PAPER No 87.

SOME ASPECTS OF TRACK MAINTENANCE AND PERMANENT-WAY ON THE NORTH-WESTERN RAILWAY.

E. WATSON, B. E.

The present call for economy by Government as regards expenditure has evoked amongst other things investigations as to how the admittedly high current cost of track maintenance may be curtailed. Since the cost of permanent-way maintenance amounts to 60 per cent. of the total maintenance of the Railway the importance of its cost is evident at once.

The question of the number of men to be employed has been allowed to drift partly through inefficiency and also on account of the comparatively low cost of labour in the past but with the cost of labour being double of what it was a few years ago, the scale of men to be employed is now of high economic interest. I will first deal with the ordinary maintenance of a main line.

A Permanent-way Inspector's charge on the main line consists at present usually of a length of about 40 miles of track whether of single or double line ; he is assisted by two Sub-way Inspectors each holding a Sub-charge of half the Permanent-way Inspector's. The charge is usually divided into sections of about 3 miles each and each section is supervised by a mate, a keyman and a certain number of gangmen, the number of the latter amounting to roughly 3 men per mile of single track, plus additional men for station yard sidings, fencing gangs, creep adjustment and earthwork repair gangs. With the arrangement shown above, the cost of a section in wages alone works out at Rs. 100 per mile of track per month.

The writer after somewhat considerable investigation reduced the above scale by the creep fencing and repair gangs and after 1½ years' experience finds that the scale is nearly correct or at all events that the old scale was too high. Where special creep fencing or other work was found necessary, a number of selected men (by depleting the standard gangs or by removing them bodily temporarily) were formed into a flying gang and when their special work was completed they rejoined their permanent posts.

The question now arises, can the strength for main line work be reduced still further. I hold that it can and would propose :—

(1) To double the length of the Permanent-way Inspector's charge.

(2) To double the length of Sub-way Inspector's charge.

(3) To lower the rate of three men per mile to say 2 men per mile for cast iron plate road of the N.-W. Railway type and for wooden sleepers under 10 years of age laid under 90 lb. rails.

(4) To retain the rate of 3 men per mile for wooden sleepers over 10 years old laid under 90 lb. rails and for all track (except on branch lines) below that weight per yard.

(5) To retain the present station yard scale of —
2 men per mile of A class sidings,
1 man per mile of B class sidings.

Regarding proposals (1) and (2) I may say that I have experience of two Permanent-way Inspectors supervising very successfully lengths of 80 miles each and though branch lines, they had to maintain the signalling works, which is not the case on the main line. The East Indian Railway Permanent-way Inspector supervises a length of 60 miles with the aid of 2 mistries.

Proposals (3) and (4) are somewhat tentative but I know of one branch which carries fast mail and passenger traffic, furnished with old sleepers, being successfully maintained on this lower scale, so that the conditions do not seem unduly severe.

Proposal (5)—This I strongly urge as most of our station yards are furnished with very bad sleepers demanding constant casual renewals and a curtailment of strength in this direction would, I am afraid, result in more station yard accidents than we have at present. Regarding branch lines the scale of Permanent-way Inspector and the Sub-way Inspectors is usually correct : the scale of men however to be employed cannot be fixed as the material laid is usually of a character difficult to maintain. The strength however should never exceed $2\frac{1}{2}$ men per mile of single track and for branches laid with 75 lbs. rails the scale should not exceed 2 men per mile exclusive of the mate and keymen.

The above scales assume that there is no necessity to employ a contractor or casual labour for loading, unloading, sorting, and handling material whether for through or casual renewal of rails and sleepers and that all these duties are performed from within the strength mentioned.

Regarding organization of maintenance of way on American railways, I would commend the perusal of Mr. Tratman's book styled " Railway Track and Trackwork." Chapter 16 deals with the organization and strength of permanent-way maintenance staff on American railways in a very interesting and instructive manner.

Turning to the cost of through renewals and sleepers as contrasted with casual renewals of these items, a work which our permanent staff cannot very well be expected to perform in addition to their ordinary routine duties, I would say that considerable economies in this can be effected by a closer scrutiny of the supervising officer.

This work should be carried out by gangs in which there is a strong infusion of the permanent gangs who are trained and understand the work, and the temporarily depleted permanent gangs should be reinforced by temporary labour. I give below three years' experience of the cost of this important detail :—

> Cost of dismantling and relaying including loading and unloading of all material, from 8 to 10 annas per yard, the lower cost corresponding to a coolie's pay of 8 annas per day and the higher to a coolie's pay of 10 annas per day.

The above actuals were arrived at under fair average conditions.

Closely allied to maintenance costs is the character of the rail jointing arrangements.

The present fish-plate joint was invented by a Mr. Adams in 1847, and though other devices have been tried including Mitre, Scarf and supported joints the fish-plate type still persists.

In our 75 lbs. type of rails the fish-plate appears to give an excessive deflection even when the road is adequately and fully packed and ballasted ; our 90 lbs. rail has the same defect in the fish-plate though in a less degree.

I am not aware of any experiments having been carried out recently as to what is the best type of fish-plates to be adopted for a specific purpose nor am I aware of any proposed experiments in this connection.

We have however on record a very valuable paper dated 1910, in the proceedings of the Institution of Civil Engineers on this

subject by Mr. C. W. Lloyd Jones who as a result of his experiments and calculations shows—

(*a*) That neither the *number* and *position* of the bolts, the tightness (within reasonable limits) with which they are screwed up, the lubrication of the fishing planes, nor the amount of clearance between the rail ends have any effect on the strength or stiffness of the rail joint.

(*b*) That the number of bolts should be reduced to two.

(*c*) That the length of a fish-plate need not exceed 14 inches.

(*d*) That there is no advantage in giving the fish-plate excessive strength or stiffness as it is not advisable to allow it to be subject to a bending moment greater than a certain value (dependent on the safe pressure on the fishing planes) which is probably about 32 inches tons.

(*e*) That weakness in a joint cannot be remedied by substituting a heavier or stiffer fish-plate unless the weak fish-plate fails by bending and not through bearing pressure failure.

(*f*) That nothing definite has been arrived at as to what the best fishing angle should be to meet with the varying conditions.

The subject at this stage requires further investigation but we can say with certainty that our existing rail joints can be much improved by—

(*a*) Planing by machine the bearing surfaces of the fish-plates and those portions of the rail with which they remain in contact, as the fit is generally poor.

(*b*) Crowding more sleepers in the vicinity of the joint sleepers.

(*c*) Increasing the depth of ballast for a distance of say 6 feet on each side of the joint to say 12 inches as against 8 inches at present provided for, to obtain a better distribution of loads on the earth formation.

We can also say with certainty that our maintenance gangs could be reduced in strength very considerably if our rail joints were of adequate stiffness since a large portion of their work consists of picking up joints which have settled more than the other portions of the road.

The sleeper problem.

A distinct advance has been made in the supply of wooden sleepers in so much that various kinds of pinewoods are now being brought into use.

Up till about 10 years ago, about the only woods employed as sleepers were—

Teakwood,
Deodar,
Sal,
Pingadu,

and various kinds of Jarrah wood from Australia but now we employ in addition the following :—

Douglas Fir,
Chir,
Kail,
Asna.

Of these latter the Kail appears about the best and will, I think, prove satisfactory provided it is thoroughly creosoted and is provided with adequate bearing plates. Douglas Fir has not been a success in this country from its tendency to crush and split.

Of the former kinds, Jarrah wood has been abandoned on account of its destruction by white ants whilst Teakwood has been abandoned on account of its high cost. Deodar and Sal have proved themselves very satisfactory in every way ; especially the latter, on account of its giving a slightly longer service in the track even without the use of bearing plates. The life of a Sal sleeper in the main line may be taken as 17 years against 16 years for a Deodar sleeper and subsequent to their main line service they can be employed for a long period in sidings. I think, however, the life of a Deodar sleeper could be considerably augmented by giving it a liberal coat of a heavy coaltar or by the use of other wood preservative before it is placed in the road. With this precaution and the use of scientific plugging of the spike holes the life could be augmented to even 25 years in the main line. A similar remark applies to Sal wood timbers ; but both these statements assume that the timber is thoroughly seasoned before being put in the track.

I am coaltarring about half a mile of new Deodar sleepers which I am now putting in the road on the Saharanpur District, *viz.*, a quarter of a mile length at mile 33½ and a similar length at mile 144 and I consider that if the attention indicated above is given them their life in the main line will be as anticipated.

The existing system of laying beautiful and sound deodar and sal sleepers in the track without any attempt at preservative treatment appears deplorable. If we construct a door or say a bridge or even a fence of these materials we always augment the life of the timber by either painting or tarring it.

Presumably this suggestion of preservative treatment has been thought of before and not operated on because it would not in any way affect destruction round the spike holes, but as already suggested a system of scientific plugging where necessary will, I think, get over the difficulty. In this connection I quote here a description of what is being done in the United States of America, *vide* page 941 of Engineering News, dated December 6th, 1923.

> "Railroad ties represent by far the greatest amount of wood treated, constituting 75 per cent. or more of the total annual treatment. Of the 41,316,474 ties treated in 1922 the preservatives and their amounts per cubic foot were as follows :—
>
> Creosote, 20,208,362 ties, 6·59 lb. zinc chloride ; 17,418,107 ties, 0·50 lb. zinc emulsion ; 3,681,971 ties, 0·50 lb. zinc and 2·74 lb. creosote ; miscellaneous preservatives, 8,040 ties. About 97·5 per cent. of the ties were for steam railroads, and of these 4,841,464 ties were adzed and bored before treatment, 1,269,117 were adzed only and 178,594 were bored only. As to the woods used, 40·9 per cent. of all treated ties were oaks (including all varieties) 23·1 per cent., yellow pine ; Douglas fir, 9·4 ; beech, 6·8 ; western pine, 3·9 ; maple, 3·6 ; birch, 3·5 ; gum, 3·3 ; tamarack, 1·5 ; hemlock, 1·4 ; elm, 0·6 ; others, 2 per cent.
>
> There were 144 timber treating plants in 1922, of which 128 were in operation ; 89 were commercial plants ; 30 railroad plants and 25 owned by mining and power companies or public utilities. Twelve new plants were built during the year and three plants were abandoned."

Even with the augmented supply of wooden sleepers the Railway still finds itself short of this material and has taken to the use of—

(*a*) Cast iron and

(*b*) Reinforced cement concrete

as substitutes. The question regarding the latter material is still in the experimental stage as the sleepers put in the road made from this material have not long enough been subjected to traffic to enable us to decide if they are a paying proposal or not.

The two most prominent concrete types are the Stent and the Green's G. M. The latter type is not in use on the North-Western Railway, but it deserves, I think, a notice here as it possesses one important feature which may give it superiority over the Stent type. This consists in a provision for resilience to resist the destructive effect of impact and vibration in the permanent way.

Amongst other advantages claimed for the Green's G. M. type are—

(1) Liberal bearing on ballast, *viz.*, 6·88 square feet against 6·25 square feet for wooden sleepers.

(2) Gauge is well preserved under traffic.

(3) Sleeper is a heavy one and so reduces maintenance costs.

Regarding the Stent type of sleeper, a considerable mileage of this is now being laid in the North-Western Railway and reports show that it gives very good running under most conditions. I am afraid that this type will fail after a few years under heavy and fast traffic as there is no provision for the absorption of vibration and impact.

Experience alone however will prove or disprove this surmise and at this stage I suggest the use of some kind of pad between the rail and sleeper to minimise the destructive effect of the factors mentioned—a pad would however be an expensive provision.

Cast iron plate sleepers.

There are two types of these in use on the North-Western Railway, drawings of which are shown at the end of this paper—

(1) The North-Western Railway type.

(2) The Lines' type.

The North-Western Railway type consists in section of a T with the leg hollow which accommodates the tie bar.

The Lines' type consists of a plate with two strengthening webs on top of the plate as contrasted with the North-Western Railway type which has its plate strengthened below instead of on top of the plate.

We have not had experience of the Lines' type for a long enough period to decide on its merits ; we can say however that the North-Western Railway type, provided it is furnished, with suitable and sufficient ballast and is efficiently maintained, gives a good running road.

Comparing the strengths of these two sleepers with that of a deodar sleeper to function as beams and assuming working stresses ordinarily accepted for these kinds of material, *i.e.*, ·41 of a ton per square inch as tensile stress for deodar timber and 2 tons per square inch as tensile stress for cast iron, the moments of resistance at sections where it can be assumed are those which will take the maximum tensile stresses are as below :—

Deodar 17·2 inch tons.

Lines' type 20·0 inch tons.

North-Western Railway type 26·6 inch tons.

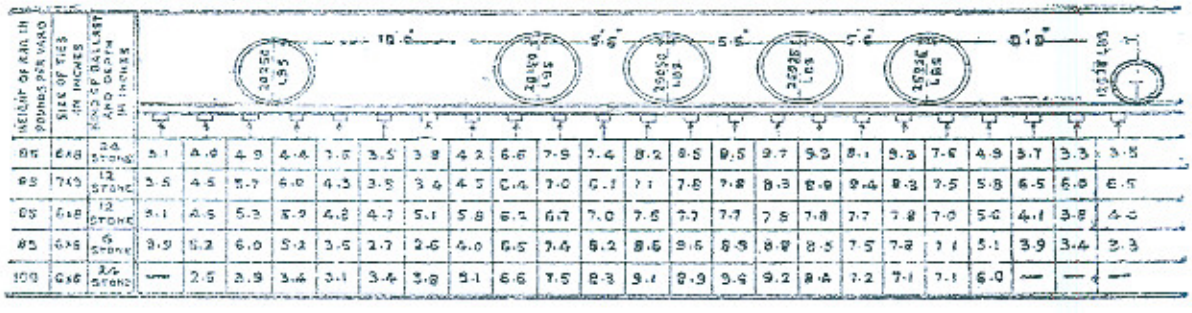
As our deodar sleepers never shew signs of excess tensile stresses unless they are old or improperly packed it would seem that at least the North-Western Railway type requires redesigning and it is suggested at this stage that the leg of the T be thinned down to the extent of ¼ inch on each side thus lessening the weight of each plate to the extent of approximately 17⅓ lbs.

The question of what proportion of an axle load of say 18 tons, which is slightly higher than any we have at present on the North-Western Railway, is borne by a single sleeper, is closely connected with this problem.

This question has been experimented on by the American Society of Civil Engineers and we cannot do better than reproduce here a diagram showing the Tie Reactions arrived at from a test made on the Illinois Central Railroad.

TIE REACTIONS IN THOUSANDS OF POUNDS

STATIC — LOAD TEST ON ILLINOIS CENTRAL RAIL ROAD WITH MIKADO LOCOMOTIVE



85	6x8	24 STONE	5·1	4·9	4·9	4·4	3·8	3·5	3·8	4·2	6·6	7·9	7·4	8·2	8·5	9·5	9·7	9·2	8·1	9·3	7·6	4·9	5·7	3·3	3·5
90	7x9	12 STONE	3·5	4·5	5·7	6·0	4·3	3·8	3·4	4·5	6·4	7·0	6·1	7·1	7·8	7·8	8·3	8·9	9·4	8·3	7·5	5·8	6·5	6·0	6·5
85	6x8	12 STONE	5·1	4·5	5·3	5·9	4·8	4·2	5·1	5·8	6·2	6·7	7·0	7·5	7·7	7·7	7·5	7·8	7·7	7·8	7·0	5·6	4·1	3·8	4·0
85	6x8	6 STONE	3·9	5·2	6·0	5·2	3·6	2·7	2·6	4·0	6·5	7·4	8·2	8·6	8·6	8·5	8·8	8·5	7·5	7·8	7·1	5·1	3·9	3·4	3·3
100	6x8	24 STONE	—	2·5	3·9	3·4	3·1	3·4	3·8	5·1	6·6	7·5	8·3	9·1	8·9	9·4	9·2	8·4	7·2	7·1	7·1	6·0	—	—	—

From the above it will be noticed that the maximum Tie Reaction is about one-third of the heaviest axle load but the sleeper spacing in America is usually closer than in India, the centres in America being usually 20 inches against 35 inches in India.

The Tie Reaction in India will therefore probably be greater proportionately and will be somewhere in the vicinity of half of the axle load so that a complete sleeper with an axle load of 18 tons will in all likelihood have to bear as a maximum about 9 tons, half of which will be taken under each rail.

From the above it will be seen that a deodar sleeper under a static load is stressed with a liberal factor of safety of four, but from investigations carried out by the American Society of Civil Engineers and recorded in the Third Report of their Track Stress Committee the stress may be increased by as much as 53 per cent. due to impact and counterbalancing of locomotives effects, still leaving a factor of safety of $2\frac{2}{3}$rds. As there have not been any signs of overtaxing the tensile stress of the timber, provided it is sound and well packed, it would seem that the present section of deodar timber is quite fit to take the maximum axle loads obtaining.

We still therefore adhere to the opinion expressed before, that the weight of the North-Western Railway type of cast iron plate can be reduced with safety to the extent of $17\frac{1}{3}$lbs. per sleeper.

Rails.

On the main line carrying passenger and mail traffic the following sections of rails with their respective moments of inertia against each, are in use :—

	Moments of Inertia.
90 lbs. F. F.	35·01 inch units.
87 lbs. F. F.	30·03 ,, ,,
85 lbs. B. H.	31·678 ,, ,,
75 lbs. B. S. S. F. F.	23·48 ,, ,,
75 lbs. 1892 type F. F.	22·35 ,, ,,
75 lbs. 1887 type F. F.	22·09 ,, ,,
68 lbs. B. H. Steel	21·80 ,, ,,
68 lbs. D. H. Steel	20·232 ,, ,,

With 1906 cross sleepers per mile, the axle loads permissible according to the most recent Government of India rules is as below :—

	Tons	Cwts.
68 lbs. B. H. Steel ..	not mentioned.	
68 lbs. D. H. Steel ..	,,	,,
75 lbs. F. F. of any type presumably ..	17	0
85 lbs. ..	20	0
87 lbs. F. F. ..	not mentioned.	
90 lbs. F. F.	22	12.

This rule is followed by a note that with closer spacing of sleepers a less weight per yard is permissible, but no rule has been made showing exactly how the closer spacing should obtain, and to arrive at one is a matter of some difficulty owing to—

(*a*) the diverse character of the rail jointing arrangements.

(*b*) the very varying character of the sub-grade and ballast arrangements.

I might illustrate (*a*) by saying that the strength of the fish-plate of a 68 lbs. rail as regards transverse strength does not bear the same ratio to the strength of the 68 lbs. rail that the fish-plate of a 90 lbs. rail bears to the strength of the rail itself.

As regards (*b*) we can state that in a road bed with little flexibility the rail will be stressed higher than in a road of greater flexibility, the bending moment in a rail being given by the formula

$$M = P_4 \sqrt{\frac{E.\ I}{64\ U}}$$

where P is the load.

E is modulus of elasticity of the rail.

I is moment of inertia of the rail.

U=modulus of elasticity of rail support defined as the load in one rail required to deflect a tie one unit divided by the tie-spacing.

The subject is one of extreme difficulty and the only method of increasing our knowledge in this respect is to institute similar investigations to those in hand by the American Society of Civil Engineers who up to date have issued three reports on track stress investigations which appear paragons of thoroughness and ingenuity, and it is suggested that Indian Railways follow this fine example set by the Americans. Our system of sleepering a track differs so much from theirs that we will, I am sure, find some new and perhaps startling results.

Up to date the rail failures in this country have been few but with the heavier axle loads proposed to be brought into use we are not sure that the same immunity from rail failures will continue.

As an example of our immunity from rail failures on the North-Western Railway, I would cite as an example that during the three years 1920—23 on section Ghaziabad-Ludhiana, a distance of approximately 220 miles and furnished with 90 lbs., 87 lbs., 85 lbs. and 75 lbs. rails, there was only one failure and that was of a 75 lbs. F. F. rail which broke under traffic due to a flaw in the foot of the rail. The total length of 75 lbs. rails in the section under reference is 48 miles of single track.

I cannot do better than refer here to some of the more salient results of the experiments carried out by the American Society of Civil Engineers :—

(1) Speed increases the stresses in straight track by 18 per cent. at 40 miles per hour speed and 27 per cent. at 60 miles per hour.

(2) Engine counterbalancing increases the rail stresses by about the same amount as the speed does.

(3) Large lateral bending stresses occur on curved track and the combined stresses on curves gave a reading as high as 75,000 lbs. per square inch.

I attach at the end of this paper a drawing showing a calculation and diagram made to obtain the stresses in a 68 lbs B. H. rail subject to a load of a superheated S. P. Engine travelling at a speed of about 8 miles per hour on straight track and furnished with about 12 inches deep of fine sand ballast under the sleepers which were spaced 30″ inches centres.

The only observation made was to obtain the track deflection, and the method of calculation followed is strictly on the lines shown in the first report of the American Society of Civil Engineers on track stresses.

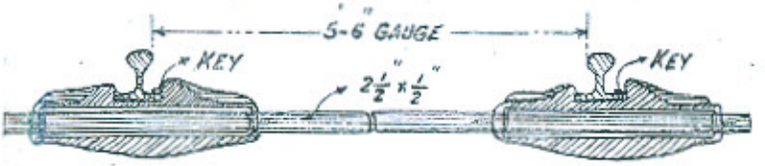
N. W. R.

PLAN OF C. I. SLEEPERS

FOR 90 LBS F.F. RAILS

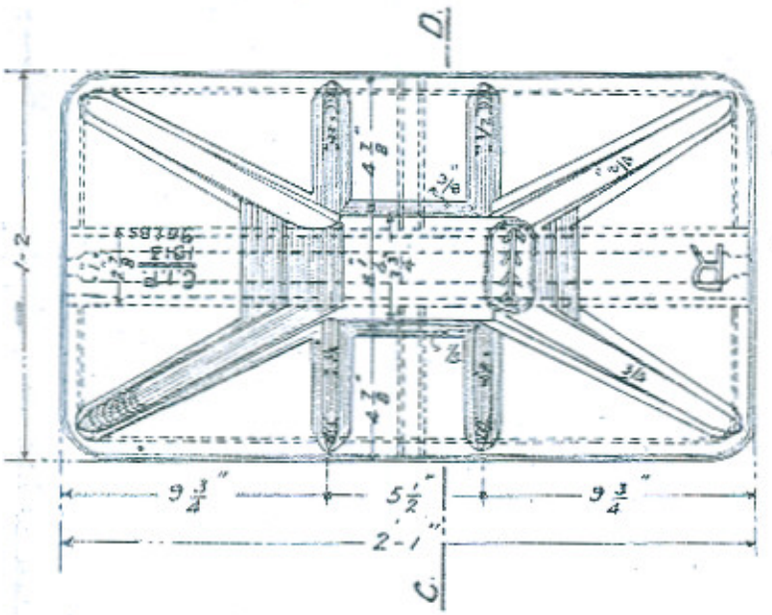
CROSS SECTION

SCALE 2 FT = 1 INCH

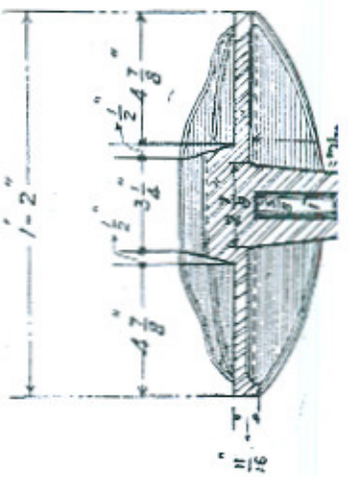


PLAN

SCALE 1½" = 1 FOOT



SECTION ON C.D.



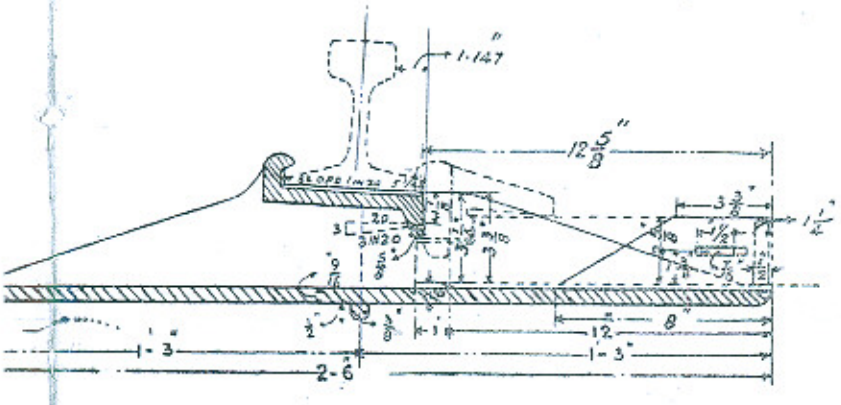
LINES' TYPE - C. I. PLATE SLEEPER

FOR 90 LBS. F.F. RAILS

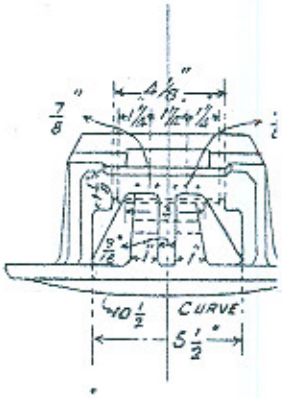
PAT: Nos { 2360/15 / 2945/17

SCALE 1 FT = 1½ INCH

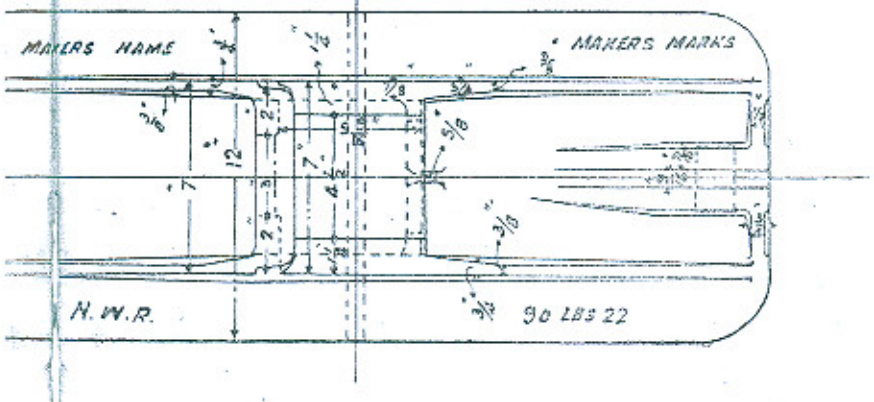
LONGITUDINAL SECTION



END VIEW



PLAN

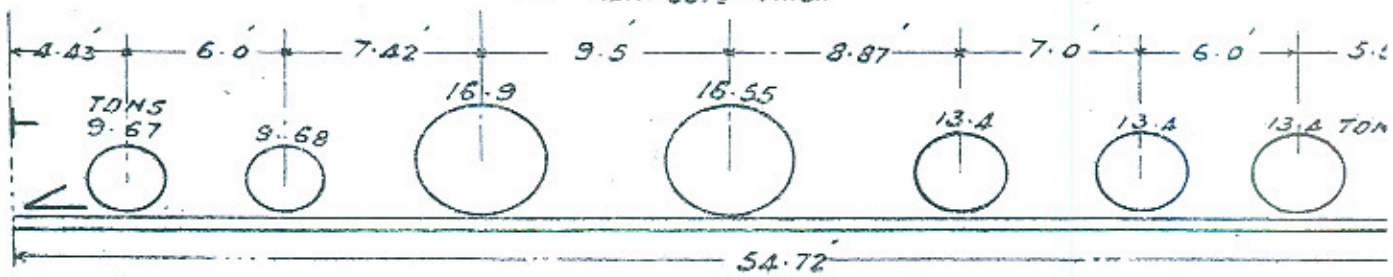


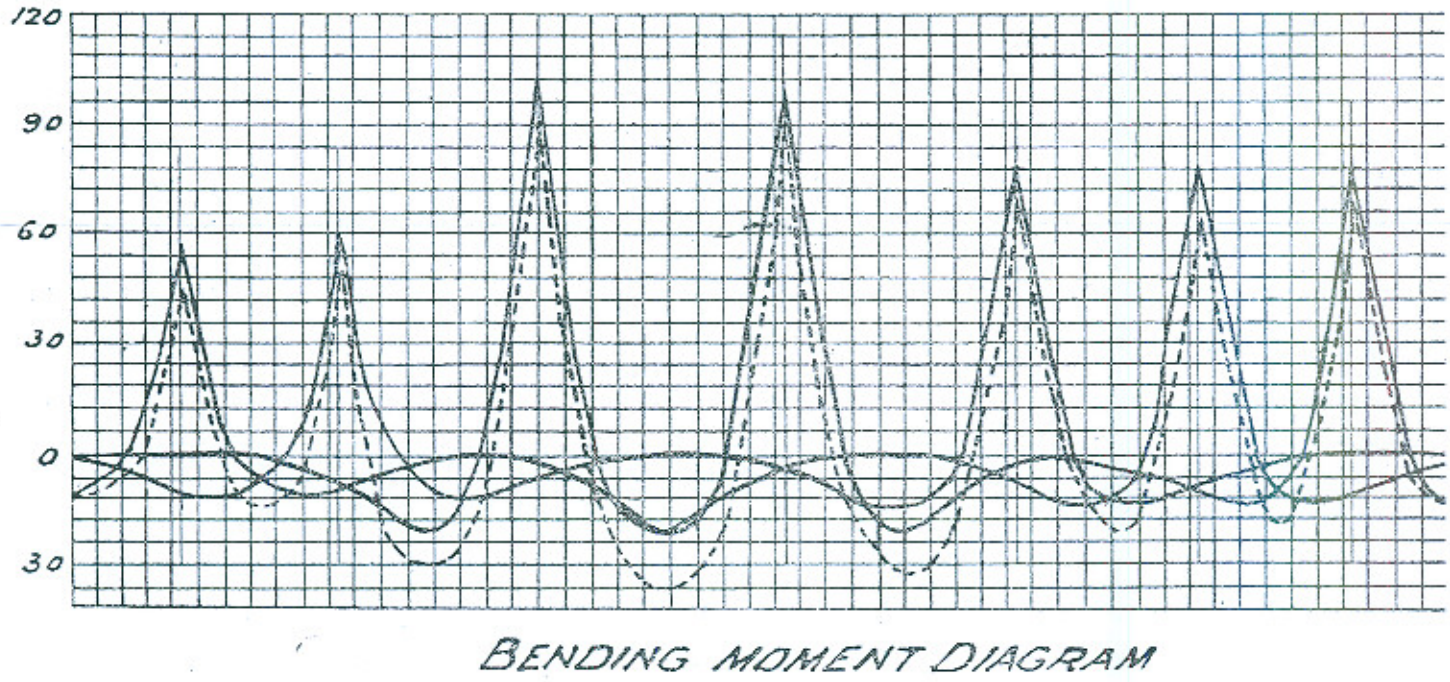
R. B. RY:

S. P. SUPERHEATER = 93.0 TONS

68 LBS. B. H. RAIL

SCALE = HOR: 10 FT = 1 INCH
VER: 60 FT = 1 INCH





BENDING MOMENT DIAGRAM

RAIL 68 lbs B.H. LOAD SUPERHEATER 93.0 TONS, $M_0 = 6P$; $\mathcal{E}_1 =$

FROM DIAGRAM

MAXIMUM BENDING MOMENT = 92.00 INCH TONS

HENCE $f_t = \frac{MY}{I} = \frac{92 \times 2.3}{21.6} = 10$ TONS/$\square$"

TAKING IMPACT FACTOR AS 50%

NOTE

FINAL BENDING MOMENT DUE TO ALL THE LOADS IS SHOWN IN DO.

DISCUSSION.

In the unavoidable absence of MR. WATSON, the paper was introduced by MAJOR H. L. WOODHOUSE, R. E., who, referring to the Author's notes on cutting down establishment, remarked that with such a reduction it was essential that the number of engineer officers should be maintained as supervision needed to be much stricter when labour was reduced, if accidents were to be avoided.

He also wished to call attention to the Joyce fishplate which the author had omitted to mention. He understood that the Bengal-Nagpur Railway authorities were so struck with this fishplate that they were substituting it for their British standard plates. It seemed to work extraordinarily well, lessening the noise, and lengthening the life of both rails and sleepers. It also fulfilled Mr. Lloyd Jones' conditions (*b*) and (*c*) given on page 52, while it was a much shorter fishplate.

Chir and fir sleepers were treated in the North-Western Railway creosoting plant at Dhilwan. Chir proved the more satisfactory, as it took up the creosote more evenly, and was not so liable to split or to be affected by dry rot while seasoning. In the opinion of the Forest Economist, Dehra Dun, kail or blue pine and asna were excellent woods for treating; they were however from 25 per cent. to 50 per cent. more expensive than fir and chir. The object of creosoting was to make the physical life of a sleeper as long as its mechanical life. It was useless to attempt to prolong its physical life beyond its mechanical life.

With regard to coal-tarring, in many cases at present, bridge timbers were being treated with coal-tar, but, although coal-tarring was an old method of treatment, he did not consider it did much good. It was just like the old custom of binding wire round the ends of sleepers to prevent them from splitting. Tests had been made at Dehra Dun and sleepers wired in this way had developed cracks just like those not wired, the reason of course being that the cracks were caused by shrinkage, not expansion.

Sleeper treating processes were rapidly increasing in popularity in America and although there were not the same monsoon conditions as in India, where the great heat and heavy rainfall combined to wash the salts out of salts treated sleepers in a few years, the creosoting process was gaining ground as compared with the salts process of treatment.

There was a new process, called the DUROL process, being tried on the North-Western Railway. This process had been widely adopted in France and Italy and tests were now being made to see whether the heavy monsoon rains in India would wash out the salts from the wood, thus rendering the treated sleepers non-resistant.

The present price of deodar sleepers was about Rs. 8 and these were assumed to give fifteen years main line service, so that the price of a reinforced concrete sleeper with an assumed life of forty years should not exceed about Rs. 14 if it were to compete economically with deodar. For this reason the Greens' sleepers, which cost about Rs. 20, could not be considered.* The Stent sleeper was, at present, being experimented with and improved. This sleeper, however, caused heavy increased charges on rolling stock. For example, it was said to be necessary to change engine springs three times as often as when running over wood sleepers.

As regards cast iron plate sleepers, the Lines' sleeper was lighter than the North-Western Railway type† and was now being tried on the Eastern Bengal Railway and the North-Western Railway. On the Khyber Railway, "Lines'" sleepers had been put in twelve months ago and no parts had been stolen or lost so far—no small accomplishment in that part of the world.

He was in complete agreement with the author, with regard to rail failures.

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* *Vide* the following comparison:—

(1) 100 deodar sleepers at Rs. 8.
Cost Rs. 800—

		Rs.
Interest charge at 5½% per annum	..	44
Sinking fund for replacement in 15 years allowing 5½% compound interest	..	35·7
Annual cost	..	79·7

(2) 100 Reinforced concrete sleepers at Rs. 14—
Cost Rs. 1,400—

Interest charge annually at 5½%	..	77
Sinking fund allowing for replacement in *40 years* at 5½% compound interest	..	10·2
Annual cost	..	87·2

The difference is due to omitting the cost of the bearing plates and the cost of relaying the deodar sleepers every 15 years as against every 40 years for concrete sleepers.

This question of the economics of sleepers was recently worked out by the N. W. Railway, and independently by the Chief Engineer of the B. B. and C. I. Railway who made out a series of curves. The results agreed very closely, though based on slightly different data. In both cases the results were that with an Rs. 8 wooden sleeper, giving 15 year life, the highest economic price for an iron, steel or concrete sleeper was between Rs. 14 and Rs. 15.

Owing to the vagaries of compound interest it appeared that after 30 years life, an addition of five or ten years extra life made little difference to the annual cost of a sleeper.

† Lines' sleeper complete about 205 lbs. North-Western Railway sleeper about 260 lbs.

MR. DORMAN pointed out that the paper made no reference to the maintenance of level-crossings which were the points where a road engineer most frequently came into touch with the railway engineer's work, and he was afraid that their having been ignored in the paper was indicative of what was only too often the case in actual practice. The railway authority was responsible for the actual crossings, and many of those present would doubtless be able to call to mind instances of cruel joltings over corrugations and pot-holes on level-crossings where the road interests had been neglected.

In some places it would almost appear as if attempts were being made to prevent the formation of pot-holes by discouraging road traffic as much as possible, and the simple expedient adopted was to keep the level-crossing gates closed for long periods at a time. This, however, was not a system which would be tolerated much longer by the motoring public, and he would like to put in a plea that more attention should be paid to the upkeep of level-crossings so as to justify their name to the motorist.

MR. A. LINES, referring to the reductions made by the Author in the strength of the gangs (page 49), mentioned that on the North-Western Railway the strength of all gangs had already been cut down to 2½ men per mile, while the length of a Permanent-way Inspector's section had been increased. The size of a Sub-way Inspector's sub-section however was still under consideration.

Also, on the North-Western Railway they were getting out bicycle trolleys to facilitate inspection work and increase facilities for moving about. The question of the extent to which maintenance gangs could be reduced was closely connected with the question of the mechanical appliances which could be used to assist labour. At present the minimum number of men employable in a gang was the number necessary to raise a rail.

In America the size of the gangs was much smaller than on Indian railways, but before anything approaching these conditions could be brought about on the North-Western Railway, special appliances, such as track jacks, would have to be obtained and supplied to all the gangs.

In this connection he wished to draw attention to the remarkable figures given in Major Anderson's paper on "Economic Railway Construction" which had just been before the Congress, and which shewed what capital could be spent in order to save the labour cost of one man.

MR. F. A. HADOW stated that the author had left out of consideration one important matter, *viz.*, the question of steel sleepers. The speaker was not sure that these were not the best, providing that the cost was reasonable on actuarial comparison.

MR. IRANI said that that Mr. Watson's suggestion to have three men per mile where the sleepers were very old instead of two men, would not be necessary if the mates of the gangs were made to maintain the road on the same standard throughout the line. An instance had come to his notice, where a slack mate in charge of a section of road with new sleepers did not keep as good a road as another more efficient mate in charge of a length with old sleepers.

As regards the clause that coal-tarring would augment the life of sleepers from 16 to 25 years he thought that an increase of 9 years in the life was too much to expect, as the effect of coal-tarring sleepers did not last longer than two or three years after they had been laid in the line, but even if coal-tarring were to increase their life by two years it would pay to do so.

If sleepers 8′ 6″ in length were used instead of the present 9′ 0″ to 9′ 6″ lengths, it would not only be cheaper in first cost, but would prolong the life, as experiment had shown that each sleeper would then act as a rigid bar under a passing load and consequently there would be less fibrous strain induced in it. It would also give a better running road.

MAJOR E. P. ANDERSON, R. E., stated that in his opinion, coal-tarring sleepers was useless—the coal tar was a mere coating which was removed by beaters or by friction.

Passing to the question of rails he drew attention to the Canadian type of switch rail which was so shaped that any ordinary rail of the same type could be used as a stock rail without planing away any part of it. Thus a switch could be put in anywhere in the running road (except at a joint,) without taking out a rail.

The German switch rails were also interesting in that their cross section was so varied as to make them of uniform strength throughout their length, instead of being extremely weak at the toe as in other types.

He questioned Major Woodhouse's figures as to the effect on locomotive springs of cast iron plate sleepers, and did not think that the increased breakages were due to the use of these sleepers to any thing like the extent suggested. Locomotive spring breakages were due to a great variety of causes of which the road was only one. With regard to track stresses, all investigations so far were made on sections parallel to the track. Investigations on sections transverse to the track were now being made by Mr. Everall and himself and it was hoped that results would be available next year.

MAJOR WOODHOUSE replying to the discussion, stated with reference to the question raised by Mr. F. A. Hadow, that the cost of a steel sleeper was Rs. 16-12-0* approximately and that

* About 18-12, for North-Western Railway pattern made in Calcutta, delivered on the North-Western Railway, and about Rs. 16, for Lines pattern under the same conditions.

the use of steel sleepers was an economic proposition where the cost of a deodar sleeper worked out at Rs. 10, but not at Rs. 8. Mr. Pearson, the Forest Economist at Dehra Dun, did not recommend creosoting deodar because mechanical failure of the sleeper occurred first.

The speaker agreed that the German S. W. rail was an excellent rail.

SUBSEQUENTLY COMMUNICATED.

MR. LINES wrote to point out that, at page 56, Mr. Watson, comparing the theoretical strengths of Lines' C. I. Sleepers and the North-Western Railway type, arrived at moments of resistance of 20 inch tons in the case of the Lines' type and 26·6 inch tons in the case of the North-Western Railway type.

He was astonished at this result, because drop tests had shown the Lines' type to be much the stronger of the two, but he had refrained from saying anything at the Congress as he was not prepared with figures.

The matter had now been investigated by the Signal Engineer, North-Western Railway, who found that under the drop test the Lines' sleeper shewed itself to be stronger than the North-Western Railway type in the proportion of about 7 to 4.

The sleepers broke at the midship section or thereabouts and on drawing out these midship sections it was found that the North-Western Railway type, *as made*, and weighing 112 to 114 lbs., was of considerably lighter section than shewn in the drawing. The Lines' sleeper, *as made*, and weighing 82 to 84 lbs. was of about the same total section as the drawing, but the thicknesses of parts varied from the drawing.

The section moduli of the midship sections as made were :—

Lines' type	..	16·6
North-Western Railway Type	..	10·1

The reasons for the weakness of the much heavier North-Western Railway plate were two-fold. First, the greater part of the material was on the compression (upper) side of the neutral axis, so that the maximum tensile stress was about three times the maximum compressive stress, whereas in the Lines' plate matters were reversed, with the result that the maximum compressive stress was about four times the tensile stress, and since the crushing strength of cast iron was about four times its tensile strength, this was as it should be.

Secondly, the North-Western Railway plate was cut up in all directions with two cross-webs below it and two diagonal webs above, leading to all sorts of unknown cooling stresses, whereas

the Lines' plate had only two long parallel webs on it, reducing cooling stresses to a minimum.

MR. WATSON, in a written reply, apologised for several mistakes in the paper due to the proof copy not having been sent to him for correction. The title of the paper should obviously have been "Some Aspects of Track Details and Track Maintenance and Permanent-way of the North-Western Railway." On page 49 the word "engineering" should be inserted before the word "maintenance" in line 5 and on page 57, line 18, the figure $34\frac{2}{3}$ should be substituted for $17\frac{1}{3}$.

He wished to record his sincere thanks to Major Woodhouse for his sympathetic introduction of the paper, the main purpose of which was to stir up discussion rather than attempt to give information on a subject which deserved more attention than it received. He agreed with Major Woodhouse that the number of engineering officers must be maintained, but that these officers would have to give more attention to outside work than they have been accustomed to in the past if a severe curtailment in menial establishment was adopted.

He had not seen the Joyce fishplate, but he gathered that it did not completely satisfy condition (*d*) of Mr. C. W. Lloyd Jones' paper, to which reference had been made. He did not comprehend Major Woodhouse's distinction between what he termed the "mechanical" and "physical" life of a sleeper, nor was he persuaded that the effect of coal-tarring, accompanied by scientific plugging, if carried out in the proper manner, would not increase the life of deodar or sal sleepers to the extent indicated in the paper. Since writing the paper he had seen records of the effects of plugging sleepers on the Danish and Swedish railways which indicated that the expense was justified.

He was in full sympathy with Mr. Dorman's remarks on the condition frequently found of road crossings over railways. The railway staff usually carried out the maintenance of the crossings in the most perfunctory manner, considering, presumably, that their responsibility in this connection ended with the track condition. To improve matters a removeable concrete slab road was suggested as found on American road crossings ; this type of roadway once constructed apparently required little maintenance attention. In any case railway maintenance officers should insist that their staff gave much more attention to the road surface of their level-crossings than obtained at present in India.

Mr. Hadow had commented on the omission of steel sleepers from the discussion, but he was not aware of any recent proposals for their reintroduction. The types formerly in use usually failed through their lugs, but it was possible that with up to date machinery a strong lug could be manufactured so that this type of

sleeper could compete with those of other materials. He did not quite agree with Mr. Irani's contentions regarding the respective strengths of gangs on old and new sleeper roads. Where the sleepers were old, heavy casual renewals were always taking place as well as plugging and recentering of sleepers and this required more labour than where the sleepers were uniformly serviceable.

Regarding the theoretical strength of the Lines' type of sleeper compared with the North-Western Railway type, commented on by Mr. Lines in his subsequent note, his own calculations had been made from the working drawings of both sleepers, and the figures shown by him were, he believed, quite accurate since they had been amply checked by a competent draughtsman. He did not derive much information from the experiments made in the Signal Shops at Lahore, referred to by Mr. Lines, for the following reasons :—

(*a*) The method of the test had not been described.

(*b*) The tests were carried with plates *as made* in the Signal Shops, and not with plates made in accordance with the drawings, and it was a fact that the plates usually turned out by these shops varied very much from the drawing dimensions.

(*c*) The castings turned out by the Signal Shops were often of a very low quality, being usually very spongy in places.

(*d*) It was not clear from Mr. Lines' note whether the Lines type of sleeper experimented on was made in the Lahore Signal Shops or whether it was manufactured by some other agency. The quality of any castings made elsewhere was usually of a good and sound character.

A more complete and comprehensive test appeared necessary before a decision should be made, and until this was done he adhered to his opinion that the North-Western Railway type of cast iron plate sleeper could be usefully lessened in weight to the extent shown in the paper.