JUL 1843

JOURNAL
OF
THE FRANKLIN INSTITUTE
OF THE
State of Pennsylvania,
AND
AMERICAN REPERTORY.

JULY, 1843.

Civil Engineering.

FOR THE JOURNAL OF THE FRANKLIN INSTITUTE.

On Cast and Rolled Iron Rails for Railways. By JOHN C. TRAUTWINE, *Civil Engineer and Architect.*

Although this subject has recently been much discussed, it does not appear to me that all the facts bearing upon it have been taken into consideration; or that all those which have been examined, have received that degree of attention which is requisite to a satisfactory solution of the question, which of these two materials is the more eligible for common railroad purposes?

It is not my intention here to enter upon an examination of all the various points of inquiry necessarily involved in a detailed investigation of this important question; but merely to draw attention to one or two matters connected with it, which have, as I conceive, either been overlooked by those who have hitherto had the subject under consideration, or have been deemed by them of less moment than I suppose them to be.

It is my opinion that injury has resulted from the fact that those gentlemen who have been most active in discussing the question, have, in too unqualified a manner, expressed themselves in favor of one material, or the other, as preferable *in all cases*, to the entire exclusion of the other: or, in other words, I conceive the question to be not an *abstract* one, but one dependent upon contingent circumstances, by which it becomes so modified as to render the one material preferable, in some cases; and the other, in others. I have myself recommended the adoption of a heavy cast-iron U-rail, on a

railroad nearly one hundred miles in length, under my charge, from considerations of economy of original outlay, which attended that particular instance, and which happened to be, in that case, one of vital importance; combined with the peculiar difficulty that would necessarily be encountered in fabricating a rolled rail, in a section of country where it would be nearly impossible to obtain, or rather to retain, a sufficient number of experienced workmen for conducting an extensive rolling establishment uninterruptedly. Those who have embarked in such undertakings, under similar circumstances, can testify from experience how much importance is to be attached to this consideration.

Added to these reasons, it was my intention to employ engines with much less weight upon their drivers than is usual on most of our railroads; a point which, as I hope to show further on, has much to do in deciding the question of a choice between cast and rolled rails.

Those who advocate the future rejection of rolled rails "in toto," and the consequent adoption of cast-iron, urge, as the chief argument in support of their views, the splitting, or *lamination*, as it is more generally termed, which experience has shown to take place, to a very serious extent, in the rolled rails used on all our railroads.

Instead of lasting from forty, to one hundred years, which was the term of duration originally predicted for the rolled rail, the supposition being based upon the probable rate of wear, or diminution of material, as deduced from some limited experiments, it has, in fact, on most of our roads doing a heavy business, needed partial replacements within some six or eight years, with a prospect of requiring much more extensive renewals within a few years more.

I conceive, however, that this defect in the rolled rail is not one inherent in the nature of the material, but one admitting of remedies of easy application; and I will proceed to point out in what particulars I think changes should be made in the manufacture of the rolled rail, in order to diminish, if not entirely to remove, its liability to split.

In the manufacture of this rail, as is well known, the process of *piling* is necessarily employed; that is, a number of short, flat, pieces of iron are *piled* on top of each other, and the *pile* is placed in a heating furnace, where it is subjected to a temperature sufficient to bring the several pieces of which it is composed, to the welding point. When the pile has attained this point, it is withdrawn from the furnace, and, without loss of time, is rapidly passed through the successive rolls, by which its pieces are at the same time welded together, elongated, and shaped to the required section of the rail.

But, from want of proper attention on the part of the workmen, the pile is occasionally taken from the furnace before it has reached the welding point; and the consequence is, that the process of rolling does not always unite, or weld together, the several pieces into one mass, so effectually as is necessary for a good rail; and we therefore see that the weight of the engines afterwards separates them, or splits the rail.

I say the weight of the *engines*, because I am perfectly convinced, from close observation, that it is the great weight borne by their driving wheels, that does most of the injury. I have seen comparatively very little of this lamination in either edge-rails, or the common flat-bar, $\frac{5}{8}$ of an inch thick, where horses are used for the motive power, drawing cars having no greater loads than $1\frac{1}{2}$ tons to a wheel; on the contrary, I have seen the five-eighths flat-bar laid even immediately upon *continuous granite sills*, (on which the splitting is more apt to occur than in any other situation,) which have for nearly ten years endured the passage of a very heavy traffic, not drawn by locomotives, without the splitting of a single bar; while the edge-rails on the adjoining parts of the road, over which precisely the same transportation has passed, drawn by locomotives, are split to a very serious extent.

During a personal examination of most of the railroads in the United States, this matter has, among others, received my close attention; and I feel confident that this lamination may be almost, if not entirely, prevented; 1st, (and principally,) by more care in the application of the welding heat;—2d, by so passing the pile through the rolls, that the finished rail shall always consist of laminæ lying parallel to the top and bottom of the rail, as in fig. 1, instead of perpendicular

Fig. 1.

to them, as in fig. 2; and, 3d, by rounding off more boldly the edges of the upper table, or top of the rail. Of the first precaution, we have already spoken. As to the second, it appears to me that the arrangement of

Fig. 2.

the laminæ indicated in the first figure, must, for reasons too evident to require explanation, present more resistance to splitting (though probably less to exfoliation) than that exhibited in the second figure; and this supposition is sustained by the fact, that the splitting does almost invariably occur in lines approaching to the vertical. From this fact, the deduction very naturally follows, that a different disposition of the laminæ would produce a different result; and it is perhaps owing, in a great measure, to the frequent occurrence (probably accidental) of a horizontal disposition of them, that we have not much more splitting than actually does occur.

I have, it is true, in some rare instances, seen splitting occur in lines forming nearly a semi-circle, transversely of the rail; but these, I am inclined to believe, may be fairly ascribed to a very bad condition of the welding.

The necessity of the third precaution, or that of giving a bolder curvature to the upper edges of the rails, has also been impressed upon me by extensive observation.

It is plain that a great weight acting on a rail, the edges of whose top table are comparatively sharp, as in this figure, (3,) has a tendency to split them off; and when it happens, as it frequently does, that the line of welding of two of the original pieces of the pile lies near either of these edges, experience has shown that, if the welding be at all defective, such a splitting actually does take place.

Fig. 3.

Fig. 4.

But, if we round off these edges, as in fig. 4, it is equally apparent that this splitting tendency must be materially diminished, inasmuch as the cohesion of a much more extended area must be overcome, before a piece can be separated.

I have universally observed so much less splitting in such rails as are boldly rounded at the top edges, than in those whose edges were comparatively sharp, that I have no doubt but that a still further extension of the same principle would be found to contribute considerably towards a correction of the evil, even if no very great improvement should be made in the welding.

Fig. 5.

Many of our railroads have rails of the section, (fig. 5,) the upper edges of whose top are dissimilar, one being boldly rounded, while the other is left comparatively sharp. Such rails elucidate my views on this point in a very satisfactory manner; for I have observed that, in every instance, after having been for some time traversed by heavy engines, the outer, or sharp edge splits off badly, while the rounded, or inner one remains comparatively uninjured.

Consequently, this section of rail is objectionable, and I hope soon to see it fall into disuse. It was originally projected to save metal in the outer lip; but I am confident that the pecuniary advantage resulting from any such saving, is far more than counterbalanced by the diminution of strength attending it.

Moreover, there is another disadvantage attached to this section of rail, which is, that when the inner lip becomes worn away, as it will in time, especially on the outer lines of curves, the rail cannot be turned so as to make the original outer lip answer for the inner one. This turning of the rails I have frequently seen resorted to on the sharp curves of much-used railroads, and the rail should, by all means, be made with a view to this facility.

Fig. 6.

A bridge, or inverted U, rail, with the edges well rounded, as in this figure, (6,) will, I suspect, be found to resist splitting better than any form of section in present use; inasmuch as it not only presents a great extent of area of cohesion to be overcome before splitting can take place, but affords *less leverage* for the weight of the engines to act through to overcome it. In some cases,

Fig. 7.

I have seen the T rail split in this manner, (fig. 7,) which proves that, in this section, the welding may, from want of care, be so very imperfect, that no rounding of the edges, alone, could prevent injury.

Such disruptions as this, evince very clearly, the utility of diminishing the *leverage* through which the disrupting weight may act.

The ordinary flat-bar furnishes strong evidence of the diminution of splitting arising from more perfect welding, combined with the

parallelism of the laminæ with the top and base of the rail, aided by an absence of leverage; for it will be found, on examining such of our roads as are laid in part with the flat-bar, and in part with the T rail, that unless the latter be of an unusually strong pattern, it has split much more than the flat-bar.

The foregoing remarks will, I trust, sufficiently explain my reasons for not conceiving the splitting of the rolled rails to be attributable to any defect inherent in the nature of the material itself, but to other causes, which admit of easy remedy; and that, therefore, the principal argument adduced against the rolled rail, is not a tenable one.

Before I conclude this part of our subject, I will advance one suggestion, depending on the propriety of rounding more boldly the top edges of rails, that may possibly be of service on some of our rail-roads, on which the pattern for the rail to be used has not yet been decided on. It is this, that while we have been gradually increasing the *weight* of our rails, we have unfortunately overlooked the important consideration, *of applying the additional metal to the place where it is most needed.*

In consequence of this oversight, it will be found that some of our heavier, *improved* (?) rails, split to pieces sooner than some of the lighter ones have done, whose upper table was stouter, and better rounded.

I have had occasion to notice this more rapid deterioration of heavy rails, consequent upon want of just proportion in their parts, in more instances than one, upon very important lines of communication.

Another suggestion, having reference to the weight borne by the drivers of our engines, may not be deemed unimportant.

It is plain that, so long as we retain a top width of rail of about 24 inches, we cannot safely place, upon any one driving-wheel, a greater load than can be sustained without crushing, and splitting, by the ends of the rails, upon that width; otherwise the ends of the rails must be crushed, as shown in fig. 8. I shall do no more than allude to this point; my reason for introducing it is, that I feel very confident, from observation, that we have already, in some cases, exceeded the proper limit of load on a driver, warrantable by a top width of 24 inches.

Fig. 8.

The success which appears to attend the new *six-driver* freight-engine of that enterprising and skilful machinist, Matthias W. Baldwin, of this city, will go far towards arresting the destruction of our rolled rails. With a weight of but about two tons resting on each driver; she draws, with ease, trains weighing 200 tons over the 45 feet ascents on the Philadelphia and Columbia railroad; and the writer has seen her start, with apparent ease, a train weighing about 150 tons, up grades of 36 feet per mile, when the rails were in an unfavorable condition, being dusty, and slightly wet by a drizzling rain, which began to fall just at the time.

An increase in the number of drivers to our locomotives, which will enable us to diminish the weight borne by each, while, at the same time, it increases the total amount of adhesion, thus enabling us

to draw heavier trains with less injury to the rails and other portions of the superstructure, I look upon as the greatest desideratum demanded, at the present day, towards perfecting the railroad system.

The advocates for cast-iron rails appear to conceive that material to be free from the danger of splitting on its upper edges, found so objectionable in our present rolled rails. But this is an error; for, unless the upper edges of the cast rail, also, be well rounded, they will be found to be fully as liable to that defect as the rolled rail. The pieces split off will not, it is true, be so long as those which separate from the rolled rail, owing to the granular structure of cast-iron; but their greater number will more than compensate for their difference in length.

From the observations I have made on rails of this material, I find that the splitting, in the case of sharp-edged rails, takes place on the outer edge to a greater extent than on the inner one; and for this reason: the friction of the flanches against the inner edge of the rails has a tendency to wear that edge gradually into a curve, conformable to that which unites the flanch to the tread of the wheel; and this curve operates as a partial protection against splitting, on the principle already alluded to, when speaking of the upper edges of rolled rails.

This action is particularly observable in the outer rails of sudden curves, where the inner edge soon becomes smoothly worn to a bold curve, which acts as a complete preservative against splitting, while the outer edges of the same rails become much injured. On straight lines, the splitting under heavy engines is very serious on both edges, if they be not well rounded; but it is perceptibly greater on the outer one. I have observed the same protective tendency of the outward pressure of the flanches very sensibly exhibited also in some rolled rails which have sharp edges.

By rounding off the edges of the cast rail about as boldly as is done in our best heavy rolled rails, and at the same time diminishing the weight borne by any one driving-wheel to about $1\frac{1}{2}$ tons, I think we should prevent either splitting, or very serious abrasion; and I should not hesitate to employ such a rail, under such circumstances, whenever important considerations should happen to demand it.

We will now glance rapidly at two of the principal objections urged against the cast-iron rail, viz., its brittleness, and its more rapid wear.

Admitting, of course, the former objection, the friends of the cast rail propose to obviate it by the use of continuous wooden bearings. But this expedient, although unquestionably effective so far as it removes the danger of the rails breaking, will, on calculation, be found, in many cases, to raise the cost of the cast-iron track to an equality with one of rolled iron, in which the continuous bearings are not employed; and especially will this remark apply if the bearings be Ky-anized.

This consideration neutralizes, in a great measure, one of the principal arguments in favor of the cast rail, viz., its comparative cheapness.

But, in cases where it is determined either to adopt, or to dispense with, bearing timbers, whether the rail be cast, or rolled, there the proportion of expense is entirely in favor of cast-iron; even when the latter has given to it an increase of weight over that of the former, sufficient to impart to it an equality of strength.

As to the *wear* of cast-iron rails, it cannot, I think, be denied that it is much greater than that of the rolled rails. According to experiments cited in "*Wood on Railroads*," the comparative wear is shown to be about as 4 or 5 to 1.

He says, (see 3d London edition, page 67:)

"We shall now give some of the results of the wear of cast and wrought-iron rails, with a view of determining the depth of bearing surface.

"In the former edition of this work, we gave an account of two experiments, on the wear of cast and wrought-iron rails, upon the Stockton and Darlington railway, as follows:—*Malleable-iron rails*, 15 feet long, over which locomotive engines pass, weighing from 8 to 11 tons; wagons loaded, 4 tons each; 85,000 tons passed over in a year, exclusive of engines and empty wagons; weight of rail, 136½ pounds; loss of weight, in 12 months, 8 ounces; the breadth of the top of the rail, being 2½ inches, gives one-tenth of a pound, per yard, per annum; and Mr. Story informs us that subsequent experiments furnish nearly the same results. In determining the premium for the best form of rail, for the London and Birmingham Railway Company, with Professor Barlow and Mr. Rastrick, we found the annual wear, estimated by some of the competitors, at one-sixth of a pound, per yard, per annum. Upon the Killingworth railway, I have had some of the rails, which were weighed and laid down in 1825, taken up and re-weighed; and find the average loss of weight of several rails, to have been eight pounds, for each 15-foot rail, in 12 years, which gives about one-eighth of a pound, per yard, per annum. These rails were laid down at a time when the manufacture of malleable-iron rails was not so well understood as at present; and, on examination, I found part of the loss of weight was attributable to exfoliation on the sides. About 100,000 tons of coals would pass over these rails annually, exclusive of the weight of the engines and empty carriages. Mr. Dixon, the resident engineer upon the Liverpool and Manchester railway, states the wear of the rails upon that railway to be one-tenth of a pound, per yard, per annum; which was determined by taking up three rails, cleaning and weighing them, and then, at the end of twelve months, taking them up again, cleaning and weighing them as before; and this being repeated for two years, the wear was found to be the same.

"We may, therefore, take the wear of the rails to be about one-tenth of a pound, per yard, per annum, which, supposing the whole to result from the wear on the upper surface, will be one-eighty-fourth part of an inch; if the top, or wearing part, of the rail were, therefore, an inch in depth, the rail would wear eighty-four years. The whole of the wear above alluded to does not, however take place

upon the top; a part, though, probably, a very small portion, is attributable to exfoliation by the action of the air: supposing, however, that the wear by the action of the wheels amounts to one-tenth of a pound, per yard, per annum; if the top, or bearing part, of the rail be made an inch in depth, it will be sufficient for all the purposes required. Any increased depth and weight, which would not be required for above eighty years, would, at compound interest, at the end of that period, amount to a greater sum than it would be convenient to expend for such a purpose, considering the remote period at which it becomes useful."

Again: he says, (page 131)

"Experiments are going on at present, where both kinds of rails, accurately weighed, are laid down, and subjected to the passage of the same quantity of traffic over them; the result of these, so far as they have gone, is in favor of wrought-iron. In the operation of making the cast-iron rails, the surface is partially case-hardened in the casting; this may be seen in all cast-iron rails, extending to a certain depth from the surface. Any experiment, showing the comparative wear, must, therefore, be continued until after the outer hardened surface be worn through; and it is presumed that sufficient time has not yet elapsed to furnish this. We have, therefore, been obliged to reject the data founded on this mode of experimenting, and shall give the result of a different sort of test, more severe, and which, it is trusted, will be deemed sufficiently approximate to justify its presentation to the reader.

"Upon the Killingworth railway we had originally cast-iron wheels upon the locomotive engines; about four years ago, we adopted wrought-iron tires. Now, as we have, in this way, the relative wear of cast and wrought iron upon the wheels which run upon the rails; and as the nature of the action will operate nearly alike, whether upon the surface of the rails or of the wheels, we shall, by that means, have a pretty near approximation to the relative wear upon the rails. In this way, we have a considerably more severe test; as, if we take the quantity of traffic, equal to 2000 tons, passing along the railway daily, and suppose the carriages to convey three tons each, with 3-ft. wheels, the relative wear of the wheels and rails is as 53 : 1, nearly.

"The average wear of the cast-iron wheels was above half an inch in nine months; and, with the wrought-iron tire, the wear of one pair of wheels has been a quarter of an inch in three years, and, with three other engines, one-eighth of an inch in twelve months; making the wear, at least, as five to one in favor of wrought-iron. The actual wear of the rails will not be to the same extent as this, as the engine wheels sometimes slip round, or slide upon the rails, in bad weather. The wear of the wheels of the common carriages will not be so much, for the same reasons; but, although it should be observed, that, from this, we ought not to deduce the actual duration of wrought-iron rails, as, their surfaces being narrower than the wheels, the wear will be, perhaps, more than proportionably greater, yet the relative

wear should, however, remain the same. We now give the following experiment made on the Stockton and Darlington railway:

“Cast-iron rails, 4 feet long, over which wagons only pass, weighing four tons each, when loaded; 86,000 tons passed over in a year, exclusive of wagons; weight of rail, 63 lbs.; loss of weight in twelve months, 8 oz. The loss of weight in malleable-iron rails was, in the same period, 8 ounces for 15 feet length; the same quantity of goods, 86,000 tons. This will give the difference of wear 15 : 4 in favor of wrought-iron rails.

“These experiments show that, if rails of the proper degree of strength be used, the durability is decidedly in favor of wrought-iron rails; and we have before observed, that, in rails properly manufactured, none of the exfoliation, or oxidation, originally dreaded, exists.”

And again, in his appendix, (page 729,) he gives the following experiment:

“On the 10th of May, 1831, on the Liverpool line, a malleable-iron rail, 15 feet long, carefully cleaned, and weighing 177 lbs. 10½ oz., was laid down. On the 10th of February, 1833, the same rail was taken up by Mr. J. Locke, then resident engineer on the line, and well cleaned as before, and weighed 176 lbs. 8 oz. It had consequently lost, in twenty-one months, a weight of 18½ oz. The number of gross tons that had passed on the rail, during that time, was estimated at 600,000. Thus we see that with so considerable a tonnage, and with the velocity of the motion on that railway, the annual loss of the rail was only $\frac{1}{288}$ of its primitive weight; so that it would require more than a hundred years to reduce it to the half of its present strength.”

In the United States no experiments have, I believe, been made to determine the comparative wear of the two kinds of rails; but, so far as my personal observation extends, I should have assumed a proportion at least as great as that deduced from experiments by Mr. Wood.

Having shown what authority may be adduced in proof of the statement that cast-iron rails wear much more rapidly than rolled ones, (a fact which some of the advocates for the cast rail refuse to admit,) I shall close this paper without entering into any calculations of the comparative outlays attending the wear of the two materials. These, any engineer may make for himself in a few minutes, having the foregoing data, and the cost of cast and rolled iron at the time and place where they are required to be used.

I have been induced hastily to throw together these few remarks on this important subject, in order to rectify an erroneous impression that has arisen from my recommendation of a cast-iron rail in one particular instance, that, therefore, I considered it preferable to the rolled rail in all cases.