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## RAILWAY FISH JOINTS.

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THE author's object in writing this paper is to call the attention of the Members of the Engineering Association of New South Wales to the especially peculiar conditions to be observed in the design and construction of railway fish joints.

It is probable that almost every studious observer and advocate of mechanical progress in railway permanent way construction will regretfully admit that the common fish joint has not been improved much since its advent as a railway appliance forty-six years ago. The fish joint of two plates and four bolts was invented in 1847, and although its constantly manifest imperfections have conjured forth hundreds of promisingly successful competitors, the old-fashioned fish joint still holds a premier place, by virtue of nearly universal usage.

With apologies to all enthusiastic, and perhaps disappointed designers of fish joints, the author respectfully submits that the vital essentials of a good joint are but rarely recognised and observed in its design. The main conditions in design are as follows :—

- 1st.* The span distances and conditions of loading being equal in fish joint and rail, the fish joint should have the same amount of flexibility as the rail intended to be spliced.
- 2nd.* To secure simultaneity of fatigue, the plates, clips, angle bars, or fish plates, must be of the same quality of material as the rail, and must be worn or abraded away in the same ratio.

- 3rd.* The bolts, cotters, keys or other fastenings must be designed and applied so as to take up no part of the travelling load. Bolts, etc., subjected to rapid repetitions of moderate loads are specially liable to stripping of threads, hammering of nut and head faces, and permanent elongation of material in shanks, and should not be relied upon, excepting as preservatives of gauge and continuous alignment. Lock nuts, spring washers, thread lockers, and such accessories can not be considered as remedies for the distortion of primally misapplied materials.
- 4th* Provision must be made at the joint for the expansion and contraction of the rails during changes of temperature. Caution to be observed—that tight joints prevent free expansion and contraction, while joints too slack cause battered rail ends and unpleasant jolts to rolling stock and freight.
- 5th.* The centre of gravity of the joint must be upon the central vertical line of the rail, so as to obviate the danger of canting under a heavy load, and also the preventive of torsional stresses due to gyratory movements at the junction of the rail and an eccentric joint.

The author believes he is correct in saying that the most approved kind of rail splice at present in use fulfils but very few of the essentials of the ideal fish joint.

Nearly every joint maker claims to have a splice that will connect two rails together, in such a way as to make the joint as strong and no stronger than the rail itself, and as flexible and no more so than the body of the rail. If these claims could be substantiated the major requirements of the ideal joint would have been attained.

One of the objects of this paper is to show that, because of certain theoretical and practical obstacles, a claim for a fish

joint of the same strength and flexibility as the rail is invalid and baseless.

In support of this negative contention the author proposes to show reasons for his assumptions.

A close observation of a long light rail placed upon sleepers widely spaced in soft ballast, and subjected to slowly-moving heavy loads, will clearly show that the road is elastic, and that a continuous and nearly vertical wave motion of rail occurs in unison with the varying depressions of the sleepers. With a heavy rail and short-pitched sleepers set in hard ballast, the sinuosities and depressions, though minimised, are still of such a character as to be easily registered by a specially designed apparatus, as shown in Fig. 3, Plate I.

This inexpensive appliance was designed in 1879 by the author of this paper for the purpose of assisting him in determining the relative working strengths of bull head, double head, and flat-bottomed rails of Bessemer steel, each rail being 75lbs. per lineal yard. The usual drop weight tests having been carried out, and duly certificated by empirically deducted formulæ, it was observed that erratic differences in the tabulated results were probably caused by chemical and molecular differences of material in rails, even when made from the same ingot cast, and that results of a different character altogether might be obtained when rails were subjected to actual working conditions. To test a rail by weighted levers, hydraulic rams, or modified pile-driving machines is entirely wrong. A test so made is in no sense similar to the tests of actual service, and especially so when the testing apparatus is incapable of registering dynamic impacts.

By Fig. 3, Plate I., it will be seen that three stakes, A, B, C, are driven firmly into permanent way formation. A lever, D, is slotted to grip the rail flange or lower head of rail at E, and is pivotted to post A at F. The lever end at G is bored to receive a sliding lead-pencil H. A notch is cut in lever to expose the blunt end of pencil at I. The post C is

slotted to receive a registry board, J, which is made to slide freely in cleats and parallel to the rail to be tested. The indicating card is pinned to the board, which is made tolerably stout and heavy so as not to be vibrated by the passing loads. An india-rubber band, K, is passed over the post, cross turned into notch of lever, and round the blunt end of pencil, for the purpose of controlling the vibration of lever, and the contact of the pencil and paper. By placing several of these contrivances at desirable intervals of a few feet apart along the rail, and using a registry board long enough to extend over a whole length of rail, it is no difficult matter to get an exact diagram of the action of the permanent way under rapidly passing heavy loads.

A movement of the registry board prior to the passing of the load draws the zero line, and another steadily regulated movement during the passing of the load draws a zigzag diagram, which is easy to plot to any scale as a line of curved continuity, when the fulcrum ratios of levers and fixed distances of posts are observed in scaling. Fig. 4, Plate I., is a diagram as seen through a piece of tracing paper gridded with tenths of an inch. By allowing a locomotive driving wheel to rest exactly over a fish joint, as at Figs. 1 and 2, Plate I., and then passing the same wheels backwards and forwards over the same joint at speeds varying from ten to fifty miles per hour, it will be found that the diagrams of each stage of the operation produce more satisfactory estimates of the relative values of various designs of fish joints and rails than can ever be attained by levers and weights, hydraulic presses, or drop weights. The strain on each extreme fibre of the rail and joint can be readily determined with an accuracy that is nearly infinite, by reason of the fact that we have registered the maximum and minimum deflections under all loads and speeds, conditions of joint fittings, sleepers, and ballast. By adjusting the positions of the sleepers and registering the results, it is an easy matter

to ascertain their best span distances for the economic and safe working of the rail, whatever may be the load.

Fig. 5, Plate I., shows the perfect elastic curve as estimated for the ideal fish joint. Fig. 6, Plate I., shows a fish joint much too strong for the rail. It will be observed that the rails covered by splice plates are horizontal, and that continuity of flexure is lost. Fig. 7, Plate I., shows a weak fish joint, and the consequent loss of flexure curves, due to the sudden bending of the fish plates, as if they were articulated in the centre of span.

The uniform continuity of vertical wave motion through rail and joint can be obtained only by making every cross sectional plane of the fish joint to be of the same inertia moment value, as every cross sectional plane of the body of the rail.

Uniform moments of inertia can only be obtained by making the sectional area of fish joint of the same sectional area as the solid body of rail.

It is undoubtedly possible for a fish joint to be designed which would splice two short pieces of rail across a span of say two feet, and be capable of carrying the same central load as, and with the same central deflection, as a solid piece of rail across the same span. Though the dead load capacity of joint be equal to that of solid rail, the deflection curves of joint and rail would differ, both in form and intensity. Therefore, as it seems impossible that we can have a built up fish joint of uniform strength and varying flexure, and an endless rail of uniform strength and flexure, occupying the same position at the same time, perhaps it is not unreasonable to deny the claims of the fish joint that is just as strong and flexible as the rail, and no stronger or more flexible.

Almost every railway engineer admits that the road cannot be made and maintained perfectly rigid, because of the immense cost that would be entailed in construction of continuous foundations and expansion joints; and that it in

unquestionably better to build the road with a minimised quantum of uniform elasticity.

The idea of the rigid railway is older than the fish joints. Mr. George Stephenson had an idea for fastening the rails down to solid rock, and he tried the plan in a rock cutting on the Manchester and Leeds Railway, since known as the Lancashire and Yorkshire, of which he was appointed engineer in 1839. According to published reports, the solid rock was trimmed level, and the chairs were spiked directly to it, but the road was so rigid, "that if a train passed over it at more than a walking pace, rails, wheels, axles, or springs were broken, and in less than three weeks from the opening of the railway, the rails were taken up and placed upon sleepers in the usual way." The failure of the system was attributed to the impossibility of keeping the chairs fast to the rock, and the consequent hammering damages inflicted by the passing loads.

Mr. Brunel originally designed the permanent way of the Great Western Railway to consist of longitudinal timbers resting on transverse timbers placed upon piles, arranged in pairs at intervals of 15 feet. This road was tried in 1838-9 between London and Maidenhead. It was found to be quite impossible to keep the sleepers full ballast packed, and the consequent damage to rolling stock by the rigidly supported rail joints at the piles, soon induced Mr. Brunel to try an elastic road, by cutting a foot away from the top of each pile, and thereby producing the afterwards well-known ballasted longitudinal sleeper system.

On many of the old railways of sixty years ago, stone blocks were used to support the rail joint chairs, and it is well known that these roads were harder on rolling stock than loose sleepers, even without ballast. This was due to the causes of failure as described for Brunel's system and as illustrated in Fig. 6, Plate 1. In some cases in India, where cast-iron pot sleepers were laid in shallow ballast in rock cuttings, the permanent way was found to be too rigid, and that the only

remedy to avoid fractured sleepers was to give elasticity to the road by deepening the ballast. Mr. C. E. Stretton in his book on "Safe Railway Working" says:—"Nothing can be worse than a permanent way that is rigid, but in the early [days of railways this fact was not known or understood, consequently many ideas and inventions proved failures. They provided a very strong road, and the rigidity was so great that the permanent way and rolling stock was jarred to pieces, not worn out by ordinary working, thus clearly showing that a certain amount of elasticity is absolutely necessary." Permanent way must be strong and firm, but at the same time possess a certain amount of elasticity. It is necessary that the elasticity shall be uniform throughout, and not a system of alternate elasticity and rigidity, as shown in Figs. 6 and 7, Plate I., in which it serves to aggravate the defects by a succession of jumps and jacks,

Professor P. H. Dudley, in writing to the President of the Boston and Albany R.R., after going over the permanent way with his dynagraphic inspection car, says:—"Your approaches and elevations are very fine, and, with the exception of a few sections on the second division, when we passed over the line the joints were so firm that we spotted more rail centres than joints. Keeping the joints so firm that the wave of transmission from rail to rail is not broken is the greatest requisite of an easy riding track. The wearing of the rails cannot be prevented, but by a proper care of the joints and renewal of fastenings, the easy riding of the track may be easily maintained."

It would appear from this report of soft centres and hard joints that the support of the latter was excessive, or else the fettlers must have given too much attention to them while the rail centres were neglected.

In the design of a fish joint, an investigation of the relative strengths of the solid rail and joint will probably be much assisted by the data herewith presented.

The double-head rail being symmetrical in form, the centre of the group of moments of inertia will exactly coincide with the centre of gravity of rail. Though a flat-bottomed rail may be designed so that the moments of inertia and gravity centre are the same as in the double-head rail, it is usually found in these as in bull-head rails, that, because of the centre of gravity or neutral axis not being coincident with the centre of height the distribution of the volume of stress unites upon the plane of moments of inertia will produce strains in the extreme fibres exactly determined by the values of their lever moments, taking the neutral axis as the fulcrum centre.

As a result of a large number of experiments on the strength of steel rails the average limit of elasticity, tension, and compression, was 17 tons per square inch, and the coefficient or modulus of elasticity was 13,500 tons. The stress unites compression, and tension must be not more than one-third of the elastic limits, so as to provide a safe margin for reduced working areas, consequent to the wear of rails and joint fittings.

The maximum central deflection of rail or joint must not, under any circumstances be more than a thousandth part of the sleeper spans, for even with that deflection there is an average rising and falling gradient of 1 in 500 at every pair of sleepers of 2 feet span. A joint designed of such a strength or weakness as to produce a deflection of one-sixteenth of an inch, at or near joint of sleepers of 25 inch span will give average rising and falling gradient of 1 in 200

Slack rail joints may be calculated as single or double cantilevers, according to position of wheel loads. Tight joints and solid rails may be treated as continuous beams with span loadings, according to the relative centres of wheels and pitch of sleepers. The maximum static load upon one wheel being 8 tons, the increase due to dynamic impact at high speeds over spans of 25 inches would be about 25 per cent., making a total working load of 10 tons per wheel.



When rail joints are constructed in accordance with the foregoing conditions, and some means are provided for preventing the pounding of the ends of rails by reason of the space left between them for expansion and contraction, and to stop the noise thereof, rail joints will have reached something like perfection.

Railway engineers cannot stop the process of evolution that applies to constant traffic increases, though something might be done to anticipate the requirements by the design of a fish joint structure radically different to that which has held its own through the last half-century. What would the world think of the architect who erected a permanent construction upon a foundation that required a standing army of workmen with unceasing efforts to make it serve its purpose? Yet this is what has to be constantly done on every railway, and despite the vast expenditure of hard cash and labour for repairs and renewals, every advance in weight of rolling stock and volume of traffic only serves to bring the whole of the railway machinery nearer to its point of failure.

As before stated, the object of this paper is to draw the attention of progressive minds to the slow advancements made in fish joint construction, and the author hopes that the subject will be productive of a good discussion by the members of this Association.

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