ants reduced again to the condition in which they were found by Julius Cæsar.

From this state, roads have delivered us, under the dispensation of Providence, giving latent faculties to man. The most perfect road yet known is the railroad; and no higher service can be done to humanity than making railroads still more perfect, thus removing the chief obstruction to man's universal interchange of ideas, and the general spread of the benefits of civilization.

The paper is illustrated by a series of diagrams from which the woodcuts have been compiled.[1]

Mr. W. B. ADAMS described the different sections of rails, of which diagrams were exhibited, and directed attention to a girder-rail of simple construction, hollow, so as to preserve as nearly as possible a uniform temperature, under the extreme thermometric variations between day and night, or even to serve as an occasional conduit, and also as a conduit for water, which latter, it was contended, might be advantageously employed in preventing the clouds of dust from which the passengers now suffered inconvenience, and at the same time causing more permanent contact between the ballast and the supports of the rails. This, he submitted, would be an efficacious, simple, and cheap mode of constructing the permanent way.

Mr. P. W. BARLOW objected, that the question of the cost of the permanent way had been almost entirely lost sight of, in the paper; now this was so important a consideration, in all constructions, that it should have been fully considered, before entering on the discussion of the various expensive innovations alluded to by the Author.

With respect to the system of cast-iron supports, for which he was responsible, it was necessary to state, that it had been proposed, before it was considered practicable to roll rails, either of such weight, or of such an extended section, as those introduced by his brother, Mr. W. H. Barlow, and now known as the 'saddle-back rail;' as soon as it was found, that such rails could be manufactured, he had advised their being tried, and he was fully satisfied with the result. Previous to that time, however, being under the necessity of determining the construction of about sixty miles of line, he had not hesitated to employ the cast-iron supports, which had, under the circumstances, fully answered his expectations. It must be admitted, however, that the saddle-back rail was, under ordinary circum-

[1] Several of the blocks, for the cuts, have been lent by members.—*Sec. Inst. C. E.*

stances, preferable; a single line of way could be laid with those rails, weighing 90 lbs. per yard (at the then low price of iron), at a cost of £900, or £1000, per mile. The portions of line so constructed, on the Midland Railway, were very successful; there was an even motion in the carriages, less noise at the joints, and evidently less wear and tear in the rolling stock, in spite of the rigidity of the rails. He apprehended, that the expense of the 'maintenance of way' would be considerably reduced.

Mr. W. B. ADAMS submitted, that the question of cost need not necessarily enter into the discussion, especially as the prices of materials were constantly varying, and the quantities being given, each engineer could make his own calculation as to first cost.

Mr. BRUNEL said, he was so fully impressed with the necessity for attempting to reduce the expense of maintenance of way, that he had not hesitated to try the 'saddle-back' rail, and as far as the limited experience of only twelve months enabled him to form an opinion, he was well satisfied with the result of the experiment, for although it had not yet induced the happy position, assumed by Mr. Adams, of there being 'no cost of maintenance of way,' there was every indication of considerable economy in the ordinary expense of repairs. The piece of railway, where the experiment was tried, was about seventy-five miles from London, and exposed to all the traffic of the Great Western Railway, under somewhat disadvantageous circumstances; yet it appeared to stand well, and, at present, the expense of maintenance of way was quite as low as that for the system of bridge-rail, with longitudinal timber-sleepers. It was well known, that Mr. Brunel was a decided advocate of the latter system of construction; he believed a line thus made to be at least as easily kept in order as with transverse sleepers; the joints were as readily made and were more solid, than those of any other system, and the cost of the original construction was not greater. The saddle-back rail appeared to possess most of these advantages, and at the same time to offer economy in the first cost; the joints, in particular, were rendered very even and secure, by fastening the ends of the rails upon a wrought-iron saddle-piece, with four, or six rivets, which united them perfectly.

He was so satisfied with the general result, that he had also used these rails on a short length of twelve miles, on a railway in Cornwall, and was about to adopt them for a considerable length on the South Wales Railway.

He must observe, that in the description, given by Mr. Adams, of the effect of traffic on bridge-rails and longitudinal bearings, results were mentioned which, during all his experience of the

system, had escaped his notice. The actual results of his first trial of the system were these;—the rails were too light, and being only attached to the timbers by a large sort of ordinary wood-screw, traversing the flanch of the rail and passing nearly through the timber below, the deflection, or 'creep' of the rail loosened the screws, and after being tightened down a few times, the holes became galled and the screws no longer held firm. They were then abandoned and were replaced by screw-bolts with the nuts on the under side of the sleepers; these in turn were reversed, the nuts being screwed on from above, and thus were accessible for constant examination; the corners of the heads were turned up, like fangs, to bite into the timber and prevent the bolt from turning.

When the bridge-rail was well bolted down, with small joint-plates, introduced beneath the junction of the ends, no system could give a smoother way for the carriages, or generally succeed better; it was, however, more expensive, in first construction, than Barlow's saddle-back rail.

It was generally considered necessary, in laying rails, to provide for their contraction and expansion. Now, however strange the assertion might appear, Mr. Brunel did not hesitate to state, that such provision was unnecessary, under ordinary circumstances, in this climate. This would become evident, when it was considered that 10° or 12° of heat only represented an amount of expansion equal to 1 ton per square inch of pressure; now if the rails were held very firmly by their fastenings, there would be sufficient resistance to counteract any effect of contraction, or expansion, between the points of attachment, as a change of temperature of even 50° would only render it necessary to provide for a tension, or compression equal to 5 tons per square inch in the whole, or 2½ tons alternately, of extension and compression.

A fact had been mentioned to him, by Mr. Hawkshaw, relative to a cast-iron parapet, which completely confirmed this view, and it was found, that in riveting together the ends of the bridge rails, the same effect was produced. When this was first mentioned, everybody doubted it, and to satisfy himself, Mr. Brunel caused a length of 100 feet of rails to be welded together, and another length of a quarter of a mile to be riveted together, with accurate gauges fixed at each end; the result was conclusive, that there was not any accumulated motion, either at the extremities, or in any part of the two lengths. This and other subsequent trials convinced him, that it was only necessary to fix the rails securely upon steady sleepers, to provide against every tendency to contract, or expand, arising from the variation of temperature in this climate, although in a very hot

summer he had found the surface of the rail heated to as much as 130°.

With respect to the various modifications of the forms of rails, proposed by the Author of the paper, in the diagrams exhibited, and with every desire to remark courteously on the papers kindly prepared for the meetings, he must say, that he could not find any suggestions calculated to advance the practice of laying permanent way. They might be ingenious, but they were not useful, and most of the forms had been already tried and condemned.

As to the split-rail, stated to have been tried in America, there was no experience of its use in this country, to enable an opinion to be hazarded upon its utility. The arguments in favour of the girder double rail were based upon assumed, but not demonstrated, defects in the saddle-back rail, and it did not appear that any experiments had been made, to prove either the positive existence of the defects, or of the merits of the proposed plan for obviating them. It was presumed, that the saddle-back rail did not take a solid bearing on the ballast, in consequence of the difficulty of packing it; now it was well ascertained, that ballast of almost any kind became, in time, so perfectly rammed into the cavity, that a nearly solid mass was formed, whereon the spreading flanches took a solid bearing, at a sufficient depth to receive the necessary lateral support, without that hindrance to perfect drainage which would be likely to occur from an extreme depth of web, unless there was such a thickness of ballast as would be very expensive in practice. On the other hand, the shallower proposed forms had the disadvantage of taking their bearing so near the surface, that the packing would be affected by any slight changes of weather.

With good materials, and judgment and care in applying them, a practically perfect permanent way could be made, either with stone blocks, or transverse sleepers and chairs, or with longitudinal timber-bearings and bridge-rails, and any of these systems were preferable to the proposed modifications; but Mr. Brunel hoped, that with Barlow's saddle-back rail a permanent way as good, or nearly as good as any of these, might be constructed, and at a less cost.

Mr. Ashcroft said, from his experience of the system of 'fishing' the ends of the rails, on the Eastern Counties Railway, where it was already tried upon a length of twenty miles, he was of opinion, that there would be an economy of fifty per cent. in the cost of maintenance of way; and he thought, that by the application of the 'fishes,' to retain the ends in the same plane, and to render

them steady under the wheels, any line, with transverse sleepers and chairs, could be cheaply put into, and be easily retained in, good working order.

Mr. BIRD said, he had been informed, by eminent German engineers, that 'seite laschen,' which were nearly identical with the 'fishing-plates,' had been used for several years in Germany. On the railway between Leipzic and Dresden, which was nearly the first line executed in that country, having been constructed in the year 1838, a portion was laid with single T rails and 'seite laschen,' holes being punched in the ends of the rails for these fastenings. They had subsequently been employed, throughout the entire length of the Lubeck Railway, and were tried on many other lines; indeed the 'seite laschen' were included in most of the specifications; their form was such as to allow them exactly to fill the cavity on each side the rail, immediately beneath the top table, and they were held together by transverse bolts and nuts. On the railway near Olmutz, in addition to the 'seite laschen,' the two lines of rails were connected transversely by long bolts, to preserve the gauge accurately. In Rhenish Prussia the ends of the rails were connected by 'seite laschen,' of such a form as to adapt the upper part to the vertical web of the rail, and with a horizontal web to be attached to the sleeper. He was not aware, that in any part of Germany fishing-plates, between the supports, had been adopted.

Mr. SAMUEL was not aware of the 'fishing-plates' having been adopted in Germany, otherwise than as a means of keeping together the ends of the rails in the joint-chair, of which they merely extended the hold on each side. He had never seen them used, in Germany, with the suspended joint, in the manner he had employed them on the Eastern Counties and other lines.

He gathered from the paper, that Mr. Adams claimed the invention of the fished suspended joint; the claim was perfectly valid, and Mr. Samuel had become first connected with it, by introducing it practically on the Eastern Counties Railway. He subsequently used a 'fished-joint chair,' which he considered a valuable modification of Messrs. Adams' and Richardson's 'fish-joint;' it was capable of easy application to the permanent way of a line of the ordinary transverse sleeper construction, and had the merit of avoiding interference with the usual position of the sleepers and rails, which became inevitable, when the ordinary 'fishing-plates' were applied to a permanent way already laid down. The result of the experience of several miles, laid on this system, on the Eastern Counties Line, had been very satisfactory.

Mr. BRUNEL had always understood, that it was to Mr. Samuel the railway world was indebted, for the valuable introduction of the 'fishing-plates' with the suspended joint, and all who had noticed the even surface of the rails and the smoothness of the travelling, on the portions of the lines so treated, must admit the great advantages of the system.

Mr. P. W. BARLOW would correct an impression which appeared to obtain, as to the extent of fracture of the cast-iron bearing-plates on his system; now the fact was, that the amount of breakage did not exceed that of the cast-iron chairs, on railways of the ordinary construction. He was convinced, that under all circumstances, the cast-iron bearing-plates could be economically employed, and this opinion was confirmed by the offer of Mr. Taylor, the contractor, to maintain and renew, for twenty years, that portion of the South Eastern line, laid with cast-iron bearing-plates, for £100 per mile per annum. It must be borne in mind, that the portion of line alluded to, was that on the Greenwich and the main line, where, from the confluence of so many trains, the traffic was nearly three times as great as the average of that of the other portions of the railway; and also, that the rails had been more than ordinarily degraded, from the employment of bad ballast.

In a Report he had recently made, on 'Permanent Way,'[1] he had given the details and the results of some extended experiments, having for object, 'to ascertain whether the weights of iron required to obtain the necessary bearing surface, and, at the same time, to insure against fracture, would make the cost greater than the value of the increased durability of the material;' and without troubling the meeting by a recapitulation of the particulars of the Report, to which he would beg to refer them, he would confidently state, that the cost was even less than that of an ordinary wooden road.

The experience he had, in the maintenance of way, convinced him, that after the selection of a good quality of ballast, the cost of maintenance of a line depended on the extent of bearing surface, which should be so obtained as not to interfere with the drainage. It would appear, that in the commencement of the railway system, the engineers had admitted this fact, as with five stone blocks, each 2 feet square, at intervals of 3 feet from centre to centre, under each rail of 15 feet in length, there was an extent of bearing surface of 40 feet, under each pair of rails on a single line. On some of the more recent railways, with transverse timber-sleepers, the extent of

[1] Vide Report on Permanent Way, by Peter W. Barlow, addressed to the Directors of the South Eastern Railway. 4to. London, 1849.

bearing surface did not exceed 24 feet, part of which was useless, as the plate-layers only packed about 18 inches on each side of the chair. In the estimate of cost of his system of cast-iron bearing-plates, he assumed 28 feet of surface, and he believed that would be found sufficient for heavy traffic, as from the proximity of the base to the surface of the ballast, complete drainage could be obtained.

He understood it to have been stated, that the actual cost of maintaining the transverse timber-sleeper permanent way of the South Eastern Railway, had not exceeded £30 per mile for six months. He must be permitted to observe, that it was very possible to reduce present expenditure, at the risk of deterioration of the road, and that half a year was a very limited period to judge from.

He had tried two small pieces of line laid with Greaves' iron-sleepers; on one piece, no breakage occurred, but on a part of the railway, where the heavy engines passed over at full speed, several of the castings had been broken; he thought they had been made too light to bear the severe test of heavy engines, with hard gravel ballast upon brick arches. They were generally reported to stand well, requiring less repair than the ordinary sleepers. The cost of Greaves' system, if equal strength of metal was used in the sleepers, was necessarily greater than Mr. Barlow's cast-iron bearing-plates, with equal bearing surface.

The quality of timber employed for the sleepers, and the mode of preserving them from decay, were important questions, in the maintenance of permanent way. He believed the most economical system was, to use only the soundest timber that could be obtained; and after trying the processes of Kyan, Payne, and Burnett, he must admit that the only one which had not completely failed was Bethell's process, which was saturation with creosote.

Mr. W. H. Barlow explained, that the introduction of the saddle-back rails, on the Midland Railway, arose from the great expense incurred in renewing the timber-sleepers. In the first instance, he proposed a rail weighing 127 lbs. per yard, but in spite of the exertions of the manufacturers, for which they were entitled to great credit, the difficulty of manipulating such masses of iron was so great, that, as a temporary expedient, a length of about nine miles was laid with cast-iron bearing-plates, beneath rails weighing 80 lbs. per yard; the weight of the bearing-plates was about 300 tons per mile, and although the road was laid under circumstances of considerable difficulty, it had completely succeeded, and he would not desire to have a more perfect length of line; the

maintenance of a portion of this length had recently been let to a contractor, for £42 per mile per annum; this demonstrated the economy of the system. The rails were 20 feet long, with two rigid cross-ties, formed of bars so deep and stiff as to maintain the bevil of the rails, which was a very important feature in all permanent way.

As soon as the manufacturers had completed their arrangements, a length of way was laid with saddle-back rails, weighing 127 lbs. per yard, resting on cast-iron joint-plates, into which the rails were keyed; this formed a very durable road, requiring very little maintenance. Subsequently, finding there was an excess of strength, the weight of the rail had been reduced to 100 lbs., and was now being still further reduced to 90 lbs. per yard, the joints being made by riveting the meeting ends upon an internal wrought-iron saddle-piece, somewhat similar to that used by Mr. Brunel and Mr. Hawkshaw, for bridge-rails on longitudinal timbers.

The traffic of the Midland Railway was, from local circumstances, peculiarly heavy, and like all narrow-gauge roads, laboured under the disadvantage of the want of base so requisite for heavy traffic and high speeds; the cross-ties had therefore been extended on each side beyond the rails, and with considerable advantage.

The cost of a line, with saddle-back rails weighing 90 lbs. per yard, when those rails were costing £6 per ton, was £2,100 per mile for the two lines of way.

Mr. W. B. Adams had assumed, in his paper, that the permanent way was a constant source of expense, arising chiefly from the deflection of the rails, and the sinking of the sleepers, under the pressure of the passing loads. These effects, he argued, could only be obviated, by giving to the permanent way a certain amount of rigidity, upon an elastic absorbent, which would be best obtained by using deep stiff rails like girders, with lateral strength, and plenty of bearing surface on the ballast, so as to avoid the undue depression of the substratum. For these reasons, although, he believed, not strictly in accordance with the regulations of the Institution, he had ventured to suggest some hitherto untried forms of rails and methods of supporting them, which he felt convinced would attain the end which was admitted to be very desirable.

Captain W. S. Moorsom, in reference to Mr. Brunel's observation, was of opinion, that only under peculiar circumstances, could the usual precautions, against the effects of expansion and contraction, be dispensed with. The experience of Mr. Brunel and of Mr. Hawkshaw was certainly conclusive (as far as it went), but on the other hand, there were many instances of lengths of line being forced

out of gauge, or lifted up, on sudden changes of temperature, owing, it was supposed, to the rails being too firmly fixed in the chairs. He had seen a length of nearly half a mile so lifted, on a railway under his charge; he therefore again recommended caution in disregarding the effects of changes of temperature.

The general questions of the first cost, and of the subsequent expense of maintenance of the permanent way, were of vital importance in railway economy, but he thought more details should be given, to enable a correct appreciation of the value of the various systems to be arrived at. The cost per mile of Mr. Barlow's saddle-back rail appeared low, but probably the amount stated only included the rails and the labour of laying them, without the ballast. This should be distinctly explained.

The data essential for making a comparison between the first cost, and the subsequent maintenance of different systems of permanent way, should comprehend—

1. The weights, and quantities of the respective materials.
2. The prices of the same—in place, and the amount per mile.
3. The character of the ballast.
4. The description of engines used on the road.
5. The number of trains—per annum.
6. The speeds.
7. The length of way subject to this traffic.
8. The time during which the expense of maintenance had been experienced.
9. The cost of maintenance per mile, per annum, including all materials and ballast.
10. The cost of maintenance, per train, per mile run, per annum.

As an example of his meaning, he would give a sketch of the particulars of the construction of the Waterford and Kilkenny Railway in 1846, when iron was at the high price of £12 per ton.

The sleepers were continuous longitudinal bearings of half balks, cut to an isosceles triangular section, with stiff cross-ties forming struts also. The double I rails weighed 56 lbs. per yard. The chairs, cast by Messrs. Ransomes and May, of their ordinary pattern, but with a parabolic section on the length of the bed, weighed respectively, for the joints, 27 lbs. each, and for the middle bearings, 14 lbs. each; the saddle-pieces weighed 7 lbs. each. The lengths of bearing varied from 30 inches, in the middle, to 15 inches at each end of the rails, before reaching the joints.

The first cost of this permanent way, if the rails cost £7 per ton,

the chairs and saddles £5 per ton, and the timber for the sleepers 1*s.* 6*d.* per cubic foot, would be per mile of single line of way—

Rails	£ 616
Chairs and saddles	143
Pins, trenails and keys (Ransomes' and May's compressed)	87
Timber-sleepers, ties and dowels . .	453
Cost of laying	88
Total cost per mile . . .	£1,387

The railway, about thirteen miles in length, with a gauge of 5 feet 3 inches, had now been regularly travelled over, for between three and four years, by eight, or ten trains daily on each line, making about three thousand trains per annum. The weight of the locomotives used was about 22 tons, and the average speed of the trains was twenty-four miles per hour.

The cost of maintenance of way, including the renewal of all materials and ballast supplied, since the line had been out of the contractor's hands, had been, for the first year, £53 12*s.* per mile; for the second and third years, £35 12*s.* per mile; and for the first half of the current year, at the rate of £31 per mile per annum, or at the rate of 2·51 pence per mile run, per annum.

He believed this cost of maintenance was less than that of many lines of equal traffic.

Mr. R. J. Hood thought it was almost impossible to draw an accurate deduction, as to the comparative cost of maintenance of way, from any published reports, as it was rarely stated what was included under that head; for instance, on one line it was strictly limited to keeping up and renewing the lines of way, the ballasting and the ditches; whilst on another line the keeping up the fences would be included, and perhaps on account of the vicinity of the line to populous districts, the fencing was of an expensive kind. He agreed with Captain Moorsom, in the necessity for specifying everything very clearly.

As to the modifications of forms, proposed in the paper, they appeared to be chiefly untried attempts, to remedy some of the acknowledged evils of existing systems, but he could not agree in commending them.

Cast-iron sleepers had been laid down to some extent on the Brighton Railway, but Mr. Hood dreaded the expense of repair and of their renewal, or, what was more probable, the substitution of some other system. There were also, on the same railway, some

bridge-rails laid on transverse sleepers; it was not a satisfactory system, and was frequently out of repair.

The 'fished' suspended joints were decidedly the best, even with only four, instead of five sleepers; he used 'fishing-plates' 18 inches long, with four transverse bolts $\frac{3}{4}$ inch diameter, and found the surface of the rails so even, that the rolling stock was less injured than before their adoption. He was certain that system would diminish the cost of maintenance of way.

Mr. HAWKSHAW corroborated the statement, as to the apparent absence of expansion and contraction, in lengths of iron securely tied down. About ten years since he erected at the station of the railway, at Salford, a parapet 750 feet long, composed of cast-iron plates, each 9 feet long, and 1 inch thick, firmly riveted together, and held down tightly; it retained a perfectly straight line, under all variations of temperature, without any special provision being made for contraction, or expansion.[1]

He commenced using the systems of fishing rails, and of riveting them firmly together in long lengths, as far back as in 1846: one end of the joint-plate being riveted to the rail in the works, and the other on the line, when in place; no ill effects had ever been experienced, on his lines, from changes of temperature.

When rails were driven hard up endwise against each other in the joint-chairs, without there being fishing-plates to keep them down, and in the same plane, there was when under expansion a tendency in the rails to rise. The best feature of the fishing-plates was their power of holding the ends of the rails firmly down, and of keeping the travelling surface even.

The question of the relative cost of maintenance of way could not be properly discussed, without a minute detail of all the dates and circumstances. For instance, a line under his charge was constructed for some miles across a coal district, where, in consequence of the under-ground workings, the surface constantly subsided, and, of course, a large quantity of ballast was required to restore the level, independent of the constant labour in packing and keeping up the line for the traffic. The mechanical questions of good forms and proportions, of good quality of materials and of ballast, and of care in construction, were now generally well understood, and the best systems were acknowledged to be the cheapest in the end. He must repeat, that the cost of the maintenance of way was so dependent on a variety of circumstances, that it was extremely difficult to form a comparison between any two lines.

After very extensive experience of almost all ordinary forms of

[1] Vide *ante*, page 241.

rails and systems of construction, he gave the preference to a strong bridge-rail, firmly attached to longitudinal bearers of sound balk; this he, at present, considered as the best system of construction. He did not think that the fibre of the longitudinal timber-balk was more crushed under the bridge-rail, than that of the transverse sleepers under the chairs; and he believed the cost of maintenance of way to be somewhat less with longitudinal, than with transverse sleepers.[1]

He had used Greaves' cast-iron sleepers successfully, and he was of opinion, that in certain situations, particularly where the sand was used for packing or the gravel ballast was small, the system would answer well; on some foreign railways they would be found useful; particularly in the East, where only such timber could be used as was known to resist the ravages of the white ant, and there it was sometimes expensive and difficult to be obtained.

Mr. C. MAY directed attention to the joint-chairs, slightly alluded to in the paper; cast in 1849, by Messrs. Ransomes and May, at Ipswich, from the design of Mr. John Fowler, M. Inst. C.E. The object of the extended chair was, to prevent the injurious effect on the rolling stock, and permanent way, arising from the ends of the rails being permitted to move, as in the joint-chairs of the ordinary construction. This evil had been felt by all engineers, and there were few who had not attempted a remedy. Mr. Fowler had tried an experiment on one mile of line, under very considerable traffic, and, after an experience of two years, he expressed himself satisfied, that there was less action at the ends of the rails, which were held down more firmly, the injurious effects on the rolling stock were diminished, and the cost of maintenance of way had been reduced.

This joint-chair (Fig. 20, page 261) was 2 feet 6 inches long, and had three jaws on each side, so as to hold the ends firmly for 15 inches of each rail, giving that length of solid bearing.

Experience had shown, that the body of the chair might be shortened about 9 inches, without diminishing its utility, as its length was determined by the power of properly packing the two sleepers on which it rested. Only three chairs had been broken, in two years, and those all near the same place, showing that a slight addition of metal to that part would be beneficial.

It was not contended, by Mr. Fowler, that this was the best method of securing the end of the rails; but as it had proved suc-

[1] In Mr. Hawkshaw's Report on the Rolling Stock and Permanent Way of the Lancashire and Yorkshire Railway, for Manchester, 1850, these points are discussed with great minuteness.—*Sec. Inst. C. E.*

cessful, and it was not the object of a patent, he had requested Mr. May to lay the facts before the meeting.

Mr. WILSON corroborated the statement relative to Mr. Fowler's joint-chairs; they had been used, in 1849, on the Lincoln branch of the Manchester, Sheffield, and Lincolnshire Railway, where there was considerable traffic, with heavy engines, and at high speeds; they were subjected to severe trials, by running engines, at considerable speeds, over obstructions ½ inch in height placed on the rails, over the joint-chair, and the shocks were borne without any injury to the joint. The bearing was originally 2 feet 6 inches long, but it was found, that the base of the chair might safely be reduced to 1 foot 9 inches, which had been done, without diminishing the steadiness of the chairs. The part of the line, on which they were used, was excellent, and the cost of maintenance of way was less than in other parts.

Mr. ALLPORT confirmed the evidence, as to the length, on which these joint-chairs were used, being the best part of the whole line, although it was subject to the action of the heavy engines and trains of the Great Northern Railway, passing over it at considerable speed.

Captain SIMMONS, R. E., being fully impressed with the importance of the subject, had listened with much attention to the discussion of a question which, however, he thought was of too great magnitude to be fully canvassed at a meeting of the Institution; he would, therefore, confine his observations to a very few points.

He had made some experiments on the permanent way described by Captain Moorsom, as at first he entertained some misgivings as to the solidity of the line, on account of the apparent weakness of the rails, the distance between the main chairs, and the absence of power in the intermediate saddle-pieces to afford lateral support to the rail; the experiment might, however, be considered generally satisfactory.

In considering the original construction of the railway, and the cost of maintenance of way, he thought that the amount of resistance to trains should be imported into the calculation. It had been stated in evidence, that at a speed of 60 miles per hour there was a resistance equal to about 60 lbs. per ton, on a narrow-gauge line, whilst, at the same speed, the resistance was reduced to 18 lbs. per ton, on a broad-gauge line. Now as there was not any very great difference in the form, arrangement, or weight of the locomotive engines on the two lines, he had been at a loss to account for the stated difference of resistance.

He would now venture to suggest, whether the difference might not, to some extent, proceed from the different systems of forming the line; the longitudinal bearing affording that regular and continuous vertical and lateral support to the rail, which it only received at intervals from the cast-iron chairs on transverse sleepers; whilst, with the latter system, it was very difficult to prevent a certain amount of rocking motion in the chairs, which must produce considerable resistance; and at the joints, unless the rails were very heavy, or were 'fished,' the resistance was very much increased.

The system introduced by Mr. Fowler appeared to be a decided improvement; the joint-chairs were very steady, and the increased length, of 30 feet, given to the rails, was a very advantageous innovation, as it got rid of half the usual number of joints; provided, however, that the extra cost of such heavy lengths of rail did not militate against the introduction of the system.

Captain Simmons had examined the roads laid with Mr. W. H. Barlow's saddle-back rails; the line appeared to be good, and the construction solid; the principal objection against it seemed to be the anticipated heavy expense of renewal, when the upper table of the rails should be worn down, or the surface be laminated, or cracked. In conversation on the subject, with Mr. Morries Stirling, he had been informed, that it was practicable, at a slight expense, to impart a very durable surface to the rails, by the introduction of a mixture of metal during the process of rolling; that the compound metal, welded perfectly, and was as tenacious and much harder than the ordinary rails. If this process could be adopted, at a reasonable cost, it would prove a most advantageous adjunct in the use of Mr. Barlow's saddle-back rail.

The cast-iron bearer-plates, introduced by Mr. P. W. Barlow, had also received his attention; they appeared to have answered well, where they had been originally well packed and had been carefully attended to; but they were liable to fracture, if the substratum was not constantly kept well rammed beneath them: in short, like almost all other systems, if it was well attended to, it was durable, but, if not, the cast-iron way as soon got out of order as any other road.

Mr. Brunel was anxious not to be misunderstood in what he had stated, relative to the contraction and expansion of rails; he did not mean to imply, that iron rails were exempt from the ordinary effects due to changes of temperature; but that when rails were effectively held down to longitudinal, or other firm bearings, the effect of the amount of contraction, or expansion, occurring under the limited

range of alterations of climate in Great Britain, would be resisted, and thus would not produce any of the effects of buckling upwards, or curving outwards, which would occur on lengths of rail inefficiently attached to the sleepers. He had tried lengths of several miles of rails firmly riveted together, and securely attached to longitudinal sleepers, without finding any ill effects from the contraction, or expansion.

He desired also to be understood, as to the opinion he expressed upon the numerous modifications of forms of rails exhibited in the diagrams, many, if not all of which, were made the subject of patents, although they had not been tried in any way, and most probably no person would ever attempt to try them; the only effect, therefore, to be anticipated from this accumulating of numerous fanciful forms in one patent was, that when a really good form was devised, it would be found to bear so close a resemblance to some one of these imagined sections, that either the use of the positive improvement would be prohibited, or a fertile field would be opened for litigation, on a case of infringement. For instance, some of the new forms shown, though in themselves impracticable, or objectionable, would have sufficed to prevent the use of Barlow's saddle-back rail, which though, perhaps, not positively new in form, must be admitted to be a decided improvement upon the rails of that description in ordinary use, and to be a good disposition of material; there was a good bearing, sufficient depth to give stiffness, and a breadth of base to insure firmness. Now the employment of this saddle-back rail, which was rather remarkable for its judicious proportions, and the good disposition of the metal, than for its novelty, might (as he before said) have been precluded by some such fanciful sections as those which had been theoretically advocated, although, he must say of them, that among them there was little that was new, and that little was not good. It was notorious, that engineers frequently found their practice restricted, by the claims of some theoretical patentee, whose obsolete invention never would have been heard of, but for the adaptation, in practice, of some, perhaps the only useful, portion of an invention, originally applied to some widely-different purpose. He feared that he should incur the ire of the inventive world but in these discussions he held it to be incumbent upon the Members; to give their unfettered opinions, however heretical they might be considered.

Reference had been made to the principle of having a false top to rails, to be removed when it became abraded, or laminated by the traffic. Now though this sounded well theoretically, it was generally considered to be useless in practice. Throwing aside the

danger and other disadvantages, liable to result from the use of a rail composed of so many parts, as would be necessary for the removal and replacing of a false top, it would suffice to consider the monetary part of the question. If a rail weighing 90 lbs. per yard required to be changed, it was true that another rail of the same weight must be substituted, but the old metal could be re-rolled and converted into new rails at an expense of about two pounds per ton, which would probably be less than the cost of replacing the false tops in more complicated rails. It had been admitted, that the average duration of rails was ten years, and many engineers contended for a much longer duration; now a very simple calculation would suffice to demonstrate, that after ten years' use, it would be cheaper, and certainly much more economical in practice, to take up the entire rail, than to take to pieces and refix a complicated subrail, in order to replace the upper table. As a matter of figures, it must be evident, that at the present price of iron and with the actual facilities for rolling rails, no positive advantage could result from renewing the upper table of any form of compound rail yet proposed.

Mr. Brunel trusted that the remarks he had made would not be considered invidious: but he felt strongly the prejudicial effect of the present system of accumulating in one patent almost every possible modification of form, or process, and thus obstructing, if not frustrating, the attempts of others to introduce improvements which would become the unrestricted property of the public.

Mr. W. B. Adams, in answer to previous speakers, considered, that the amount of expansion and contraction must depend very much on locality and circumstances, as the iron might be laid where the heat would be carried off with such rapidity as not to affect the metal. It might, no doubt, be practicable to overpower a given force of expansion and contraction, by a greater force holding down the rails, but it then became a question whether it was desirable to do so, and whether the iron might not be injured, by the unnatural restriction to which it was subjected.

He could not comprehend, how the ballast remained firmly pressed upwards into the apex of the interior of the saddle-back rail, when the vibration occasioned by the travelling was considered, and he thought the deep cross-ties, necessary for preserving the inward level of the upper table, indicated a certain tendency to unsteadiness in that form, although its base was so widely spread.

With respect to the use of the fishing-pieces, he thought common sense must point out the advantage of giving to the joints, which were the weakest parts, such an amount of support, or stiffness, as would render them as steady as the intermediate parts, and in no

manner could this be done so simply, or so effectually as by applying what might be termed 'splints,' to unite the two ends and impart to them as much strength as was possessed by the body of each rail, even if as much weight of metal was abstracted from the entire length as would supply the fishing-pieces; by this means the cost of fishing was much reduced. Experience had shown, that by the application of the system to old lines, the expense of relaying was avoided, and the increased comfort to the travellers, and the diminished wear and tear of the rolling stock were generally admitted.

The experiment tried by Mr. Hartley, had proved, that a certain elasticity of substratum was essential for a good permanent way.

He must submit, that the opinions, adverse to the forms of rails proposed in the paper, had been supported by assertion rather than by argument, or by the deductions of experience. If the various forms and arrangements were as defective as had been stated, they could not, by the simple fact of being included in a patent, become sufficiently important to interfere with the inventions, or improvements of engineers. The cast-iron subway, the saddle-back rail, the chilled chairs and wooden trenails, innumerable turn-tables and switches, and almost all the various parts composing a railway were already patented, so that, at all events, if there was any error in accumulating several forms in one specification, the sin had been committed, in emulation of very numerous, if not very good, precedents. The discussion of the question, whether patents should be permitted to be secured at all, belonged rather to another subject, and should not be imported into the present proceedings.

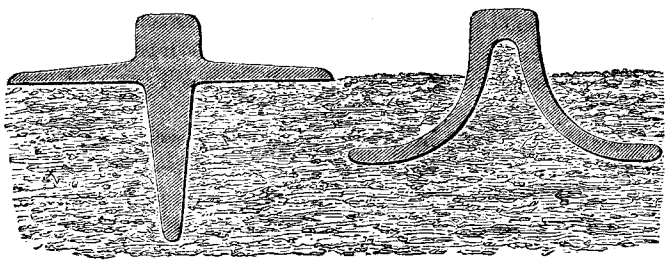
The moveable top for the rail, which had been so strongly objected to, had been proposed merely for certain localities, where the difficulties and cost of transport of rails of heavy weight would be considerable, when it should become necessary to replace the original rail. There were other forms, more analogous to the saddle-back rail, with which the latter might have been more correctly compared. There was a marked mechanical distinction between the saddle-back rail and the solid girder rail. In the specification of the former, it was described as "a trough rail bearing on the ballast and riveted to bearers," and the intention was, by widening a bridge rail to obtain a broader base. In the latter, the object was to obtain a T girder of such a depth as would prevent undue deflection, and with sufficient breadth to give ample bearing surface on the ballast, whilst the tread of the rail should be so slightly elevated, that there should be little, or no tendency to lateral yielding, or rocking.

In fact the saddle-back rail might be said to represent the shallow

bridge rail of the longitudinal system, whilst the deep girder rail exemplified the T section of the transverse sleeper system.

A comparison of the actual proportions of the two forms would show (Fig. 25), that the girder rail possessed more bearing surface

Fig. 25.



Adams' Girder Rail. Barlow's Saddle-back Rail.

on the ballast, combined with a deep keel to prevent oscillation, and there was no greater difficulty in packing one form than the other, or rather, if there was any difference, it was in favour of the girder rail. As to the cost of manufacturing the deep girder rail, the same objections had been raised to the saddle-back form, but they had been overcome by the energy and skill of the iron manufacturers, and if there was a positive advantage in any given form of rails, means of producing them at moderate cost would soon be discovered. A crack, or flaw in the horizontal top of a "saddle-back" rail, would seriously injure it, but such a crack in a "girder-rail" would not impair its efficiency. The matter resolved itself into the question of which form, with a given weight of iron, offered the best bearing surface on the ballast, and possessed the greatest number of collateral advantages. Experience alone must decide; meanwhile Mr. Adams felt bound to endeavour to clear himself from the imputation of having proposed forms without ideas. The object of the paper was to direct attention to the T girder rail and its varieties;—to suggest the resumption of stone blocks, combined with either transverse, or longitudinal timber-sleepers; —the substitution of durable materials for the perishable ballast now in use;—giving to the rails a sufficient amount of elasticity to avoid the jarring which now acted so prejudicially on the rolling stock, and detracted from the comfort of the passengers; —and whilst providing for the drainage of the ballast, to afford the means of employing water, in dry seasons, for consolidating the packing, and laying the dust during the passage of the trains. In treating these various topics, the mention of the proposed methods

for meeting certain difficulties, or for obtaining certain ends, was unavoidable, and experience had shown, that in bringing forward any new proposition, unless the first claim included every apparent mode of attaining the object, an unscrupulous improver, seizing upon the idea which had cost the inventor much thought, would, by a slight modification, obtain the credit and reap all the advantage of the invention.

When in 1847 Mr. Adams specified the "fish-joint," for the double-table rail supported on chairs, he thought that a good and valid title to an original idea had been recorded; but a host of followers in the same track immediately obtained patents for improvements, on the method of securing the joint of the double-table rail, used with chairs. This experience determined him, in future, to combine as many of these, so called, improved forms, or optional modes, as his imagination could supply, in order to avoid those disputes, which the protection of a successful invention was nearly certain to induce.

It was well known, that upon all lines of railway, there were used a multitude of patented inventions, and therefore, inventors might be permitted to hope, that even Mr. Brunel's antipathy to patented inventions would eventually be modified, and that the deep girder rail might be admitted for trial on the Great Western, or some other line of railway.

Mr. ERRINGTON said more reference should have been made to the use of stone blocks for railways, as, although they had been generally discarded in Great Britain, he thought there were many localities where stone might be used with advantage. It would be well to inquire into the causes of the block road being so completely abandoned. He had recently examined the Lancashire and Preston Railway, which had been open for twelve years, and in that period the blocks had only been replaced, to the extent of one-fiftieth of the whole.

The timber sleepers on the line had been replaced to the extent of one-half, though they were of excellent quality, and had been supplied at a time when there was no difficulty in getting larch timber. One-fortieth of the quantity of rails had been replaced, and it would now be requisite to replace one-twentieth more. The chief injury to the rails appeared to have arisen from the splitting at the joints, which clearly pointed out, that "fishing," or some other system, than had been hitherto pursued, was required. Whether, ultimately, there would not be a great deal of wear and tear, even with that new system, appeared doubtful, as the nuts, bolts and fishing-pieces would probably have to be replaced.

With reference to the cost of maintenance of way, it was desirable to define what was meant by the term. In a document, published under the authority of the London and North Western Railway Company, it was stated, that the cost of the road, over an average of four hundred miles, had been hitherto £200 per mile per annum. Now it was impossible, that the small sums (£70 to £100) mentioned for maintenance of way, could comprise the same items as those in the document alluded to; he had known cases where, on one mile of railroad, there had been deposited 2,000 cubic yards of ballast, in one year. The upholding, referred to in the London and North-Western Railway Report, included the maintenance of every great work on the line—bridges, tunnels, slips, drains, and ballast, in fact, everything an engineer could desire to have done, in order to preserve a perfect plane for the rolling stock, and that condition was generally rigidly enforced. In some cases it was not usual, in maintaining a road, to replace a key, or spike, or rail, the moment it was wanted, and to include it in the maintenance, but it was reserved for a future time, when the cost was included in that of more special restoration out of the capital. He thought, on the present occasion, although the object was, perhaps, rather to discuss the mechanical merit of certain forms of construction, yet in so purely commercial a matter as a railway, the vital question of cost should not be lost sight of. It was yet to be proved, whether the saddle-back rail could be maintained at anything like the expense that had been stated; but he could not believe, that in the price named, anything approaching to a general maintenance of way had been included. It was therefore desirable to obtain further information on that point.

Mr. P. W. BARLOW stated, that the cost of maintenance given by his brother at £42 per mile, included the upholding of the fences, ballasting, and the ordinary repairs of the road; any extraordinary expenses, such as the giving way of tunnels, or other large works, or large slips, were not included. Everything was comprehended that would be comprised in a contract for maintenance. Mr. Wythes, the Contractor for maintaining the way with cast-iron bearings, had informed him, that when the road was consolidated, one man per mile would be sufficient to keep it in repair, and in that he included the ordinary cost of fences and of maintaining the road.

Mr. BIDDER said much valuable time had been wasted in the discussion of the speculative portions of the paper, which he thought was not quite of the character pointed out in the list of subjects circulated among the members of the Institution. No more important subject could be treated of, than the construction and

maintenance of permanent way; a paper on such a subject ought to enter fully into detail, and the first thing to be clearly ascertained was, what was meant by the term "maintenance of way," which was stated to have cost all sorts of sums, varying between £42 and £200 per mile. Descriptions of the mode of laying transverse, or longitudinal sleepers were not required, but a paper on this important subject, should have traced the results of all the experiments upon, and trials of, the various systems which had been tried. Now the paper under consideration chiefly contained observations on a great many forms of rails, but did not attempt to supply information on the methods of doing the best work in the most economical manner, whether in the construction of a new line, or in repairing an old one.

Allusion had been made to the rail first laid on the Blackwall Railway; it had bevelled joints, which were described as being weak; now in fact the joint was not weakened, as it was made by twisting the web of the rail and cutting off a portion of the protuberant end. The rail was certainly rendered somewhat more expensive, by the introduction of a process, which he would recommend on every railway, namely, by causing the iron to undergo additional hammering in the course of the manufacture; that had only cost thirty shillings per ton, and he believed the extremely durability of the old rails was, to some extent, owing to the extra-manufacturing process to which the iron was submitted. If instead of introducing large and heavy rails, a more perfect mode of manufacture had been sought for, he thought they would have had more economical railways.

The great question (although he admitted they were scarcely in a condition to settle it) was, which was the best system of construction to be adopted, at the present time, for a new line of railway; they would have to choose between the longitudinal system (which was, perhaps, brought to the greatest perfection by Mr. Brunel),—the transverse system,—and the saddle-back rail. There remained then to be considered, the prices of wood and of iron, the relative durability of all the materials employed, and their value when renewed. If the price of wrought-iron was assumed to be £5 10*s*., and cast-iron £4 per ton, and sleepers 4*s*. each, it was practicable to use heavy rails, and cast-iron bearings, if otherwise deemed advantageous; but if iron rose to £12 per ton, it would be necessary to use more timber.

He had been in the habit of assuming the durability of a good rail to be fifteen years; that an ordinary unprepared sleeper would last six years, and a creosoted sleeper fifteen years: then arose the question of the value of the old materials, and, at the present

prices, he thought those of the longitudinal system were of the least value, next came the transverse system, and the most valuable were those of the saddle-back rail system. Therefore, in England, he should be inclined to adopt the latter; at the same time, in Norway, it had been found more expedient to adopt the longitudinal system, because sleepers cost there only about sixpence each, and for that locality, which offered several peculiarities, it was considered the safest kind of road; and he begged to acknowledge the handsome manner in which Mr. Brunel had supplied him with all the information he required.

Then came the question of the best mode of repairing an existing road; and, from observation and careful inquiry, he had arrived at the conclusion, that the fish-joint was the most effectual system. He was of opinion, that the simple packing of the road could be done, as had been stated, for £40 per mile; but on the question of maintenance of way, generally, the Institution required to be furnished with a considerable amount of data, before the subject could be satisfactorily discussed; and he trusted some Member would supply a comprehensive paper on the subject, in the course of the next Session.

Mr. G. H. PHIPPS said, the statement, of there being, practically, no prejudicial effect from riveting together long lengths of rails, had excited considerable surprise; but, from his own observation, he was prepared to admit the fact of there being no perceptible effect of contraction, or expansion, if the rails were firmly fastened down upon longitudinal bearings; he thought this was as demonstrable by theory as it appeared to be positive in practice.

Mr. HAWKSHAW regretted there had not been more precision in the terms of the discussion. It was just as practicable to define the duration of a rail, as that of a grindstone; it must be evident, that it was dependent on certain considerations; a rail might last any term, between five years and twenty years. The fact was, the life of a rail was in proportion to the number, velocity, and weight of the trains running over the line. He had some rails, weighing 42 lbs. per yard, on the Preston and Wyre Railway, which had been laid twelve, or thirteen years, and now appeared capable of serving for ten years more, whilst, on other lines, he had renewed heavier rails, which had only been laid from three to nine years. When, therefore, the duration of permanent way was mentioned, the nature and amount of the traffic should be specified, or otherwise the conclusions arrived at would be erroneous. The cost of maintenance of permanent way had been referred to, without any statement of the weight and number of the trains, of the expense of the

ballast, of the cost of the iron, or of the precise character of the works.

It was important, also, to consider which system of permanent way offered the least resistance to the passage of trains. He was aware of the difficulty of treating the subject; but it was evident, that a railway might be cheaply laid, and yet, by increased deflection, might offer great resistance, and if it thus augmented the cost of power, there was not much gained by the innovation. A few years ago he had been obliged to take up a piece of railway, which offered less resistance to trains than any line he had yet seen; it was laid by Mr. Hartley, who had attempted to make a line like a lathe bed; the construction was very rigid, the rails were rubbed by hand, into blocks of stone, until a perfectly smooth surface was obtained, and while the line was in working order, it offered only small resistance; but when, partly from its inherent rigidity, it once got out of order, there was no remedy but to take it up and to put down what must be considered to be an inferior road, but which was better adapted to the nature of the traffic.

Captain SIMMONS, R. E., said, that even if, in addition to the gross cost of maintenance of way, the separate expense of each kind of material was given, with all the details that had been mentioned, and all necessary allowances were made, it would still be nearly impossible to arrive at an accurate comparison of the cost of any two lines, on account of the difference in the rolling stock. The weight on the driving-wheels of the engines varied with every class, and the hammering effect of certain kinds of locomotives, must have a very serious effect on the permanent way.

Mr. BRASSEY, in answer to the President, said his experience did not enable him to accord with the statement, that a line could be maintained in effective working condition for £30, or £40 per mile. He admitted that his practice in the maintenance of railways, though extensive, had been confined to lines laid on transverse sleepers, generally with rails of 75 lbs. per yard, chairs of 25 lbs. each, and with iron spikes, and he must state, that he had not been able to find any road which had been more economically maintained, yet he could not have it well done for less than £80 or £90 per mile, and he believed he had not done worse than other contractors, nor had he many idle men in his employ. If he had to construct a railway and to keep it in repair for twenty years, he should use rails of 75 lbs. per yard, on transverse timber sleepers, with 25 lbs. chairs, fastened down with iron spikes, as being less liable to rot than wooden trenails.

Mr. BETHELL, through the Secretary, begged to correct what he

contended was an erroneous statement relative to the inflammability of creosoted timber. During its very extensive use, for upwards of fifteen years, there was only one instance of a structure suffering from fire; and that one was a bridge in Wales, which had been set on fire by a workman driving a red-hot bolt into a creosoted beam.

When Mr. Bethell's premises, at Battersea, were burned down in 1847, the stacks of unprepared timber caught fire long before that which had been creosoted. He conceived the reason for this, to be, that unprepared timber, when heated, gave off a vapour which caught fire at a lower temperature than that at which the vapour from creosoted timber would inflame, because creosote oil required a high temperature to volatilize it. Therefore he contended, that creosoted timber would not catch fire so soon as unprepared wood; but he admitted that when once it was on fire it burned for a longer time.

There was not any instance on record of any of the stacks of creosoted sleepers catching fire, although they were generally placed close beside the railways, and were constantly exposed to the falling upon them of red-hot cinders and sparks from the locomotive engines.

With respect to the duration of prepared sleepers, it was now an accepted fact, that if carefully creosoted, they would endure for at least twenty years; and as regarded the price, the general estimate of 5*s*. per intermediate sleeper, and of 10*s*. per joint sleeper, had proved to be rather over than under the actual contract prices.

Mr. R. Stephenson, V.P., said the subject under discussion had occupied his attention for many years, and he had some time ago arrived at the conclusion, that the maintenance of permanent way was, as nearly as possible, an insoluble problem, unless by first carefully analyzing every element by which it was influenced; and even then, as those elements were inconstant, and as no two cases could be found exactly parallel, it was evident, that no correct comparison of cost could be arrived at. He quite agreed, that if the traffic was small and the speed slow, stone blocks sufficed for a railway for the conveyance of heavy minerals, at a speed of about ten, or twelve miles per hour, indeed he thought that a stone-block road offered less resistance than a timber-sleeper line.

With these slow trains resistance was a very important object, because by its diminution, an engine of a given power, was enabled to drag after it ten tons, or twenty tons, in addition to the ordinary load; but when it was necessary to convert the power of the engine into velocity, the case was entirely changed, and then that kind of permanent way, best adapted to resist repeated shocks, with the least

injury to the rolling stock, became necessary, and under these circumstances the stone blocks made the worst road.

Even if it was admitted, for the sake of argument, that there was a little more resistance with one system than with the other, it became of little importance, as at high velocities the question of atmospheric resistance came into consideration, and that was entirely apart from the present question. He could not suppose the remarks had intended to imply, that any ordinary difference in the construction of a line could cause any material difference in the resistance of trains. At the time of the discussion on that subject, a wide difference of opinion was entertained by men of experience, but that had nothing to do with the present question. Therefore the distinction he drew was, that on a mineral road, with moderate speeds, stone blocks could be safely applied; but with the high speeds required by passenger traffic, they were quite out of the question; he conceived that his position was proved by the result of the experiment tried by Mr. Hartley, who in constructing a very rigid unyielding line, as nearly as possible resembling a lathe bed, had only produced a perfect block road, which was soon proved to be unfitted for traffic at a great velocity. The cost of maintenance of way must depend, in a great degree, upon the nature of the strata, and the character of the country, through which the line passed; one cutting would keep the men continually employed in repairs, whilst in another cutting, the grass would grow even beneath the rails; the former being in a wet clay, with sand, and the latter in a dry, firm, sandy soil, without any water near it. The simple introduction of a little water, which would be found to vary in all localities, made all the difference; so that if the costs of maintenance of each railway were separately analyzed, it would be found, that instead of being able to compare one line with another of the same length, it would scarcely be possible to compare two miles of the same line. It was therefore a problem, which, at present, could not be solved. He did not wish to be understood as decrying the value of a record of actual facts; on the contrary, it would be highly useful, as if all the circumstances and considerations were clearly stated, an approximate judgment might be formed. But it required great care in ascertaining whether the cases, to which the facts were applied, involved the same facts to the same extent. The question was one of great importance to the railway world, and he hoped the Institution would continue to receive, from resident engineers on railways, the results of the cost of maintaining permanent way, and that the papers would clearly define what was comprehended under the head of maintenance.

It was imperative to arrest the impression, which was entertained by some persons, that it was desirable to obtain a perfectly rigid road; Mr. Stephenson's experience had led to exactly the opposite conclusion. It was quite true, that a rigid road might, theoretically speaking, be considered the best, but in practice it was the worst, for although from its rigidity it might offer the least resistance, it increased the wear and tear prodigiously. His attention had been called, some years ago, to the fact of the rails in the Watford Heath cutting, on the London and North Western Railway, being split and crushed, to such an extent, that although the cutting was through gravel, the rails were removed two, or three times. On a personal examination of the spot, he soon perceived that the destruction of the iron, arose entirely from the gravel having been extremely well consolidated, and the stone blocks so firmly bedded and packed, that the line was rigidly unyielding, and consequently the iron rails were literally crushed under the fast traffic.

The chief causes of deterioration of the permanent way, were the mileage, the speed, and the weight of the trains passing over the line; though the weight *per se* of the engines and its distribution upon the wheels, must also be considered. Wear and tear was, then, entirely a question of certain weights passing along the rails, at given speed; in a given time; the destruction of the surface being accelerated nearly as the speed, and the general dilapidation being augmented in an increasing ratio, as the number and the weight of the trains were increased beyond a given point.

Mr. Stephenson trusted, that the question of 'permanent way' was only opened by the present paper, as it was one of vital importance and could not be too frequently brought before the Institution of Civil Engineers.

February 17, 1852.

JAMES MEADOWS RENDEL, President, in the Chair,

and February 24, 1852.

ROBERT STEPHENSON, M.P., Vice-President, in the Chair.

THE discussion upon the paper, No. 866:—"The Construction and Duration of the Permanent Way of Railways, and the modifications most suitable to Egypt, India, &c.," by Mr. W. B. Adams —being renewed, was extended to such a length, as to preclude the reading of any communication on either evening.