VIII.—*On the Principle and Construction of Railways of continuous bearing.*

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THE conditions essential to a good railway may be defined as being,

1st. That it should be the closest practicable approximation to a perfect plane of perfect stability.

2d. That it should be adapted to prevent or neutralize vibrations from the impacts of imperfect cylinders rolling on imperfect planes (perfection in the surfaces of wheels and rails being unattainable in practice).

3d. That it should possess the greatest degree of durability, and the greatest facility of being repaired, which are compatible with the first two conditions.

The objects and advantages of continuous bearings will be rendered more apparent by examining in what respects isolated bearings appear to be inadequately adapted to fulfil the above conditions.

As regards the FIRST CONDITION, it may be observed, that a railway with the latter kind of bearings consists of an alternation of rigid points of support and intermediate flexible spaces; the consequence of which is, that the carriages passing along it alternately descend below, and are projected above the mean or true line of progression*. This diversion of the momentum from the straight course which it has so strong a tendency to maintain, occurring as it does 500 to 600 times in a minute, occasions a series of rapid concussions on the rails near to, or on the points of support, the severity of which is in proportion to the degree of the deviations from a straight course, the rapidity of their occurrence, and the solidity of the supports. In like manner the outward pressure of the wheels, occasioned by their being in a slight degree conical, deflects the rails sidewise between their fixed points, thereby producing a to and fro lateral motion in the carriages.

The supports being independent of each other, renders it impracticable to maintain them at exactly the same height, differences in the stability of the sub-

* Professor Barlow has shewn, in a Report to the Directors of the London and Birmingham Railway Company, that the deflection of rails between their points of support, occasions a considerable resistance to the progress of carriages upon them at high velocities.

soil, and in the degree in which it and the ballast are consolidated by the workmen, must occur, and slight variations in the rails must preclude equality of pressure and concussion on the blocks. When a block has sunk in ever so small a degree below those next adjoining it, one of these things must happen, either the rail will be held down in permanent flexure, or its efforts to regain its previous position will loosen it from the chair—loosen the chair from the block,—or hold the block in suspension.

When a rail is deflected between two chairs, they act as fulcra, by means of which the rail (or the weight causing its flexure) lifts or strains upwards the chairs next beyond them—thus each wheel in its progress successively strains up and presses down every chair it passes over, which must evidently, more or less rapidly, wear and loosen all parts of the structure.

It is evident, that the above described evils have a tendency to produce and aggravate each other. To them the greater portion of the repairs of ways and carriages is attributable.

In regard to the SECOND CONDITION, blocks of stones weighing $\frac{1}{4}$ of a ton each, must act rather as anvils than as neutralizers of impacts.

In regard to the THIRD CONDITION, the action of the rails, chairs, and blocks on each other, cause the chairs to get loose, their nail-holes becoming larger, and the nail-heads becoming less, by wear. The great height of the top of the rail above the base of the blocks, renders the latter easily tilted by the lateral action of the wheel flanges—the displacement of the blocks, from this cause and from irregular sinking, can only be repaired by digging out the ground all round them, in order to ram additional ballast under them.

The inadequacy of isolated bearers to fulfil the above stated conditions having been pointed out, it has now to be shewn in how far the continuous bearing principle, under the mode about to be described for reducing it to practice, is adequate to the purpose.

This mode consists in placing on and in a bed of “ballast” or gravel, trough-shaped bearers of cast iron connected end to end by overlap or inflexible joints. The bearers may either have the rail cast on and with them, (as shewn in Figs. 1 and 2 of Plate VII.) or have sills of wood inserted in them, (as shewn in the subsequent figures,) on which sills, rails of wrought iron, are supported throughout their whole length; the rails, sills, and bearers “breaking joint” with each other, so that the joinings of no two of them occur in the same place; they are compressed and held together by bolts or clamps, so as to

form an uniform and entire structure of the whole line, the continuity of which, therefore, can only be broken by the three materials being fractured at the same place. (See Plate VII.) This continuity causes them to be unaffected by any slight variations in the firmness of the ground which supports them, just as a beam resting upon springs of various force, would be supported by them all collectively, though pressing upon each in proportion to its individual power of resistance, whereas if a separate portion of the beam rested on each spring the several portions would assume different levels.

In investigating the effects of this mode of construction, it is desirable that the following points should be borne in mind, viz. :

1st. That gravel or ballast is a material which will not slip away from pressure like quicksand, but will become more and more hard or dense in proportion to the pressure acting upon it, till it finally resists it, however severe it may be.

2d. That ballast being non-elastic, or practically so, will retain any degree of density it may have acquired from pressure or concussion, after the force which has produced it is withdrawn, and be incapable of further condensation by any subsequent force which does not exceed that which had previously acted upon it.

As regards the fulfilment of the FIRST CONDITION, (see Fig. 11,) if pressure were applied to the rail forcing the bearer downwards, it would move and compress the ballast in the directions of the plain and dotted lines, or at right angles to the sides of the bearers.

If pressure were applied by rollers or beaters in the directions of the arrows, the ballast would still be compressed in precisely the same manner, for the plain arrows and plain lines, and the dotted arrows and dotted lines indicate similar or parallel directions.

If the bed of ballast were of exactly similar quality and thickness throughout, and its foundation equally solid, it is evident, that any amount of vertical pressure applied equally to all parts of the bearers would make them sink equally, until they were supported in all parts by ballast of the density due to the pressure, so also, if sufficient pressure were equally applied to all parts of the ballast in the direction of the arrows, (additional material being supplied to keep the height of the ballast undiminished by its compression,) the bearers, without sinking, would be supported in all parts by ballast, of the density due to the pressure so applied.

Supposing (as usually will be the case) the ballast to be of variable thickness and quality, and the sub-soil of unequal solidity, then, since the sub-soil

possesses in common with the ballast the property of acquiring density proportionate to the pressure it is subjected to, it is plain that pressure in the direction of the arrows will compress the ballast or subsoil, or both, until their density will resist that pressure, and (the depressed surface of the ballast being restored to its proper height by additional material) the bearers will be supported in every part by ballast of equal density, as in the previously mentioned case.

It thus appears, that whatever may be the circumstances of the ballast and sub-soil, they will easily be made to afford a similar and permanent support to all parts of the bearers, and it has next to be shewn, that the density or hardness of ballast which may be thus attained, is sufficient to resist the greatest pressure or concussion which can be imposed upon it by carriage wheels on the rails.

If it be assumed that the weight of a wheel would be diffused longitudinally by the rail and bearer to an extent equal to only double their united vertical depth, or (if Fig. 5 be taken as an example) to 10 inches on each side of the point of pressure, it would be sustained by a horizontal area of 220 square inches, or the intensity of the pressure on a square inch would be $\frac{1}{220}$ of the incumbent weight; hence, if by means of rollers or beaters, a pressure or percussion equal to $\frac{1}{4}$ of a ton on a square inch, were applied to the ballast in the direction of the arrows, it would thereby acquire a density, capable of resisting a pressure or concussion on the rail, equal to 50 tons; whilst the weight on a wheel must be limited probably to less than 5 tons, to avoid laminating the surface of the rails.

It can hardly be doubted that a pressure on the rails would be diffused longitudinally by them and the bearers to a much greater extent than has been assumed; (probably to the extent of 3 feet on each side of the point of pressure;) and it is certain, that a much greater force than $\frac{1}{4}$ of a ton on a square inch would be easily applied by rollers or beaters. Coach wheels apply a pressure exceeding this intensity to the surface of the common roads.

It should be observed, that by the divergency of the directions in which the bearers compress the ballast, (as shewn by the dotted lines, Fig. 11.,) and by the lateral cohesion of the particles of ballast to each other in consequence of such compression, the weight on the rails is diffused over a base, the breadth of which increases with its depth below the surface of the ballast.

The foregoing are the grounds on which the *vertical stability* of the railway is believed to be established; its *lateral stability* may be deduced from the following considerations:—

1st. By the rectangular shape of the bearers*, the vertical support they obtain from the ballast is rendered equally operative as a lateral support.

2d. The height of the rail above the base afforded by the bearers (or their width) is only one fourth of that base; and even this proportion may be diminished to any desired degree by extending the outer sides of the bearers, or those which have to resist the lateral action of the wheel flanges, whereby both the breadth or base of the bearers on that side is increased, and the vertical height of the rail above it, is diminished. (See *d*, Fig. 14.)

As the lateral force applied by carriage wheels is always accompanied by a still greater force acting vertically, the resulting force must necessarily act in a direction much nearer to the vertical than 45° , or than at right angles to the sides of the bearers.

No lateral vibration or oscillation can be produced by the passing of carriages; for their weight, by pressing the rectangle of the bearers into a coinciding angle of hard ballast, must hold them steady, that is, since their support acts as much laterally as vertically, they are as incapable of motion in the one direction as in the other.

The SECOND CONDITION is considered to be complied with by means of the sills of wood which are inserted between the rails and the bearers.

As a further security against vibration where the rails are fastened down

* This form, as compared with a flat base, affords the following great advantage. In beating or ramming ballast under the angular base, (in the direction of the arrows Fig. 11,) only one half of the force applied operates to lift the bearers upwards, whereas if the base were *flat*, the *whole* force would thus operate; hence if the weight and stiffness of the bearers were equal in both cases, the former would permit, without being raised, double the density to be given to the sustaining ballast which the latter would.

It having been supposed that the angular base of the bearers is a wedge, and will sink into the ground more easily than a flat base of equal breadth, the following observations are offered on the subject.

A rectangle is not mechanically a wedge, inasmuch as its base, instead of being *less* than its length, is nearly double its length. Whether or not a body having an angular base can, under pressure, exert a separating force on a substance in which it is embedded, must depend upon its own friction against, or adhesion to, that substance, and on the friction or cohesion of the particles of that substance in respect to each other; hence it is evident that a rectangle of cast iron could not exert a separating force on a bed of compact gravel, and still less on a bed of angular and interlocking stones. It might farther be shown, that (the breadth of base being the same) the more acute the angle of the bearer, or in other words, the *longer the sides of the wedge*, the greater would be its resistance to a depressing force.

by clamps, pieces of wood are inserted under the clamp-heads, causing the rails to be in contact exclusively with wood.

In explaining the degree in which the plan fulfils the **THIRD CONDITION**, the first point to be noticed is that of durability, which is expected to be obtained on the following grounds.

1st. Its strength and stability depend mainly on the cast iron bearers, which not being subject to corrosion, as wrought iron is, may be considered as indestructible.

2d. The timber, from its small dimensions, can be easily saturated with matter preventive of decay, whether by being boiled in tar *, &c., or soaked in Kyan's solution of corrosive sublimate.

3d. As the office of the timber, after the road is permanently settled, will be merely that of a cushion to neutralize vibration, its efficacy will be but little diminished by its partial decay.

4th. The timber being confined in a stiff iron case, cannot derange the line by shrinking or warping, neither can it be split or bruised by the flanges of wheels which may get off the rails.

5th. The contraction and expansion of the rails and bearers can take place without causing them to slide or rub against either the nuts or heads of the

* The application of tar, oil, &c., to wood in the ordinary manner can merely preclude the *ingress* of additional air and moisture, whilst it tends to confine in the wood the air and moisture it may contain at the time of the application. But if wood be immersed in oil or tar, and heated till it has throughout acquired as great a degree of heat as will not be injurious to its texture, (probably about 300°,) nearly all the air and moisture it contains will be driven off, and the small portion remaining in the pores and cells will be highly rarified air and steam, which, on cooling, would be condensed into perhaps $\frac{1}{1000}$ part of its volume; (depending on the proportions of air and moisture the wood may have contained, and on the heat applied to it;) therefore, if *the wood be cooled whilst* submerged in the fluid, the pressure of the atmosphere (to which mechanical pressure might be added) will force the tar or oil, &c., into its exterior pores, and probably compress the cells or pores into which the tar, &c., is too viscid to penetrate. The exterior pores of the wood will thus, as experiment has shewn, be imperviously closed against the entrance of air or moisture.

This process could be applied with most facility to timber of small dimensions. It would be less expensive than Kyan's process, and may perhaps prove a more permanent preventive of decay, since it wholly excludes moisture, the admission of which into the kyanized wood may give rise to decay, notwithstanding the change produced in the sap, and it certainly occasions the sills to swell and shrink as the weather changes from wet to dry, which is very objectionable.

bolts, whereby a certain amount of wear and consequent loosening is avoided. The motion from expansion and contraction will merely produce a very slight swaying or radial motion in the bolts, which their flexibility and the size of their holes will readily permit, and which will be too minute to affect their vertical length in any detectable degree. (See Figs. 4 and 8.) Figures 6 and 7 exhibit a mode of fastening in which clamps affixed to the bearers in the manner of a "lewis" are substituted for bolts; and they also readily permit the contraction and expansion of the rails; and in order that the closing and opening, thus caused, of the spaces between the ends of the rails, may be equal at every joint, it is desirable that the *middles* of the rails should be fixed to the wooden sills by means of screw bolts or spikes.

6th. To preserve the ballast from being softened by water, the rain which may fall on the rails and bearers is collected and carried off by the channels in the sides of the bearers, and by the spouts, (shewn in section in Fig. 10,) also the ballast under each line is laid in a raised ridge, and therefore open to drainage on both its sides; in addition to which, the ballast under the bearers forms a drain throughout. (See Fig. 11.)

The "facility of being repaired," which the plan possesses, is the last point to be noticed.

Since all parts of the structure are so combined together as to be incapable of motion in respect to each other, the only cause of derangement to which it appears to be exposed, (and this in common with all other plans,) is the sinking of the sub-soil. Those cases of subsidence which can be provided for in the mechanical construction of a railway, may perhaps be considered as of three classes.

1st. Those which, although of small extent, occur suddenly, as the slipping of a portion of embankment.

2dly. Those which occur gradually and are so extensive in length as to form a curvature, with which the flexibility of the railway will allow it to coincide from its own weight.

3d. Those which occur gradually, but are so limited in length as to form a curvature with which the railway can only coincide when depressed by an incumbent weight.

The evils of the first case can only be mitigated in their degree; and the means of mitigation which this plan affords, consist in its longitudinal con-

nexion, its lateral stiffness, and in its admitting tie-bars to be readily applied to it at any time.

The most convenient and ready mode of applying them is shewn in Fig. 14. Spaces or notches about two inches wide being cut in the portion of the sills which projects above the bearers, the tie-bars are passed under the rails, and their hooks (or ends bent at right angles) are then turned downwards so as to take hold of the bearers. They can be applied or removed with great facility.

Fig. 12. Shews a mode of applying wooden tie-bars, which being level with the middle of the road between the rails, may be used where horses work on the line.

In comparing this plan of railway as connected with tie-bars, (of whatever kind,) with a railway whose wooden sleepers act as ties, it must be obvious, that the lateral stiffness, firm longitudinal connexion, and imbedment in the ground, of the former, must enable it to oppose a much greater (at least, a ten-fold greater) resistance to being moved *sidewise*, than the flexible rails, and unconnected sleepers lying on the surface of the ground, of the latter plan, can oppose to the sleepers being moved *endwise*.

The second case requires simply, that the railway should be restored to its proper level by beating or rolling additional ballast under the bearers, and this may be very easily done, since the structure possesses a degree of vertical flexibility which, though very limited, is yet sufficient to allow it both to sink into gradual curves, and to be raised to its previous position, without any disconnection of its parts, or deterioration of its properties. Portions of the line may be successively raised by levers or screws to the required height, and ballast be driven into the space between the bearers and the bed from which they have been lifted.

The occasion for this kind of repair will, of course, wholly cease when the sub-soil and ballast have attained permanent solidity, similar to that of a good turnpike road.

The third case differs from the second only in this respect, that the bearers not being in contact with the ballast, except when they are depressed by an incumbent weight, the space between them and it is visible on the surface, and it only requires that such space should be filled up by beating or rolling ballast into it; sleepers or bearers having flat bases beneath the surface of the ballast,

would, in such case, expose the fact of the ballast being sunken, only whilst they were depressed by a weight upon them.

The exposure on the surface of the ballast of any the smallest degree of the third case of subsidence, is an advantageous consequence of the rectangular form of the bearers, to which may be added, that the remedy is applied at the surface without disturbing the consolidated ballast.

With respect to such repairs as wear and decay may render necessary, the plan allows the rails and wooden sills to be removed and replaced without disturbing the bearers, or the foundation on which they rest.

The foregoing pages explain the objects of a continuous-bearing railway, and the mode of construction which is believed to be the best calculated to attain them; there still, however, remain to be added, a few remarks on the details.

Figures 1 and 2 shew the rails and bearers combined in one piece of cast iron, as laid on Chatmoss of the Liverpool and Manchester line in April 1836*.

The high elasticity of cast iron, and its liability to slight defects in its surface, render it ineligible for railways on which the traffic proceeds with great velocity; but where only a moderate speed is required, the combined rails and bearers (Figures 1 and 2) may be used with advantage, from the little trouble and expense of laying and maintaining them.

Figures 3 and 4 shew the two modes first adopted of affixing wrought iron rails to cast iron bearers; of these, nailing down the rails (Fig. 3) has proved to be inefficient. Bolting down the rails (Fig. 4) is effectual, but the water channels as shewn in the figure are too small.

The mode of fixing the rails by clamps (Figs. 6 and 7) is much superior to that of fixing them by bolts, since the rails have no bolt holes, and need not be cut to exact lengths, but may vary 2 or 3 inches from the mean or average length required. By the intervention of a piece of hard wood between the heads of the clamps and the rails, the latter are held in contact with wood only, whereby noise and vibration will be, as far as possible, prevented. The clamps can be applied, tightened, or loosened, with much greater facility than bolts, and as the only force or pressure to which they are exposed, acts upwards, and

* The defect exhibited in this experiment is the compression of the packings which support the extremities of the small ends of the bearers, in the saddles or large ends. This arises from the packing being *solder cast in*, and which, therefore, cannot be tightened as wear or compression takes place; this is obviated by the mode of packing shewn in the Plate, Fig. 9. In other respects this piece of railway fully answers its intention.

therefore tends to tighten them in their sockets, they cannot become loose. The sockets are so arranged in the bearers, (which are 10 feet long,) as that when the latter are connected end to end in proper order, two pair of clamps with a space of 6 or 8 inches between them, occur every 15 feet, in some part of which space the ends of the rails meet. (See A B, in Figs. 16 and 17.) This requires three patterns of bearers, as regards the position of their sockets; the number and position of the sockets, however, as also the lengths of the bearers and rails, must depend upon circumstances, and the opinion of the engineer. To secure the ends of the rails from sinking or *dingeing* into the sills, or being forced out of their true line, pieces of hard wood, 6 or 8 inches long, and of the form of the hollow or bridge of the rails so as to fill it completely, are inserted with half their length in each of the adjoining ends of the rails, whereby an additional bearing surface on the sills is afforded at the rail joints, (*c*, in Figs. 6 and 15.) Pieces of iron rolled to the required form, with thin sheets of lead between them and the rails, may be substituted for the wood*. On the outside of the rails, or the side on which the flanges of the wheels do *not* run, pieces of bar iron about an inch wide and $\frac{1}{2}$ inch thick, with strips of wood under them, are placed on the flanges of the rails across their joints, and are held down by the clamps, (as shewn at *a*, in Figs. 6 and 16,) so that the rail-ends cannot rise or shake. By the above means firm and even joints are obtained, without impediment to the contraction and expansion of the rails, and without permitting them to be in contact with iron.

The most convenient mode of laying the railway, is to render the ground on which a line of bearers is to be placed equally solid by heavy rollers or beaters, so as to form a shallow trench about 2 feet wide, taking care to give its bottom a little declination towards the places (10 to 20 yards asunder) where the cross drains will intersect it; then to fill the trench to the depth of 6 or 8 inches with stones, &c., rendered firm by rollers or beetles; on this the bearers are to be placed, and broken stones and clean gravel are to be beaten or rolled under and against their sides. After a convenient length of bearers have been ad-

* If the rails be of the form shewn in Fig. 14, then at the places of their joints, notches or recesses of 4 or 6 inches wide, and $\frac{1}{4}$ to $\frac{3}{4}$ inch deep, should be cut in the timber which projects above the bearer. The bottoms of the recesses should have a slight bevel or slope transversely to the rail. Pieces of iron or hard wood made to fit these recesses, should be driven into them after the clamps or bolts near the ends of the rails have been tightened down; this will insure a firm bearing to the rail-ends—pieces of teak wood would probably answer well.

justed by the packing pieces at the joints, and bolted together to a true level, a long straight edge should be applied to the parts on which the sills are to rest, and if any unevenness is perceptible, the hollows, however small their depth, should have strips of wood or felt, of the proper breadth and thickness, placed in them (the workmen being provided with strips of wood cut in a saw-mill to every possible variety of thickness and taper). A level bed being thus insured for the sills, whose sides are exactly parallel, (being sawn by machinery,) the rails when fixed down upon them will present a level surface.

A perfectly level bed for the sills may be obtained by filling the interior angle of the bearers (after they have been adjusted and bolted together) with Roman cement, and rendering its surface parallel with the surface line of the rails by means of a mould sliding on a properly adjusted guide bar *. (See *b*, Fig. 14.) Before the sills are placed on the cement, its surface should be smeared with coal-tar or other similar matter.

Instead of Roman cement, a slightly elastic bituminous cement may be employed, perhaps, with greater advantage; and as either kind of cement will adhere firmly in the angle of the bearers †, it may be inserted in them severally before they are laid, and its surface (whilst plastic) be reduced to an accurate level by means of a mould or scraper guided by planed grooves in a frame properly adjusted to the bearer, the effect being the same as though the angles of the bearers had been cast solid, and their surface planed by a machine.

The intervention of a board of hard wood between the rails and sills, as shewn in the plate, will not only reduce the risk of the wood being bruised, but should this eventually happen, the boards could be replaced with but little trouble or expense. They also afford the means of easily correcting any slight deviations from a true level which may be observed in the surface of the rails by the insertion of strips of wood, pasteboard, sheet iron, or felt, between them

* It having been suggested, that the cement would probably be pulverized by the weight and concussions of the engines, &c., on the rails, the following experiment was made:—the interior angle of a bearer was filled with cement, rendered level by a mould sliding on guide bars. After a few days had been allowed for it to harden, a sill of deal 3 inches thick was laid upon it, and on the sill a bar of iron $\frac{1}{2}$ an inch thick was clamped down. The bearer being placed on a stone floor, the bar of iron was violently beaten with a sledge hammer. Although the concussion thus applied very far exceeded what could be occasioned by wheels rolling on the rails, yet the cement was neither cracked nor bruised by it—also, not a single clamp was loosened.

† A few small projections or nipples cast in the interior angles of the bearers would insure the retention of the cement.

and the sills. Such boards, however, may be safely omitted, if the hollow or bridge of the rails be filled up with hard bituminous cement, since the breadth of their bearing surface on the sills would be thereby materially increased.

The rails should have bevelled ends, as shewn in the drawings; and it is desirable that one-half of their number should have their bevels cut the reverse way to that of the other half, in order that *both* lines of rails (forming one track) may be so laid, as that the flanges of the wheels (the direction in which the trains are to travel being known) may always pass *off* or *from*, and not *on to*, or *against*, the points of the bevelled ends.

The ballast or gravel should, from time to time, be rolled or beaten till it has attained the solidity of a good turnpike road. Although a rectangular form is adopted for the base of the bearers, yet no particular forms or dimensions are prescribed; these may be varied as circumstances or opinions may dictate; therefore, all that can be stated as indicative of first cost, will be the weights and quantities of materials contained in the examples adduced in the plate.

The bearers will weigh,

as shewn in Fig. 1.		140 lbs. per single lineal yard.	
do.	3.	80	do.
do.	4.	75	do.
do.	5.	112	do.

The rails will weigh about 45 to 50 lbs. per yard. The sills, (common deal, elm, or other cheap wood,) including waste, will be less than half a cubic foot per yard, or less than one third of a cubic foot if the interior angles of the bearers be filled with cement. The quantity of ballast will not exceed the half of that required for blocks, and of this about $\frac{1}{4}$ th of a cubic yard per single lineal yard should be broken stone or gravel free from earth. Hence, it will appear, that when iron is at an average price, a railway on this plan would be considerably less expensive than one of equal strength on the usual plans, except in cases where blocks and ballast are unusually cheap*. The bearers shewn in Fig. 5, &c., are stronger and heavier than would be required in ordinary cases.

* The relative expense of cast iron and wooden continuous bearers can only be determined in a comparison of particular cases. It may, however, be observed, that as the stiffness of deal is to that of cast iron less than 1 to 15, (Barlow on the strength of timber, iron, &c., 1837,) bearers of equal stiffness will be of nearly equal cost. To ascertain the comparative advantages of the two kinds of bearers, would require an investigation into the value of form, occasion for repairs, durability of material, &c., for which, at present, there are no sufficient data from experience.

EXPLANATION OF PLATE VII.

Fig. 1. Is a general section of a rail and bearer combined in one piece of cast iron. A specimen of this construction is on Chatmoss on the Liverpool and Manchester railway, where it was laid in April 1836.

Fig. 2. Is a section of Fig. 1 at the overlap or inflexible joint, shewing the small end of one bearer bolted into the saddle or large end of another bearer. The construction of the joint is similar to that shewn in Figs. 8 and 9.

Fig. 3. Is a general section of the *first mode*, adopted for combining wrought iron rails with cast iron bearers. The bearers have the form of troughs, into which sills of wood are fitted. The rails are fastened to the sills by nails or spikes.

Fig. 4. Is a general section of the *second mode* adopted for combining wrought iron rails with cast iron bearers. In this the rails are fastened down by screw pins passing through them, the sills, and the bearers. The joinings are the same as Figs. 8 and 9.

Fig. 5. Is a general section of the *last and most perfect mode* adopted for combining wrought iron rails with cast iron bearers. In this, the rails are fastened down by clamps fixed "lewis" fashion in the bearers, boards of hard wood intervene between the rails and the deal sills, as shewn longitudinally in Fig. 15.

Fig. 6. Is a section in the line AB of Figs. 16 and 17, shewing the clamps at a rail joint, with the pieces of hard wood inserted between their heads and the rails. On the side on which the wheel flanges do not run, the two adjoining clamps hold down a bar of iron, which crosses the rail joint and confines the ends of the rails. In the hollow or bridge of the rail is seen a piece of hard wood or of iron (shewn longitudinally at *c*, Fig. 15,) to distribute the pressure of the rail ends over a larger area of the sills.

Fig. 7. Is an inside front view of a clamp, and of the key by which it is fixed in the dovetailed socket of the bearer.

Fig. 8. Is a section in the line DE of Figs. 15, 16, and 17, shewing the screw pins which connect the bearers, and which in conjunction with the packing pieces (Fig. 9) render their joints inflexible.

Fig. 9. Is a section in the lines FG of Figs. 15, 16, and 17, shewing the tapered packing pieces *h h*, of iron or hard wood, which support the extremities

of the small ends of the bearers within the saddles or large ends, and by which the troughs to receive the wooden sills are adjusted to an accurate correspondence before the screw pins, Fig. 8, are tightened.

Fig. 10. Is a section in the lines HI of Figs. 15, 16, and 17, shewing the spouts by which the water collected in the side channels of the bearers is discharged beyond the bed in which they immediately rest. Draining tiles may be placed under the spouts.

Fig. 11. Is a transverse section, on a reduced scale, of a portion of finished railway, shewing the foundation, or stone drain, under the bed of broken stone or hard gravel on which the bearers are supported. The arrows and lines shew that the directions in which the ballast is compressed by the bearers, and in which it is beaten or rolled under them, are the same.

Fig. 12. Is a transverse section of a portion of finished railway on embankment, having the two lines of rails connected by a tie-bar of wood.

Fig. 13. Is an end view of the tie-bar *f*, and cleat *e*.

Fig. 14. Is a section of a rail and bearer shewing a mode of applying tie-bars of iron. Spaces or notches about two inches wide being left or cut in the wood which projects above the bearers, the tie-bars are passed under the rails with their bent ends horizontal, which are then turned downwards so as to clip the bearers; *d*, shews an extension of that side of the bearer which has to resist the lateral action of the wheel flanges, whereby both the base is extended and the vertical height of the rail above it, is diminished. In this figure, the bottom or interior angle of the bearer is represented as filled with cement.

Fig. 15. Exhibits a portion of railway in longitudinal section and in elevation. *c* is shewn in section in Fig. 6; DE, in Fig. 8; and FG, in Fig. 9. R shews a rib giving additional depth and strength to the part of the bearer immediately under the joint of the rails, where, otherwise, their want of continuity would weaken the structure.

Fig. 16. Is a plan of a portion of railway shewing the position of the clamps; in respect to which, however, no particular number is prescribed. AB is shewn in section in Fig. 6; DE, in Fig. 8; FG, in Fig. 9; and HI, in Fig. 10.

Fig. 17. Is an isometrical view of a portion of railway. The letters refer to the same sections as in Fig. 16.

REYNOLDS ON RAILWAYS OF CONTINUOUS BEARING.

J. Reynolds del.

F. Marcell sc.