated one. The engine passed over this without any visible effect. Subsequently another plate was added, thereby raising the sleeper about an inch, but with the same result, as even under these circumstances it withstood without change the extra strains brought on it.

The sleeper chairs of $\frac{3}{16}$-inch plate iron had hitherto been pressed hot, and were completely finished at one operation. Mr. W. F. Batho, M. Inst. C.E., the engineer of the Oude and Rohilkund Railway Company, had for some time urged their being

Mr. Blair. cold-pressed. With the aid of improved and more powerful machinery this was now being done. The saving of cost of heating, and waste from scale formed in the furnace, was an important factor; but by this mode of manufacture the scale, or black oxide, formed in rolling the plate was entirely removed, and the sleeper

FIG. 38.

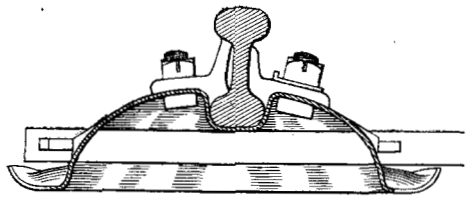


was thus left in a better condition to resist the action of corrosion, or to receive any coating that might be applied.

With regard to coating, in his opinion nothing better had yet been found than Dr. Angus Smith's composition. This effectually preserved them until they were laid on the railway, and had traffic passing over them, after which the corrosion became inappreciable. He had had some coated by the Barff process, as a

trial, but found that very little straining in a hydraulic press made the magnetic oxide come off in scales, so that this system was not applicable for coating metals subjected to straining. He was not aware if galvanising had been tried; but he thought Mr. Blair.

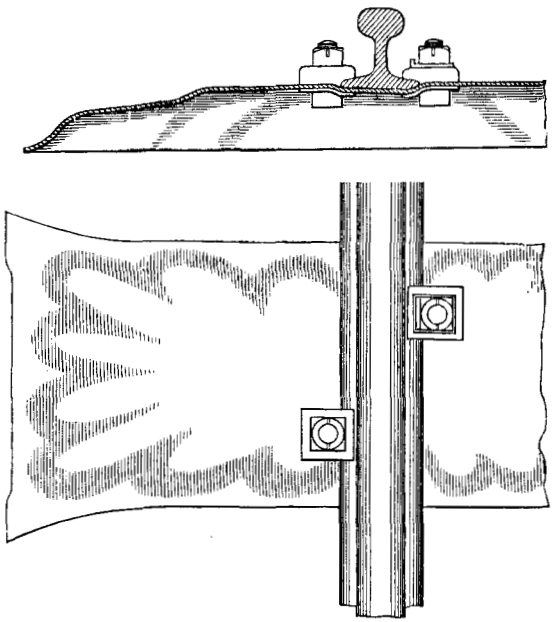
FIG. 39.



that in many circumstances this coating might be adopted at little cost, especially in connection with very thin plates.

He thought the cost of steel sleeper chairs, such as those he had described, would bear very favourable comparison with either cast-iron or timber sleepers. Steel sleeper-chairs were not one-

FIG. 40.



third of the weight of cast-iron chairs, and thus a great saving was effected in freight and carriage. In addition to this, there

Mr. Blair. was the loss from breakage in cast-iron sleepers, which was entirely avoided in steel. He therefore considered the time not far distant when they would, to a large extent, supersede both cast-iron and timber sleepers.

This sleeper was especially adapted for the flat-bottomed section of rail, but Fig. 39 showed the form suited for a double-headed rail.

An embossed steel transverse sleeper, adapted for metre or other narrow-gauge railways, was shown in Fig. 40. The rail fastenings were similar to those already described. These sleepers could be delivered in India at about the same cost as creosoted timber sleepers.

Mr. Bruce. Mr. G. B. BRUCE said that Mr. Cowper had drawn attention to the large use which had been made of malleable iron sleepers on the Continent, and the very slight use made of them by English engineers, which he regarded rather as a reflection upon the latter for not being sufficiently progressive, and as a commendation to the former for their spirit in having done so much in that direction. It appeared to him that English engineers had been wise in their generation, that their caution and slowness had been wisely manifested, that they had shown their judgment as engineers and their care for the shareholders whose interests they represented, because he ventured to think that from the beginning to the end the Paper was more or less a record of failures. There was scarcely any, if any, system of permanent way laid with malleable iron sleepers, transverse or longitudinal, of which it was not stated that in some direction or other it had failed. In many cases it appeared that the system was no longer adopted on the main line, but only in sidings; in other cases the fastenings rattled and got loose. He did not think anything had been stated which would lead an engineer of sound judgment to trust to such a system the traffic of the London and North Western or the Great Northern Railways. The great difficulty on the Continent no doubt arose to a large extent from the use of the Vignoles rail, which appeared to him incompatible with the use of malleable iron or steel sleepers. It was a very good rail where laid upon cross timber sleepers, and where the traffic of the road was such that it could be fastened to the sleepers by the ordinary dog spikes, or at most by a fang bolt here and there; but when the rail was fastened to an iron sleeper with all the contrivances of bolts, screws, clips, and the like, and in some cases gibs and cotters, there must necessarily be a good deal of shaking, and it was very difficult to fasten the Vignoles rail to an iron sleeper in any other way. The only iron cross-sleeper permanent road that

commended itself to his judgment was that used by Mr. Webb on the London and North Western Railway; it appeared to him to be the nearest, if not the only, approach to anything like a perfect permanent way. He believed that there was something in it foreshadowing the sleeper of the future. Mr. Webb had a good strong heavy steel or malleable iron sleeper on which he had riveted steel chairs, well made, and the whole formed a heavy and stable permanent way. The Author's method was an ingenious mode of fastening the rail; he had adopted, like Mr. Webb, the ordinary old-fashioned wooden key, which was by far the best. He had made some inquiries with regard to the Author's permanent way, and had found that although it had many good qualities, several of the sleepers had split underneath the rail. With regard to the horse-shoe clip mentioned in the Paper, the shoulders, where they bore upon the underside of the sleeper, were wearing very rapidly. That probably was the fault of the construction in the first instance; had they been larger they might perhaps not have worn in that way. He thought that Mr. Webb's permanent chair riveted on to the sleeper was much better than any loose method like the Author's, however ingenious. There was one difficulty in connection with all hollow malleable iron sleepers—the difficulty of packing them. They were not nearly so easily packed as wooden sleepers. The gravel underneath got hard and compact, and when the platelayers lifted the road they had to break up the ground before the road could be properly packed. That was a disadvantage, and added materially to the cost of the road. He thought it probable that the sleeper of the future might be a soft steel one, with a steel chair riveted to it; but he was strongly of opinion that none of the contrivances of bolts, gibs and cotters would ever answer. With regard to cast-iron sleepers, he could confirm what Mr. Leslie had stated, that a large number of those in India stood admirably. He had laid many miles in India of Greaves's pot sleeper with a depression in the centre, and the rail resting on wooden cushions on each side. The breakage was practically nil, and for a road of moderate speed and weights, he did not think any better system could be adopted. It was a very different matter with the great speeds and heavy weights of this country. Mr. Bruce.

Mr. H. Law desired to direct attention to the statement in the Paper alleging the superior stability of a cross sleeper compared with a longitudinal roadway, which he thought might lead to a false impression, because the measure of the stability of the rail was the area of the surface of the sleeper which bore upon the ballast multiplied into the distance of the centre of pressure from Mr. Law.

Mr. Law. the centre of the line of rails. It would be seen from the diagram (Fig. 28) that unless the cross sleepers were very large or very close the stability of the longitudinal sleeper would be greater than that of the cross sleeper. The points of the cross sleeper were of course more distant; but inasmuch as the centre was so much nearer, it was the centre of pressure which should be considered, and not the extreme point of the sleeper. He wished also to draw attention to the fact that in considering the question of permanent way it was quite as important to look at the wear and tear of the rolling stock as it was to look at the wear and tear of the road. In the Paper, and in the observations which had been made upon it, nothing had been said as to the comparative effects of the various permanent ways upon the rolling stock itself. The experiments upon the North London Railway, where successive short portions of different permanent ways were laid down, might lead to conclusions as to the relative wear and tear of the permanent ways, but not as to the effect upon the rolling stock. The experiments might lead to the belief that an inelastic road was the best so far as the road itself was concerned, but he thought that could hardly be the case when the effect upon the rolling stock was taken into consideration.

Mr. Williams. Mr. R. PRICE WILLIAMS said the remarks made by Mr. Bruce entirely accorded with some of the observations he had intended to make, especially as to the Paper being practically a record of failures. Mr. Webb had furnished him with several details of the cost of his iron and steel sleepers, which fitly supplemented some of Mr. Bruce's remarks. These afforded an answer to the main question in the Paper, namely, as to the relative advantages of iron and steel sleepers, not upon lean traffic lines, such as those to be met with in agricultural districts, but upon severely worked main lines, where sleepers were not destroyed by decay, but had their lives hammered and pounded out of them by heavy and rapid traffic. The Author had given particulars of the average life of oak, and of red and white deal sleepers, showing that they endured longer when preserved, and for much shorter periods when unpreserved; as a matter of fact, however, this was not a question of the average life of sleepers, and it would not do to take into account the element of natural decay when associated with the long life of sleepers on lines of light traffic in this country. On main lines of railway practically no advantage resulted from the life-preserving action of creosote under such circumstances. A life of six years on the main line of the London and North Western was in fact unattainable. He had carefully examined Mr. Webb's iron sleepers, which had been laid for

nearly two years, and from his own and Mr. Webb's observations, he found that up to the present time the cost of repairs had been practically nil. The Author of the Paper did not appear to attach much importance to the question of the first cost of the sleepers, because he said the prices varied, but Mr. Price Williams thought that the only requisite for instituting a reliable comparison between the cost of different forms of iron sleepers was the adoption of the same price of materials in each case. From a reference to the tabular statements, which he had prepared from the data furnished by Mr. Webb, it would be seen that an equation had been brought about in the cost of the steel and the wooden sleeper road, a result which he was not quite prepared for at this early period:— Mr. Williams.

COST OF WOODEN SLEEPER, WITH CHAIRS, KEYS, &c.

	s.	d.
1 wooden sleeper, adzed and bored	3	7
2 B 1 8-inch chairs	2	8
4 galvanised screws	0	7¼
4 spikes	0	3½
4 trenails	0	1¼
2 pieces of felt	0	2
2 keys	0	3
Total cost per sleeper	7	8

COST OF IRON AND STEEL SLEEPERS, CHAIR BRACKETS, &c.

Weight of Materials.

	Iron Sleepers. Cwt.	qrs.	lbs.	Steel Sleepers. Cwt.	qrs.	lbs.
1 sleeper punched	1	0	26	0	3	16
4 chair brackets	0	0	22¼	0	0	22¼
2 liner plates	0	0	12¾	0	0	12¾
12 rivets	0	0	5	0	0	5
	1	2	10	1	1	0

Cost of Material—Steel Sleeper.

	s.	d.
Steel sleeper, 1 cwt. 1 qr. at £5 5*s.*	6	7
2 keys	0	3
	6	10

Cost of Labour on 374 Iron Sleepers.

	£.	s.	d.
Smiths' work	3	11	8
Shoring	1	18	4
Punching and putting together	3	17	11
Riveting	4	13	6
Painting	1	11	2
	15	12	7

Cost per sleeper— £15 12 7 / 374 =	0	10
Total cost per steel sleeper	7	8

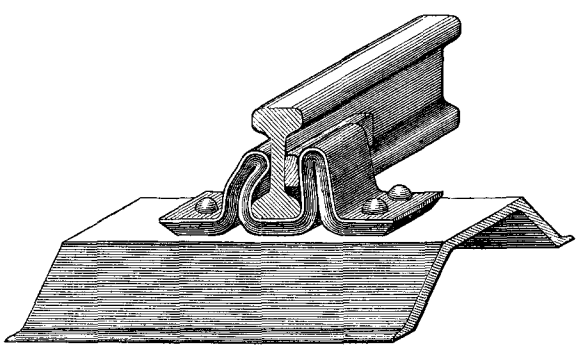
Mr. Williams. Having regard to the satisfactory behaviour of these sleepers, and the enormous amount of traffic which had already passed over them on one of the most severely worked portions of the main line of the London and North Western Railway, he was disposed to agree with Mr. Bruce in thinking that something which deserved the name of a permanent sleeper road had at length been discovered.

Mr. Rapier. Mr. R. C. RAPIER thought it would be hardly wrong to say that the leading characteristic of permanent way had hitherto been that there was nothing permanent about it. It could scarcely be satisfactory to any engineers, in an essentially iron country, to know that their permanent way required complete renewal every few years. The Author of the Paper had been favoured for the last few years, by the low price of iron, in the endeavour to produce an efficient iron permanent way. He had taken up much the same ground as that occupied ten years ago by Mr. Livesey, who had attained considerable success, but who unfortunately was overtaken by the great rise in the iron markets during the years 1872, 1873, and 1874. At that time the price of iron rose to a point which precluded the use of wrought-iron sleepers. With the present price of iron, sleepers could be made at about the figure given by Mr. Price Williams; but even if there should be a considerable rise in the price, he thought the capital account might fairly be debited with some portion of the cost of the iron permanent way, say not more than the value of the old material; which in the case of iron sleepers he thought might be about half the original cost. So that, favoured by the low price of iron and by the inventions of many ingenious minds, there appeared to be now a prospect of producing a really permanent iron way. Up to the present time, for the traffic on high-speed lines, nothing had been so good as the square 12 inches by 6 inches sleeper held with wooden fastenings; but no one could consider that method as really satisfactory and permanent. With iron sleepers difficulties arose in the fastenings much greater than with wooden sleepers. In the latter the weakness was essentially in the sleepers; in the former the trouble was all in the fastening; the screws would work loose, even if they were riveted over, and the clips of course set up a chatter. There was nothing for it but to rivet one jaw of the chair securely on with two or three rivets to the sleeper. That method of fastening commended itself to his mind, as more satisfactory than any system of bolting or keying. The element of cost was a cardinal one. It might be well worth while in the North Eastern districts

to try and develop the use of wrought-iron sleepers; because, if the world were satisfied that iron was the proper thing to make sleepers of, Middlesbrough must flourish, and consequently the North Eastern Railway. It was satisfactory to know that some assistance in the development of the question had been derived from a purse so well able to bear it as that of the North Eastern Railway. He thought it was only fair to advert somewhat more fully than had hitherto been done to what had been accomplished previously by others. He had lately inquired how Mr. Livesey's wrought-iron sleepers had been getting on. Many of them were fastened with rivets, much in the way now proposed by Mr. Webb, one side of the jaw being riveted on with a space left in which to insert an iron key, the other jaw being a fixture. It would never answer to leave the ends of the sleepers open; the road, round curves especially, would travel outwards. He had seen even wooden sleepers, where the platelayers had been obliged to pack up the ends tight and solid, to prevent the road going out bodily on a warm day. The more square the angle at which the end of the iron sleeper was closed the better, so as to get a good end-way hold on the ballast. Mr. Rapier.

Mr. Russell Shaw said that a sleeper resembling that of Mr. Webb was patented in England in 1860, and had been in use in Mr. Shaw.

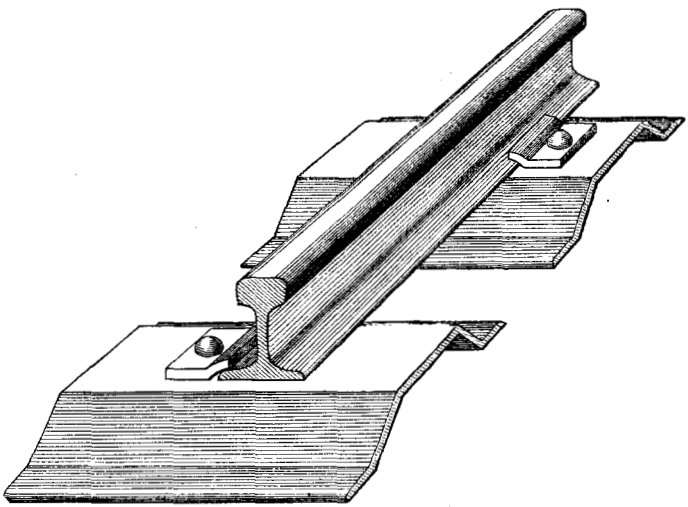
Fig. 41.



Belgium for some years, but not on the same gauge as that of the English lines. Mr. Le Grand, who had great experience with wrought-iron sleepers, having devoted his attention to the subject for upwards of twenty years, and had manufactured more than 5,000 miles of wrought-iron railway sleepers, chiefly in connection with mines, and some for the ordinary gauge, was present, and had deputed him to say a few words on the subject. Mr. Le Grand's sleeper though similar to Mr. Webb's, represented in Fig. 41, was

Mr. Shaw. not exactly like it, as it was made of one piece of iron only, which was closed up while hot by a machine for the purpose. There were either two or four rivets, one or two on each side. This chair being riveted to a "Vautherin" sleeper, it was found to be exceedingly efficient, particularly in mines, where the Vautherin iron was replaced by worn-out rails, which then served as sleepers. Mr. Le Grand's favourite system, however, was that of a sleeper entirely of one piece. His permanent way consisted of only the rail and the sleeper, or, properly speaking, two sleepers, because, as would be seen from Fig. 42, there were sleepers which clipped the rail outside, and sleepers which locked the rail inside. The

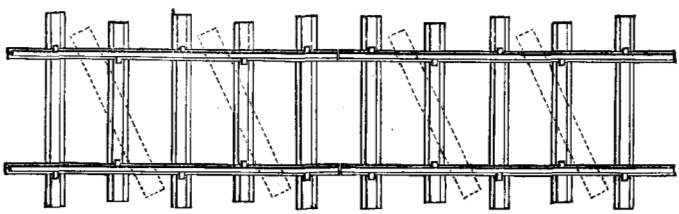
FIG. 42.



clips were riveted on to the Vautherin section of iron by means of one heavy square rivet, the inclination to the rail of 1 in 20 being given by the cant of the sleeper. It would be seen that this was a perfect fastening, without bolts, nuts, or keys, and he thought that was the nearest approach to a permanent way. The only tool required to secure the road was a hammer to bring the inside locking sleepers into place, as in Fig. 43. He did not speak of the 17,000 miles of railways in England, or the 100,000 miles of railways in the United States. The cost of repairing the lines in England was a question for the engineers in charge, who knew, doubtless, the best way to satisfy the shareholders and the public. He referred particularly to lines in Australia, New Zealand, India, and Turkey. It was stated in the Paper that a sleeper

for the 4 feet 8½ inches gauge ought not to weigh less than 90 lbs., and to have as few loose pieces as possible. Mr. Le Grand's sleepers weighed 90 lbs., their length being 8 feet 2 inches and 7 feet 8 inches, the cost 6*s.* for a 4 feet 8½ inches gauge, and they had no fastenings. Taking two thousand sleepers per mile, the weight was 81 tons, as against 170 tons measurement for two thousand wooden sleepers 9 feet by 9 inches by 4½ inches. Since he had commenced business Mr. Le Grand had made about ten million sleepers, and many of those supplied by him twenty years ago were still in a good condition, a fact which dispelled any idea of dangerous corrosion. There were two thousand large sleepers on a railway in Belgium which had never been touched Mr. Shaw.

FIG. 43.



Scale ⅛ inch = 1 foot.

since they were laid in 1877. In that year the Indian Government asked for specimens of all kinds of permanent way; many were sent in from various quarters, and there was some of the old iron at the India Office now. He did not think that much came of it, and certainly none of the systems presented were adopted. At the time referred to he saw a gentleman connected with the Indian railways, and said he thought he had a system which would answer the purpose. He was then asked, "Has it been down ten years?" and he replied, "No." He was also asked, "Have you ten thousand sleepers laid anywhere?" and he replied, "No." "Then," said the official, "it is useless to come to me." That was very much the story that all gentlemen had to tell with regard to any improvements they proposed.

Mr. J. LIVESEY said that on the occasion referred to his system of sleeper was adopted for the Indian States Railway, and a large quantity ordered. Mr. Livesey.

Mr. RUSSELL SHAW was aware that Mr. Livesey's sleeper had been ordered, but he did not know that any specimens had been sent to the India Office. He had thought that it was not necessary for Mr. Livesey to send his sleeper anywhere, because it was so well known. Mr. Shaw.

Mr. Bergeron. Mr. CHARLES BERGERON said that he had attended some experiments conducted by Professor Willis, of Cambridge, on the flexure of rails on the passage of trains running at great speed, at the meeting of the British Association at Birmingham in 1849. Similar experiments had been made before that date at Portsmouth by Sir Henry James, R.E., and Captain Douglas Galton. Two light rails were laid upon two solid supports distant several feet from each other. A heavy vehicle standing at the middle of the rails produced a depression of about $\frac{1}{2}$ inch. The same vehicle, descending an incline and running over the light and flexible rails, forced them down four times deeper, or about 2 inches, not at the middle of the rails, but at two-thirds of the distance from the point at which it entered upon the rails. The tendency of the vehicle, obliged to mount over the remaining distance, was to jump and leave the track. The conclusion drawn from that experiment was that, for obtaining a solid permanent way, it was necessary to employ rails not subject to bend, or to have the supports close to each other. According to Captain Douglas Galton, under a line of rails 30 feet long, American engineers had put sixteen sleepers, the distance between two adjacent supports being less than 14 inches. Under such conditions the permanent way of the Pennsylvania Railroad was so firm that the manager proposed to run express trains at a regular speed of 60 miles an hour.

In the present state of railways, the successive sleepers or supports of the rails did not present the same amount of resistance to the vertical pressure of the trains. On the railways with wooden cross sleepers, as used generally in Europe and in America, the longitudinal system of permanent way might be considered as pyramids of compressed ballast, the intervals between those pyramids being filled with porous ballast, presenting no resistance to the horizontal displacement of the sleepers. Rain-water percolated freely through it. Gradually particles of sand filled the interstices; the water did not escape, the pyramids of compressed ballast which supported the sleepers lost their consistence, began to sink, and required fresh packing. The engineer of one of the principal railway companies in France had given him as a definition of the maintenance of the permanent way, that it was a continual fight between the engine drivers and the platelayers.

In walking along a line open for traffic, upon which trains ran at great speed, the sleepers would be observed to undulate according to the oscillations of the rails. It might happen that several consecutive sleepers sank deeper than those between which

they were included. In that case the rail was supported by two chairs at 9 or 10 feet distance, and under the pressure of a heavy locomotive running at a speed of 60 miles an hour it could not preserve its rigidity. It bent exactly as the flexible bars in the experiments of Professor Willis to which he had referred. The locomotive which ran over it had a tendency to jump and leave the way. In his opinion the greatest number of instances of trains leaving the line were produced in that manner. Mr. Bergeron.

After an accident on the Midland Railway last year, Colonel Yolland made the remark that accidents of that sort were more frequent upon lines where the sleepers had been newly packed, than on those which had not been repaired.

He was not disposed to believe that the permanent way with iron sleepers was able to resist the destructive action of trains running at great velocities. In his opinion its solidity depended in great measure on the comparative amount of its dead weight. The Author did not mention the weight of the iron cross sleepers used on the North Eastern Railway at Middlesbrough. He supposed they were lighter than those of wood. They would move horizontally under the pressure of trains at great speed more easily than the latter. For that reason he believed the road with the double-headed rail, as generally employed in England, was more stable than the Vignoles rail used on the Continent. With cast-iron chairs, which weighed about 40 lbs. each, every sleeper was embedded deeper in the ballast in proportion to the thickness of the chair; its dead weight was increased to about 80 lbs., and it would be much more difficult to move them than the others.

He agreed that one of the best kinds of ballast was small broken stones or slag. Calcareous broken stone, from the deep cuttings in the Jura and the Pyrenees, was used in large quantities in France for ballasting the lines of the Paris, Lyons and Mediterranean and of the Southern railways. The permanent way was better supported with such ballast than with sand; but it had less elasticity, and the wood was more exposed to decay by the action of humidity and air circulating freely through the interstices of the broken stones than when embedded in sand. The packing of the iron sleepers with broken stones 2 inches thick did not appear to him very easy, and he did not see how it was possible to secure uniformity of resistance for the sleepers when there were no means of ascertaining the quantity and the density of the ballast underneath.

After many trials, and many years of study and observation, he

Mr. Bergeron. had arrived at the conclusion that the problem of the best permanent way could be solved by the application of two principles:—

1st. Ballast of sand, instead of being spread in a loose state over the formation of the railway, ought to be embedded in it and compressed by rollers, like the broken stones of a Macadam road.

2nd. The sleepers, of wood or iron, instead of being packed with ballast caulked underneath, ought to be sunk into the compressed sand, or ballast, in the same manner as piles support the foundation of an edifice were sunk in the ground.

In the early period of railways, the rails were attached to blocks of stone lying on sandy ballast. It was a great mistake to treat wooden sleepers in the same manner as stone blocks, and to bury them in a stratum of loose ballast, 2 feet thick, above the formation of a railway. The wooden sleepers ought to rest upon a solid foundation, and engineers had begun to understand this, as they showed by advising that broken stones should be substituted for sand or fine gravel for ballasting railways. He had observed that the most steady parts of a railway, upon which trains ran with smoothness, and never got off the way, were long viaducts or bridges, on which the rails rested upon longitudinal wooden beams laid to an accurate gauge, on the iron girders of the viaduct. There was no flexure of the way, no tendency to derailments; the wood possessed sufficient elasticity to protect the iron girder against the destructive pressure of heavy trains rolling at great velocity. A similar reason had induced engineers to apply the Mansell wheels, with wooden centres, as cushions to counteract the pressure of the tires in contact with the rails. He had always been in favour of rails bearing upon wood. He thought the wood ought to rest upon ballast equal in rigidity to the iron bridge girders. For that reason he proposed to put the ballast in cuttings or ditches made in the formation of the railway, and to compress it with heavy rollers exactly as those used for metalling Macadam roads. There was no danger of having the fine ballast or sand of the railway turned into mud, because the rain-water could not percolate through it. It was the same with good Macadam roads; any rain falling upon the surface flowed over without penetrating the road. It would be the same with railways ballasted in the manner which he proposed.

More than ten years ago he offered to renew the permanent way of the Northern Railway of Spain between Madrid and the Escorial. The ballast on that section was quarry sand, rather

clayey, through which rain percolated with difficulty. Although in that country rain was not frequent, and the permanent way was in tolerable order, it happened occasionally that it was dangerous to run trains at great speed after rain. The railway was then covered with water, and the ballast, being very muddy, could hardly support the weight of heavy trains. To remedy this state of things the engineer of the railway had made cuttings across the line at every joint of the rails, and had filled them with broken stones, so that the water between the rails was able to escape through the interstices between the stones. The three sleepers at every joint of the rails, lying on the stones, did not move much at the passage of the trains; but the others sank in the muddy ballast, and the road was exposed to great springing which prevented its being travelled over with safety by rapid trains. He observed that this circumstance produced a singularly destructive effect on the rails. They were put out of order not as was generally the case, by the friction of the wheels, which had a tendency to grind off the surface of the metal, but by frequent bendings and deep oscillations of the rails, the iron pile, composed of different seams of iron compressed together in rolling the rails, had those seams unwelded, and long ribbons of iron could be easily detached from the rails by hand. Mr. Bergeron.

On the 27th of January 1873, he addressed to the board of directors of the railway a report describing a new sleeper and a new mode of laying down the permanent way of the section from Madrid to the Escorial. In his report, he had described the advantages of the sleeper.

1. The bottom of the Vignoles rail was maintained by the sides of the cutting made in the vertical iron bar; it could not move, and the accuracy of the gauge was perfect.

2. The rails lay upon wood, which was preferable to the metallic surface of iron sleepers on account of its elasticity.

3. The blocks of hard wood, principally of green oak trees which grew in Spain, and were cut only to be burned as firewood, would be found in abundance on the spot, and were to be bought at a very low price.

4. Such short wooden blocks could be creosoted or pickled more easily and at much less expense than large sleepers.

5. After many years, at least double the life of an ordinary sleeper, these blocks might have to be replaced—an operation that could be done at a low price, because the vertical cross-bars, the bolts, and the nuts and spikes could be used again with new blocks.

Mr. Bergeron.

6. In the curves, the gauge could be easily widened with a file, a chisel and a hammer, by enlarging the cuttings of the bar on the spot.

7. When a train ran off the line upon a permanent way supported by iron sleepers, these were completely ruined and could not be repaired; with the composite Spanish sleeper the common iron bar could be dressed and forged at any smith's shop.

8. The usual iron sleepers must be made of steel or wrought iron of the best quality, and could be rolled only in the large ironworks of England, Belgium or France. A quadrangular bar, as the one for the composite sleeper, could be obtained in every town of Spain.

When he proposed his scheme to the Spanish engineers, he had not thought of changing the ordinary manner of making the permanent way, by laying it upon a thick deposit of loose ballast spread on the formation of the railway. It was in the ballast itself that he proposed to make the ditches, to be filled afterwards with broken stones at the bottom and sand on the top, in which the wooden blocks were to be rammed, and were to act as the stone blocks of the first railways. He had come to the opinion that ballast simply spread over the formation of a railway had not sufficient cohesion to resist, without fear of derailment, the high velocities that trains in future would be likely to attain.

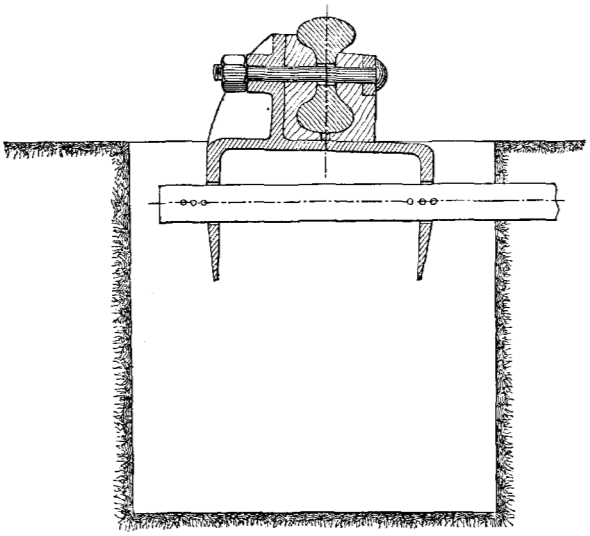
Obviously particles of ballast which were not inclosed in frames and surrounded by supports, would be displaced and move and roll in every direction, both from atmospheric causes and from the shaking and concussion of the passing trains. That evil must be prevented. He had ascertained from experiments on the Swiss railways, of which he took the management by contract twenty years ago, that the lines on which the ballast was embedded in the formation, as the broken stones used for metalling Macadam roads, were more easily and more cheaply maintained than the others.

He had at the same time conceived the idea of a new iron sleeper and system of permanent way (Fig. 44). In this, every sleeper was composed of two troughs in cast or wrought iron, tied at each end by cross-bars maintaining them at the required gauge. The troughs were 2 feet long and 10 inches wide. The vertical sides had a sharp bottom-edge to facilitate their penetration into the compressed ballast. The top of the trough was inclined $\frac{1}{20}$ according to the usual cant of the rails. The cross-bars passing through the four vertical sides were tied to them by bolts which maintained the gauge accurately. The trough was surmounted by a longitudinal jaw against which the rail was supported as

by a fish-plate, and was tied to it by three bolts and spring nuts. Mr. Bergeron.

The rails would be pierced at the works with the proper holes for the bolts which tied them immovably to the jaws of the troughs. The joint of two rails occurred at the middle of a trough, and a single bolt held both ends tight. The distance between two consecutive sleepers being no more than 1 foot, the rail, strongly

FIG. 44.



attached to the jaws at the extremities of the troughs, would not appreciably bend, even under the heaviest locomotives. In the formation of the roadway, and under each line of rails, two ditches would be dug 18 inches deep, 18 inches wide at the top, and 15 inches at the bottom. The ditches were to be filled with sand mixed with an equal volume of water. The molecules of sand carried by water filled the interstices of the earth in which the ditches had been dug. Gradually the sand acquired greater density and became impervious to water. Before it was quite dry it was submitted to the pressure of a heavy cast-iron roller, which transformed it into a soft sandstone, into which the two vertical blades of the trough could easily penetrate when properly sunk by a rammer, and at the same time were able to support, without sensible alteration of form and volume, the weight of any large mass standing or rolling over it. It was in such walls that the

Mr. Bergeron. troughs were sunk; they would be struck by a rammer till the plate at the top lay evenly on the sand wall and could not be driven deeper. In that condition, the rail was laid on the trough and strongly bolted to it. The permanent way was then in order. The sleepers could not sink; and the trains drawn at the highest speed by the heaviest locomotives would roll over it like sledges upon a frozen lake, derailment becoming almost impossible.

Mr. Rawlinson. Mr. R. RAWLINSON, C.B., said he scarcely need tell railway engineers that one of the worst foundations for a railway would be a hard base. That might seem paradoxical, but it was a fact, and an engineer who wished his road to be smooth in running, and to be enduring, would have an elastic foundation. The road across Chatmoss was perhaps more easily kept in repair than any similar length of line in England, because it was elastic throughout. He could recollect very well the commencement of railway making, and he remembered when stone blocks were placed upon the hard bottoms of the cuttings. It was well known what came of that. At great risk they had to be removed. He was old enough to recollect a much more absurd arrangement, when one of the greatest engineers in another department was called upon to design a line of rails, and was so particular to have a rigid foundation that he brought up rubble sleeper walls through all the embankments, in some instances even from a depth of 60 feet. The entire length of line was thus made with stone sleepers and with Vignoles rails. The consequence was that when the carriages ran over the line, the vibration was most annoying. Road-makers also knew well that a rocky foundation was most destructive, unless they got rid of the jar by cutting the rock away and putting in a certain depth of intermediate ballast. He did not think that any engineer who was practically engaged in making and maintaining railways would seek to obtain even an approximately solid foundation for the sleepers. He would rather seek an elastic foundation, such as fine gravel would give, one that he could easily manipulate in raising and packing the sleeper. He would be contented with that, and would shun anything approaching to a permanently solid base; for wherever such arrangements had been made, they had proved a failure. On the Great Western railway, for instance, where piles had been put across the embankments underneath the ends of the rails, they had to be cut off in order to restore the line to a workable condition. Railway engineers now knew by experience that the rails and sleepers lasted longer upon the embankments than in the cuttings; and, inferentially, that the rolling plant also lasted longer.

Mr. W. MARTINEAU said he thought that every engineer who had had experience in materials in tropical climates would welcome any system which should combine sufficient durability and strength with economy and lightness. It was well known that all timber, even the best, decayed in tropical climates with a rapidity unknown in this country; and the transport of materials was also a very serious matter. Engineers therefore sought especially for lightness and sufficient durability. It was not a question of solidity such as that required for railways with the enormous traffic of the lines in England. He could not agree with the statement that the corrosion of iron sleepers and iron permanent way was almost nil; it might be so in this country, but it was not so in tropical climates. Of course the conditions specified by the Author of perfectly dry ballast, good drainage, and the like, might ensure, even in tropical climates, a greater durability for the permanent way, but that could not be the case when a new line was being constructed. He had seen a great deal of material used in tropical climates, and his experience was that even iron decayed with great rapidity, varying according to the soil. The soil itself no doubt contributed very much to it, and the heat of a vertical sun upon the surface of a wrought-iron sleeper in many soils, especially where there was much vegetable matter, as in tropical forests, generated acids which acted rapidly upon the iron. It was highly desirable, therefore, that wrought-iron sleepers sent to hot climates should be protected by the best possible means. With regard to the end-shifting of sleepers, it was possible that the curved form of sleeper might to some degree prevent that effect, but he agreed with what had been stated as to the necessity for the end-turning or for a web in the centre to prevent movement, because in lines in undeveloped countries and in mountainous districts curves were employed which were not known in this country. On sharp curves and steep gradients the pressure on the outer rail was very great, and anything which would prevent the end movement arising from that would be desirable. He thought that very good fish-plating presented a resistance to end movement. He exhibited some photographs showing what a good fish-plated line would stand. They represented a railway in the north of Chili, in a district supposed to be almost rainless. Last year heavy floods occurred, and embankments and bridges had been washed away, but in every instance the rails formed suspension bridges over chasms from 300 to 500 feet in width. Mr. Martineau.

Mr. W. A. DAWSON said he thought there was one disadvantage in the cross sleepers and fastenings of Mr. Le Grand's system. It Mr. Dawson.

Mr. Dawson. appeared very simple and good, but he believed that after the line was once laid and packed, when it became necessary to replace a rail, the ballast would have to be disturbed; to get a rail out it would be necessary to twist one of the sleepers sideways, and this would entail the removal of nearly the whole of the ballast up to the next sleeper. That appeared to be a serious disadvantage, which, on a line where the traffic was considerable, would render it almost unavailable.

Mr. Shaw. Mr. RUSSELL SHAW replied that that was the disadvantage, but the work would only have to be done once in every twenty years, or as often as the rails were worn out.

Mr. Dawson. Mr. W. A. DAWSON remarked that where the traffic was considerable the rails would not last twenty years.

Mr. Allan. Mr. G. ALLAN was afraid that the impression conveyed by the Paper would lead to the opinion that English engineers were behind the times in the matter of iron permanent way, as compared with Continental engineers. That certainly was not the case. English engineers had been the first to enter upon the subject of iron permanent way, and they had been conversant with it during the past twenty years. In India iron permanent way had taken the form of pot sleepers, bowl sleepers, and others of different type, but on the same principle, and the system had worked satisfactorily. Mr. Livesey had been one of the pioneers, and his sleeper had always been considered satisfactory. The type which had been preferred by English engineers was the pot sleeper, which he thought might be more properly called the chair sleeper; but there was no doubt that that form had many advantages over the longitudinal or transverse sleeper. He knew from conversation with Belgian engineers that they considered the Hilf longitudinal system rather objectionable. It was difficult to pack and maintain the ballast under it; the blows of the engine indented it; and it was impossible for the platelayers to take out the indentations or waves, so that the line became crooked. The pot sleeper had the advantage of being very readily packed. Greaves's sleeper had a couple of holes in it, and could be packed on the top; and the others were so shallow that they could also be easily packed. There was no doubt, however, that a flattish bottomed sleeper had an advantage over the pot sleeper if it had such a depth at the ends as Mr. Bruce had mentioned. Unquestionably vertical ends or flanges were preferable to any rounded surfaces. As the result of some years' experience, it appeared to him that iron surfaces were objectionable, all things considered. For high speeds the question of iron sleepers had

not been touched in England, simply because timber continued to be cheaper in first cost. That was not the case on the Continent, where the shoe pinched more tightly. Unfortunately, however, Continental engineers had not profited by the experience of their brethren in India, otherwise they would never have adopted the transverse or the longitudinal sleeper. Mr. Webb had adopted a sleeper that would no doubt answer. Something was required which was more economical both in first cost and in maintenance than either the transverse or longitudinal systems. In England, on lines of high speed, something more substantial and durable was required. Light sleepers would be knocked to pieces, the engines would get off the roads, and the wagons would be soon destroyed. After the introduction of the pot sleeper, the breakages in India had been so enormous that wrought iron was insisted upon, and now that was being gradually superseded by steel. No doubt with a good steel sleeper there was greater durability than with either cast or wrought iron. The style of sleeper which had suggested itself to his own mind was one with a good wooden cushion combined with iron. It had been approved by the engineers of the Metropolitan and Metropolitan District Railways, and engineers of such lines would not consent to make a trial of a sleeper on their main roads for the first time unless there was something substantial and good about it. Unfortunately the price of iron became so high that the system was not carried out. A period had now been reached in England when engineers would certainly have to take up the question of steel sleepers, and devise some system of combining sleepers and rails in such a way as to present an elastic road. It would be a question whether the interposition of a good wooden cushion would not be more advantageous than having two metal surfaces in contact. Mr. Allan.

Mr. Ernest Benedict observed that in 1877 he had read a Paper on metal sleepers for railways before the Institution of Engineers and Shipbuilders in Scotland,[1] and his four years' experience since that time had confirmed the opinion therein expressed, that, under certain circumstances, it was impossible to improve upon a cast-iron bowl sleeper if it were of a proper shape and properly maintained. He understood from Mr. Leslie that there were nearly half a million iron sleepers on the main line of the East Indian Railway, which could hardly be called a line of small traffic. Mr. Benedict.

1 *Vide* Transactions, vol. xxi., p. 105.

Mr. Arrow. Mr. J. T. ARROW said that only wrought-iron sleepers had been mentioned as having been actually employed, but that since 1874 steel sleepers had been used on the Oude and Rohilkund Railway, and had answered most satisfactorily, the amount of repairs being absolutely nil. The sleeper was formed of steel $\frac{3}{16}$ of an inch thick, and was stamped into a pot 6 inches deep with corrugations round the sides which were found to increase the strength considerably: the sleeper weighed 33 lbs. The rail was held in position by three clips, two of which were riveted, the third being held by nut and bolt. A Sterne's washer was interposed between the nut and the flange of the rail, which prevented its being shaken loose; £100,000 worth of those sleepers had been sent out, and there were large orders still uncompleted. The rail used was of the Vignoles pattern. The sleepers gave a bearing surface of about 4 square feet each. The road was not too rigid or too elastic, and the wear on the rolling stock had been considerably reduced since that form of sleeper had been adopted. Four different kinds had been tried—two of wrought iron, one of cast iron, and one of teak, all of which had been given up and were being replaced by steel. The cost of the steel sleepers was about the same as that of wrought-iron sleepers. The cant of the rail was effected by the tie-bar and the position of the holes or slots in the sleepers. When the sleepers were stamped, the holes to receive the tie-bars were both punched while they were in that position in order to ensure similarity in every sleeper. The sleepers were fastened together by means of gib and cotter; and with these connections they never shook loose. The gib was fixed in the tie-bar by means of a recess, and it could not be shaken out. The cotter was a split one, and that prevented any movement. By means of the recess in the gib, a variation of gauge to the extent of $\frac{1}{2}$ inch could be obtained between the sleepers. The plan of laying the rails direct by a rigid tie-bar independent of the sleeper had been found to answer better than passing the tie through the sleeper.

Mr. Wood. Mr. C. WOOD, in reply, desired to make one or two remarks on the drawings that had been hung upon the wall. With regard to the design by Mr. C. Bergeron (Fig. 44), he might mention that a similar plan had been described in the volume of Proceedings of the Institution for 1857, except, perhaps, that the tie-bar and fastenings were a little different. He was aware that many of Mr. Le Grand's sleepers had been used in collieries during the last fourteen or fifteen years. Some of them, from Earl Durham's collieries in the county of Durham, had been taken out only a short

time ago and weighed, and after fourteen years' use in the mines, they had only lost ½ ounce. That was a pretty good criterion as to the question of corrosion in a damp atmosphere. Practically the sleepers were as good as new. Reference had been made to the turning down of the ends of sleepers to prevent end shifting. He had before him a model showing two sleepers—the English sleeper (Fig. 45), 9 feet long, and the Continental. The Continental sleepers were from 6 feet to 6 feet 9 inches, the largest being about 7 feet long (Fig. 46). If these short sleepers were watched as a train was going over them, it would be seen that the end worked considerably. The hammering of the wheel over the rail knocked the ballast down under the rail, and it was also pitched out away from the ends. Practically there was no bodily end shifting. The idea had arisen in former times through bad fishing, and through an insufficient outside bearing of the sleeper. If the joints in the rails were moderately tight, and a good sized sleeper was put down, no end shifting would take place. Where

Mr. Wood.

FIG. 45.

FIG. 46.

a short sleeper was used, something was wanted at the end to keep the ballast from working. Immediately under the rail, whether it was of wood or iron, there was a vacant space, and in this respect Mr. Livesey's sleeper was worse than the Continental sleeper.

An end without resistance, or with lines of least resistance to prevent shifting, would somewhat resemble the breast of a plough, as represented by Mr. Livesey (Fig. 27). Evidently there must be a hollow underneath—on account of the compression of the ballast—and as the wheel passed over the rail it would pitch the ballast off the top towards the end; and this being clearly the case (Fig. 46), he wished to know what end resistance there could be there, and what was therefore the good of the complicated, turned-down end? There could be no doubt that a short-ended sleeper, such as he had described, must be a bad one. Fig. 28 showed the effects of a good, wide-spread sleeper with outside bearings, and of a short one, as also Figs. 45 and 46. The longitudinal sleeper, the

Mr. Wood. bowl, and the short sleeper, all came under one category. The bowl sleeper was nothing more than a longitudinal sleeper cut up into pieces. They were all far better than the short-ended sleeper. The hammering of the rail over the longitudinal sleeper caused a uniform subsidence in the ballast immediately under the rail, while, on the contrary, in a short sleeper the ballast was hammered away under the rail; thus causing a riding on the ridge in the centre between the rail (Fig. 46). That was why it was said on the Continent that some of the short sleeper railways were worse to ride on than the longitudinal. With the longitudinal system there was a general subsidence uniformly all the way along, whereas the short sleepers rode on the middle ridge between the rails, and as they travelled along the carriages and engine pitched and rocked from one side to the other, there being nothing to steady them. With regard to the long-ended sleepers he thought that Mr. Webb and he were the only persons who had availed themselves of the experience of English practice. To get a good, steady road for quick travelling, there must be a long sleeper. The strains upon the sleeper were completely reversed. In the case of the short sleeper there were strains of tension on the top, and a compression on the lower web, because there was no outer support; but the ends of a 9-feet sleeper extended beyond the zone of disturbance of the ballast from 1 foot to 15 or 18 inches and outside that zone the sleeper took the bearing (Fig. 45), the strains on the sleeper thus became completely reversed, the tension being on the foot. That was no mere theory; it could be seen on looking at the sleepers on the North Eastern Railway and at Mr. Webb's on the London and North Western Railway. It would be observed that in all cases the ballast had more or less given way through the elasticity of the sleeper immediately under the rail, but outside this zone of disturbance the ballast lay unmoved. The sleeper had thus three good bearings, the two outside ones for steadiness of travelling being the most important. The support between the rails was done away with, and the value of the bearing surface upon the ballast was more than doubled (Figs. 45 and 46), which conclusively showed the value of the long sleepers over the short, and also showed the fallacy of the turned-down end theory. A further proof on this point was supplied by Mr. De Bergue's plate sleeper, thousands of tons of which had been in use for thirty years, and of which during the last two years the Author had made several thousand tons more. Engineers in Spain, where they were in common use, surely would not go on ordering them

year by year if they found them shift. Again, large quantities of the Denham-Olpherts sleeper (a modification of De Bergue's plate-sleeper) were being sent out to India at the present moment, and had been sent for several years; therefore no importance could be attached to the end shifting theory by the Indian State railways engineers. Mr. Bruce had mentioned that on the North Eastern Railway several of the sleepers had broken. Many of the sleepers employed were made of puddle bars, and had cracked through the lower web, and the ends had what the platelayers called "cocked up." That was the effect of what he had been explaining. The ballast had given way under the rail, and the whole weight of the heavy traffic had come on the centre and on the outer ends, so that the strains had been reversed; from a tension on the top it had become a compression on the top, and a tension through the lower web, which had not been quite strong enough; but since this had been strengthened not one sleeper had broken. Mr. Wood.

A length of 2 miles of the sleeper, represented in Fig. 24, had been laid at Middlesbrough. One half was over a sharp curve, over which three hundred and fifty trains per day passed up and down; the traffic over one line of rails alone had amounted to 60,000,000 tons.

It had been stated that some of the iron-plate sleepers in India had replaced and been mixed with the wooden ones. That plan had been tried on the Continent and had failed, because, wherever wooden sleepers had been in use the rails were both out of tilt and out of gauge. If, therefore, an iron sleeper were put in between wooden sleepers the rail would be drawn up tight to gauge, and this would twist the rails in and out. If the old sleepers were bad the road must be completely relaid. The attempt to mix one kind of sleeper with another was a mistake. With regard to the question of corrosion he wished to direct attention to a sleeper that had been in use thirty years on the Bristol and Exeter Railway, which was somewhat corroded. Wherever there had been a loose bolt the heads had nearly worked through. He also exhibited a fish-plate taken off the North Eastern Railway after three years' use. It had been recently removed on account of the heads having sunk deeply into the fish-plate. He likewise exhibited a specimen of the Barlow rail which had been in use twenty-two years, having been laid in ballast in Spain. Two cargoes of rails had been recently brought into Middlesbrough to be cut up and re-rolled, and the specimen was a piece that had been cut out from them. It would be observed that the rail had the scale which was on it when it left the works. The rails

Mr. Wood. had been destroyed, the heads worn off, and the ends battered to pieces, but there was no corrosion. He had also a tie-bar, used on the Guisborough Railway, which had been buried twenty-five years, and the scale was hardly off. In some neighbouring works to his own a tie-bar had been buried sixteen years in the ballast, and the scale was on it still. He thought, therefore, that whether in Spain, in England, or in India, there was nothing to fear from corrosion. No one had challenged the simplicity of his sleeper and fastenings. The bars on the North-Eastern Railway which had failed were all rolled lengthways irregularly and badly. The shoulders had been cut away, and Mr. Cudworth showed him one that was taken out which never had any shoulder. When these sleepers were made no machinery existed for bending and cutting the shoulders, and all was done by hand, and by contract. At the present time everything was executed by machinery, since which, in all the lines where the sleepers have been laid, not a single failure has taken place. Mr. Cudworth admitted that the fastenings and keys had held better than any that had ever passed through his hands. He had mentioned the cost in one or two instances, but he had come to the conclusion that it was better not to do so because in some instances the heavier and more complicated forms cost less per yard than some of the more simple forms, the difference depending upon the prices of material and labour. He had, however, recently made a calculation bearing upon that subject. He had avoided any mention of pots and bowls because they were too numerous for his liking, and he thought it would be better to confine himself to the two systems of longitudinal and transverse sleepers.

Thus cast-iron bowls for a 5 feet 6 inches gauge, weighing, with the fastenings, 230 lbs., cost, free on board ship at Middlesbrough, 10*s.* a pair. Adding 2 per cent. for breakages between the works and the place where they were laid, 30*s.* for freight, shipping charges, and insurance, and 20*s.* for inland carriage, all of which were moderate charges, the cost of a pair of pots and bowls would be 15*s.* 6*d.* or £1,364 per mile. The cost of a 5 feet 6 inches wrought-iron sleeper, with a stronger section than any that he had shown as being in use on the Continent, weighing 116 lbs., 9 feet 6 inches long and 9 inches wide, with the clips, including the same charges, was 10*s.* 3½*d.* against 15*s.* 6*d.*, showing a saving of one-third, and this same sleeper would give 1 square foot more area on the ballast than the oval bowls. Taking the round pots and a lighter sleeper for the 4 feet 8½ inches gauge, the price in England was 7*s.* 10*d.*, and for wrought-iron sleepers 7*s.*; in India,

COMPARISON BETWEEN the COST of CAST-IRON BOWL or PLATE SLEEPERS and HOOD'S PATENT WROUGHT-IRON SLEEPERS, for DIFFERENT GAUGES. Mr. Wood.

Particulars of Sleepers.	Gauge of Railway.	Weight of each Sleeper and Fastening.	Cost of each Sleeper in England. F. O. B. Middlesbrough.	Percentage added for Breakage before laying down abroad.	Cost of each Sleeper, with 30s. per Ton Freight and 20s. per Ton Inland Carriage.	Weight per Mile.	Cost per Mile abroad, with 30s. per Ton Freight and 20s. per Ton Inland Carriage.	Saving per Mile in favour of Wrought-iron Sleepers.
	Ft. In.	Lbs.	s. d.		s. d.	Tons.	£.	£.
Two cast-iron bowl or plate sleepers, with tie-bar, gibs, cotters, &c. .	5 6	230	10 0	2	15 6	180¾	1,364	..
One wrought-iron sleeper 9 feet 6 inches long by 9 inches wide, with clips	5 6	116	7 8	..	10 3½	91¼	906	458
Two cast-iron bowl or plate sleepers, with tie-bar, gibs, cotters, &c. .	4 8½	193	7 10½	2	12 5¼	151½	1,094	..
One wrought-iron sleeper (for light traffic) 8 feet by 9 inches wide, with clips	4 8½	98	7 0	..	9 2	77	807	287
Two cast-iron bowl or plate sleepers, with tie-bar, gibs, cotters, &c. .	metre	106	4 5	5	7 0	83¼	616	..
One wrought-iron sleeper 5 feet 6 inches long by 9 inches wide, with clips	metre	65	4 6	..	6 0	46½	528	88
One wrought-iron sleeper 9 feet long by 10 inches wide, for heavy English traffic	4 8½	150	10 0	..	..	..	..	..

or in any place where 30*s.* freight and 20*s.* inland carriage were charged, the cost would be 12*s.* 5½*d.* against 9*s.* 2*d.* Again, take the metre gauge laid with plate-sleepers, but in this case adding 5 per cent. for breakages, the difference was 1*s.* per sleeper in favour of the wrought iron, in India. He had assumed the wrought-iron sleeper to weigh 65 lbs., to be 9 inches wide, and $\frac{5}{16}$ inch thick, which for such a gauge and weight of rail was very strong. There was thus a saving of £458 per mile in favour of wrought iron for large sleepers for the 5 feet 6 inches gauge, and £287 in favour of wrought-iron sleepers against the cast-iron round bowls, and for the small metre gauge there was a saving of £88 per mile in India, whilst the railway if laid with long

Mr. Wood. sleepers would have increased stability as shown in Fig. 29. There would be no outside disturbance, but a far better sleeper, and a far better road. With regard to packing, he would not say that a flat plate or a flat wooden sleeper might not be more easily packed than the hollow pot or wrought-iron sleeper, but unquestionably when once the iron sleepers were packed they held their position in the ballast better. The plate-layers on the North Eastern line had told him that they did not require the packing that wooden sleepers did; whilst the saving of cost in relaying or laying a new line was considerable.

Correspondence.

Mr. Boucher. Mr. A. BOUCHER stated that trial had been made on the Northern of France Railway, some twelve years ago, of five thousand Vautherin sleepers, but the experiment had been abandoned. Beyond the question of price, which need not be alluded to, the system presented certain practical defects. In the first place the sleepers took little grip of the gravel ballast, doubtless from their being open ended. The mode of securing the rail to the sleeper left much to be desired, and needed the employment of too many parts to keep it in good order. Finally it was proved by a case of a train leaving the line that these iron sleepers greatly aggravated the consequences of an accident by increasing the time it took to put the track in order again. In an accident that occurred in October 1867, the wheels of the carriages which left the line destroyed all the iron sleepers which they touched; this would not have happened had the sleepers been of wood.

Mr. Cudworth. Mr. W. CUDWORTH observed that a length of 2 miles the Author's pattern of sleeper had been laid on the mineral lines of the North Eastern Railway for two-and-a-half years; but they were not doing well owing to faults in construction, which might, however, be remedied. Many of them had cracked in the bottom flanges immediately underneath the rails. The clips which held the rails were wearing rapidly where they had projections bearing against the underside of the sleepers, but these projections had been too small at first. The iron sleepers took a good deal more packing than wooden sleepers, as the consolidated ballast within the sleeper had to be broken up. In other respects the sleepers answered very well. They were easy to travel over, and the keys were kept well in place by the clips.

Mr. Demoly. Mr. A. DEMOLY contributed, through Mr. Suquet, Traffic Manager of the Algerian lines of the Paris, Lyons, and Mediterranean Rail-