

# MECHANICAL & ENGINEERING SECTION

*(Stated Meeting held January 6, 1910.)*

## STEEL IN FREIGHT CAR CONSTRUCTION.

BY

C. A. SELEY,

Mechanical Engineer, C. R. I. & P. Ry.

[It has been the custom among designers of freight cars either with underframes of steel or of wood to depend upon the strength of the underframe alone in making computations for a specified carrying capacity, despite the fact that the superstructure in many cases can and does constitute a truss. The author presents the evolution in design of structural steel freight cars, with which he has been closely identified, where the value of the superstructure as a truss has been duly considered as an element of strength and in reducing weight.]

In the history of American railroad-car building and especially of freight cars, it is found that steel did not play an important part as a body material until very recent years. Iron and steel have always been used for bolts, rods, and other fastenings, but wood has been the principal material for the framing, flooring, lining, and roofing of the majority of cars. Wood was first displaced by iron or steel in the truck construction and side frames; cross frames and bolsters have been successively changed so that now wood is seldom found in modern freight-car trucks. In car bodies steel was slower in obtaining recognition and use in lieu of wood; first in bolsters and then gradually into the sills and framing.

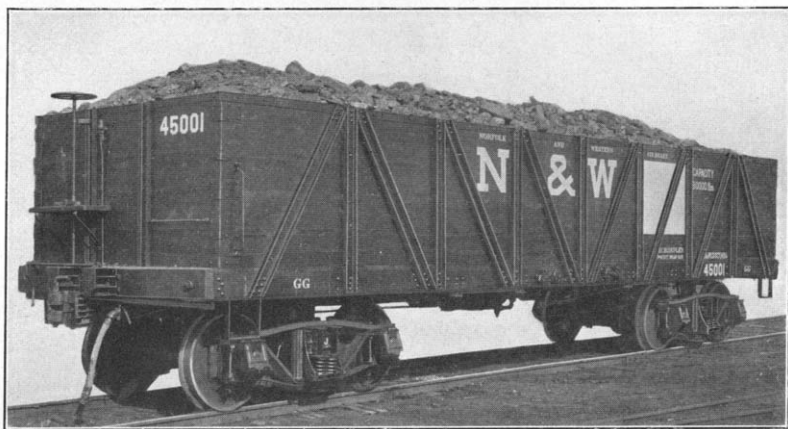
There is very little authoritative literature on freight-car construction. It is mainly found in technical journals, club and society proceedings, and the M. C. B. Association standards and rules which have undoubtedly contributed most to the uniformity of car design in its general features.

In the designing of wooden cars, particularly those having superstructures, it was the common practice to provide for the

carrying strength in the underframing and not depending on the superstructure framing for carrying any part of the calculated load. Not only was this the general practice of car designers and builders but the principle has been discussed and approved at Railroad Club meetings which are on record.

The writer could not agree to this theory of design as applied to general car construction. It might be advisable as regards ordinary house cars of wood construction, but with other types of cars, particularly those presenting an unbroken side, such as flat-bottomed or hopper gondolas, there is such an opportunity presented for a truss or a plate girder of proper depth as to give

FIG. 1.



any strength required with a minimum of material. The writer has since found the same principle to apply in house car designs. There was no opportunity to make a demonstration of his belief that the side framing of a car could be successfully used in carrying a considerable proportion of the load until the year 1900, when as Mechanical Engineer of the N. & W. Ry. he designed a steel framing for a 40-ton flat-bottomed, drop-door gondola, using wood for floor, side, and end lining. Five hundred cars were built at that time and twenty-five hundred cars two years later, thoroughly and successfully demonstrating the principle involved.

Photographs showing the design, using channel centre sills,

built-up-body bolsters, and trussed side framing made of standard sections of angles, channels, etc.

Fig. 1 shows a completed car with load and was the first car of this kind and series ever built.

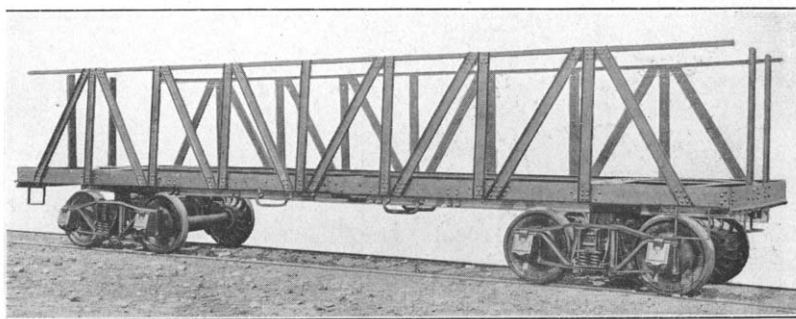
Fig. 2 shows the steel framing before the application of the wood floor and lining as viewed from the side.

Fig. 3 is the same except that the view point is at the end.

Fig. 4 is of another completed car of the same type, but of another series built two years later and on the original drawings. Attention is called to the neat, trim appearance of these cars, the readiness with which they can be inspected, their light weight, yet withal a stiff, staunch construction.

Drawings and description of this car were first published in

FIG. 2



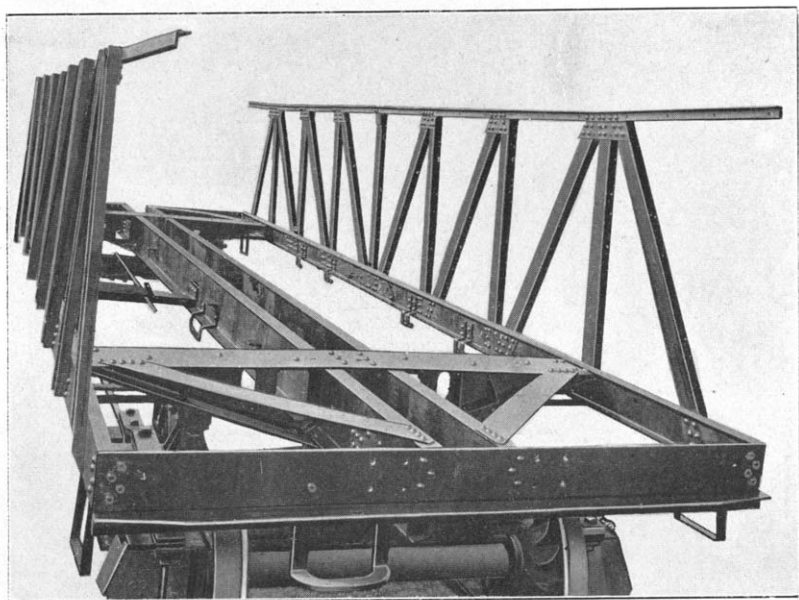
the April, 1900, issue of the *American Engineer and Railroad Journal* and also in other papers.

Following the successful application of the trussed side frame to the flat-bottom gondolas, designs were made for hopper cars which have been copied more or less exactly in many thousands of cars on various railroads. Photographs showing some hopper designs: Fig. 5 is of a steel underframe with wooden stakes and box, designed before my connection with the road owning them and a lot of 1000 were built with which we had some varied experiences. There being nothing on the diagonal except the chute planks, these had to take the full effect of fore and aft movement of the body when shocks occurred in trains of these cars when empty, and we had the fastenings of these planks fail in large numbers, so as to require a modification that

would permit a certain amount of swing. When loaded the wedge effect of the load did not permit the movement which so strongly manifested itself in cars running empty.

After our experience with the trussed-side, flat-bottomed gondolas shown in Figs. 1 to 4, it was determined to apply the principle to the hopper design, which resulted in the car Fig. 6, this photograph being of the first car of the design and series ever built. It will be noted that there is an open centre panel

FIG. 3.



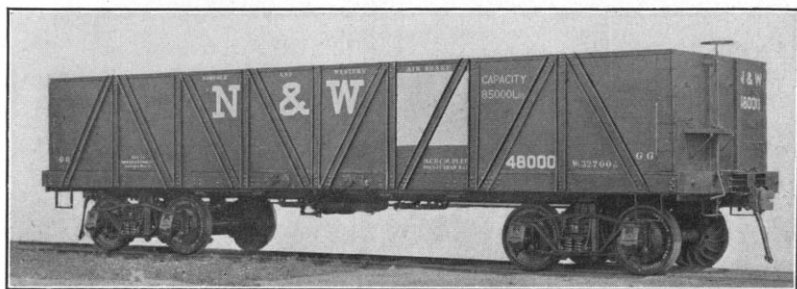
and that several of the vertical members are extended below the bottom chord of the truss to assist in carrying the door supports. The steel frame-work for one of these cars is shown by Fig. 7 as viewed from the side and Fig. 8 as viewed from the end.

Drawings and descriptions were first published in the February, 1901, issue of the *American Engineer and Railroad Journal*, and also in other papers.

The D. & H. Co. copied the truss side feature, but with a different door arrangement; the steel frame is shown by Fig. 9, and a completed car by Fig. 10.

Ordinary bridge truss formulas were used in calculating the foregoing N. & W. Ry. Co. designs and subsequent performance shows these to have been properly used. In 1902 it was deter-

FIG. 4.



mined to build some box cars with complete steel framing, but with wood flooring, lining, sheathing, and roofing. Box cars have side doorways, which do not permit of an uninterrupted truss. The centre panel of the Burr truss of 5 panels which most closely

FIG. 5.

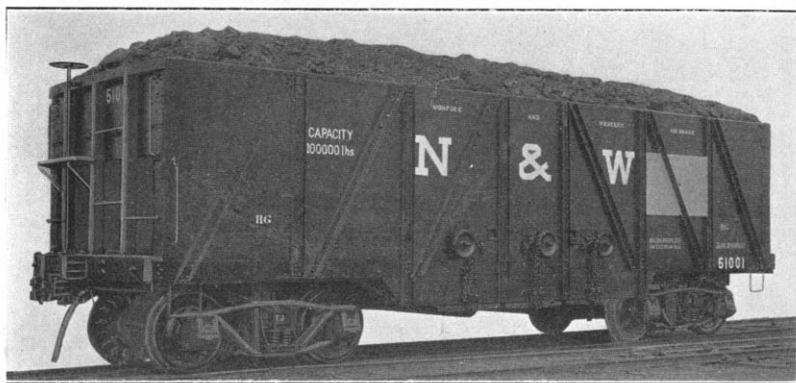


approximates car framing is filled with an "X-bracing" which serves to carry over to the other side strains resulting from unsymmetrical loading of the structure. We must, however, leave the side doorways of the box car clear openings and just

how to take care of the shear in case of unsymmetrical loading was first to be settled.

A wooden model of the side frames was made on a scale of 1 inch equal to 1 foot. The posts and braces were notched over sills and plates and the latter was reduced so as to have no strength as through members or sills. A floor was laid and the whole structure mounted on the bolster bearings. A silk line was stretched and marks made for indicating deflection. The floor was then covered with cast-iron washers and although the complete model weighed but  $2\frac{3}{4}$  pounds it sustained over 200 pounds of loading. The load was then removed from the ends which resulted in increasing the centre deflection.

FIG. 6.

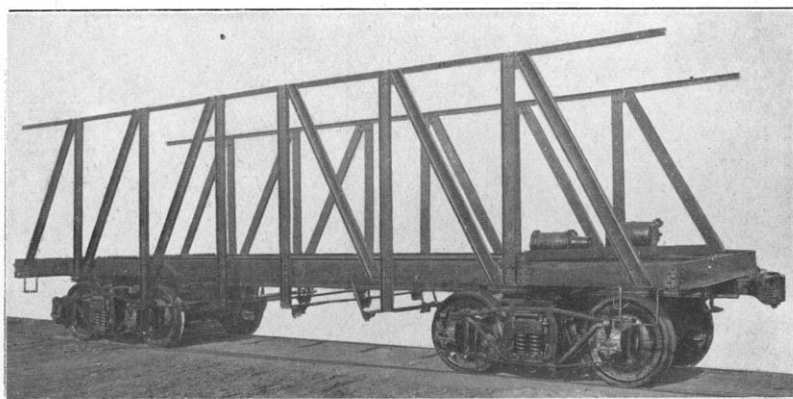


A considerable number of unsymmetrical arrangements of the load were tried and the gauging points on the frame showed the "S" curve indicating shear in the centre panel, but from deductions assumed from the results of these tests, use of some formulas on models and other calculations it seemed as though the "X-bracing" in centre doorways might be omitted if the top and bottom members were slightly reinforced. As a matter of fact, however, the sections used in these side trusses are excessive for the strength required in order to have thickness of material that will stand the waste and corrosion in railway service, and as some of the members are combined in the structure for other purposes as well, it is not difficult to get proper strength to resist shear in the doorway.

The first box cars built after this fashion proved that the calculations were correct and now many thousands of steel-frame box cars, stock cars, and other house cars have demonstrated the feasibility of the design.

I regret not having a photograph of the very first steel-frame box car built from my design, but one from a later series is shown in Fig. 12. This is not as complete as one which will be shown later. The open centre panel at doorway in the sides may be particularly noted. Fig. 13 is of this same frame as viewed from the end, and it will be noticed that in a general way

FIG. 7.



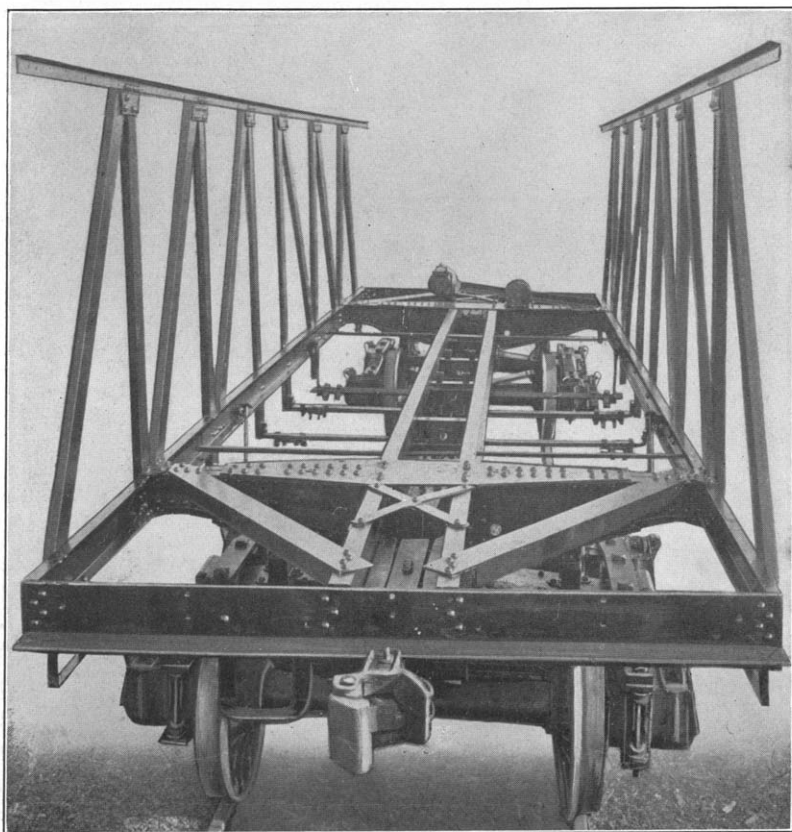
there is a consistency and similarity in all the designs whether hopper or flat-bottomed gondolas or for box or other house cars.

Fig. 14 represents a complete steel-frame box car, and the only way to identify its construction is by the absence of truss rods under the car and its clear, open appearance facilitating inspection and examination. This car is of the American Railway Association dimensions, viz.: 36 feet long by 8 feet 6 inches wide by 8 feet high (inside measurement).

Fig. 15 is another complete steel-frame for a box car, one of my later designs, and is somewhat more complete than Figs. 12 and 13 in showing the steel girths in sides and ends. These assist materially in holding the ends of the car to resist the shock of shifting loads. The corner and end intermediate posts are securely riveted top and bottom and with an inside end

wooden lining  $1\frac{3}{4}$  inches thick, making an end construction that cannot be approached in wood construction. If photographs were available I could also show a new design of furniture car 40 feet long, 9 feet wide, and 10 feet high in which the side doors are not directly opposite but are each offset 27 inches from

FIG. 8.



the centre line. This is to facilitate loading of automobiles and other vehicles. It was somewhat of a problem to the designer, as it called for unsymmetrical side framing and a diagonal connection in the underframing between door posts.

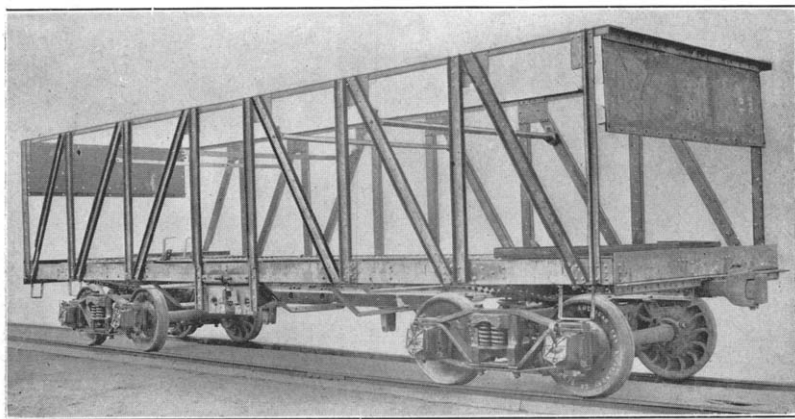
Fig. 16 shows a completed box car, and there are over 6000 of these in service on the C. R. I. & P. and St. L. & S. F.

These cars are 40 feet long inside by 8 feet 6 inches by 8 feet, and as the four feet of extra length goes in between the bolsters the car is not quite as strong laterally as those of the standard length of 36 feet made up of similar sections.

The N. & W. steel-frame box car was first described in the May, 1902, issue of the *American Engineer and Railroad Journal* and also in other papers.

Fig. 17 shows the steel frame, and Fig. 18 a complete stock car which is an interesting example of this type of construction. The wooden slats are secured to the inside of the steel frame, leaving the latter outside and exposed.

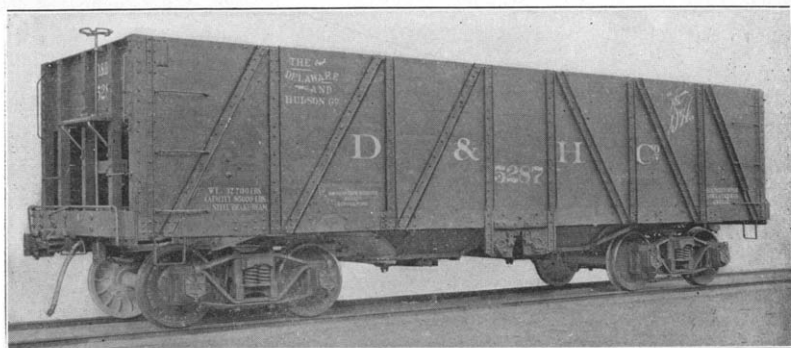
FIG. 9.



A number of designers have used steel underframes for freight cars, placing thereon a wood superstructure. In the case of house cars, however, there are many reasons why a complete steel frame is superior to the above arrangement. Any steel frame is designed to work within small limits of deflection, while the wood structure cannot be so limited, so that the two do not combine well. The requirements of modern train service are better met by steel framing as it is almost impossible to so frame an end for a wooden car that it will successfully stand the shocks in switching and road service. Steel framing also resists bulging of the sides as the tension members are given a bowstring effect by the loading. Steel-frame cars do not sag, sway, or work so as to require the constant tightening up, renail-

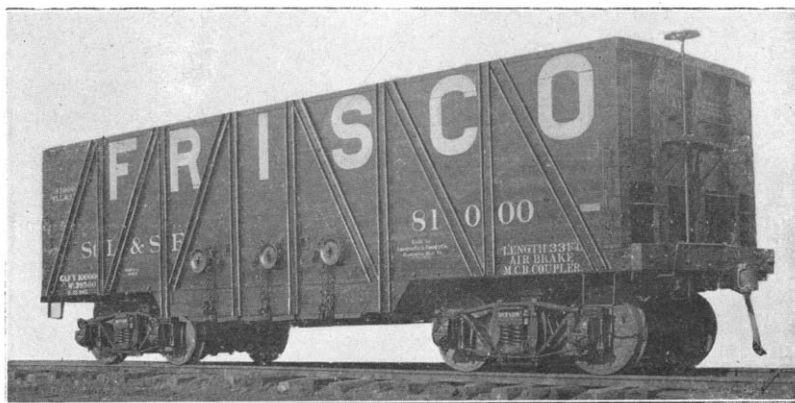
ing, etc., as is necessary on wooden cars. It is now very difficult to find lumber at all suitable for car framing and the prices have equalized so that steel can be used for framing at about

FIG. 10.



equal or better cost than wood. As to whether we should go further than that in the use of steel is a question to be decided by local conditions, service, etc. Lumber is still available for

FIG. 11.



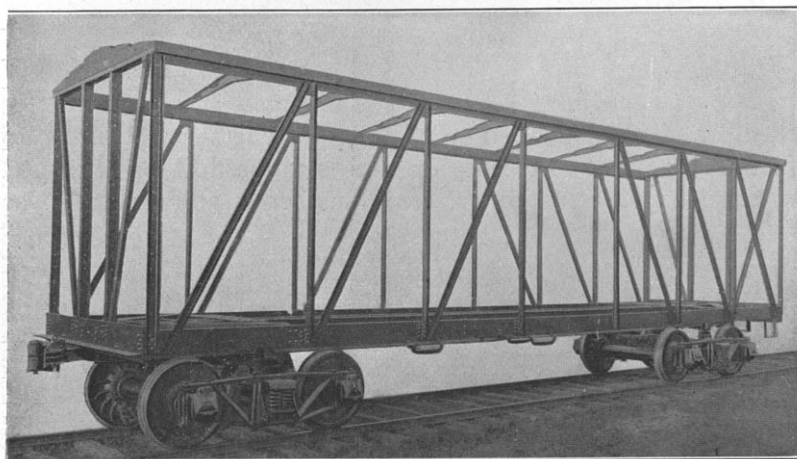
flooring, lining, and covering, and probably will be for some years.

Considerations of weight and strength are of much interest in car designing and especially so in introducing steel wholly or in part in place of wood. Composite construction particularly

favors economy of weight in open cars, giving high percentages of revenue load with low dead weight and the advantages of strength and durability. In steel-frame house cars, however, these percentages of revenue load are necessarily lower as the proportion of wood is higher than in open cars, this for roofing, lining, and sheathing, and the nailing strips for securing them. The well-designed steel-frame box car need not weigh more than a well-designed wooden car and be a better, stronger, and longer-lived car.

The economical application of wood for liners, nailing strips, and fillers is the more difficult part of the design of steel-framed

FIG. 12.

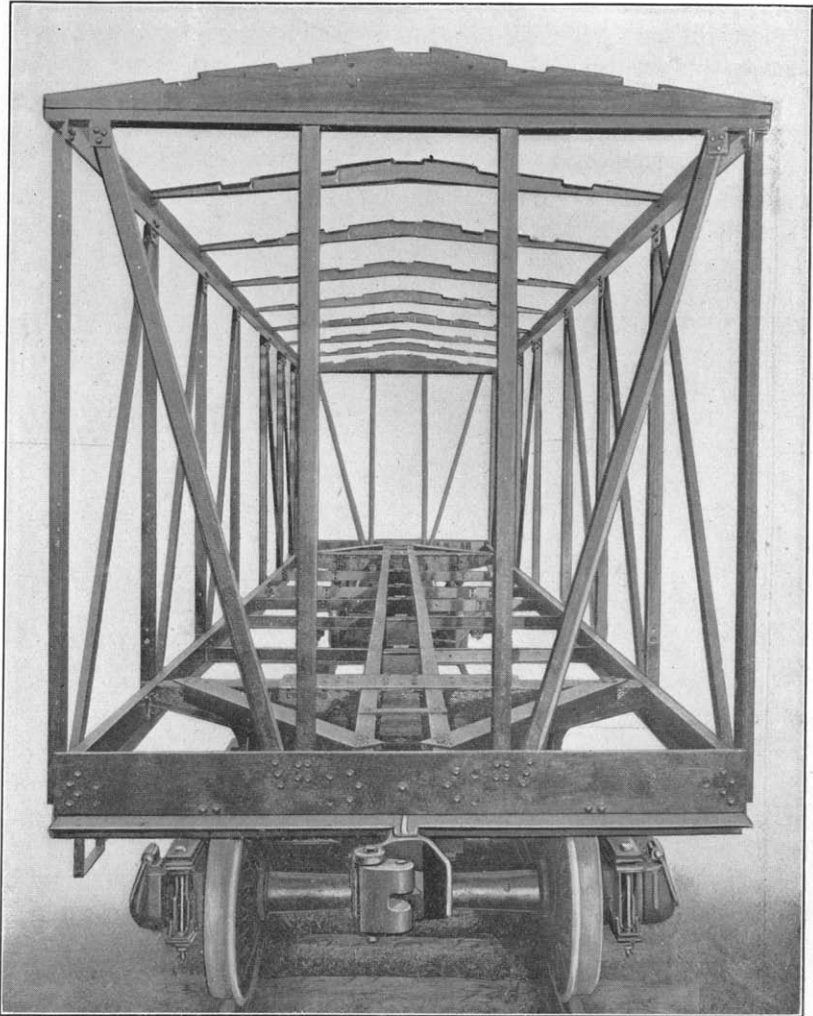


house cars in order to keep the weight down and still offer an adequate fastening surface to which to nail sheathing and lining.

Extensive use of cars of these types of construction has developed considerable information of interest. The cost of repairs of freight cars is not generally divided on railroads into sufficient detail to show the comparative costs for wooden and for steel or composite cars, but such information as we have is greatly in favor of the steel-framed cars. In heavy repairs of wooden cars the cost may be divided into from two-thirds to three-quarters for material and from one-quarter to one-third for labor. When steel is used for framing the proportions are reversed, the larger part for labor and the lesser for material.

In other words, the steel is again usable even though more or less damaged. Shocks which would break wooden members

FIG. 13.



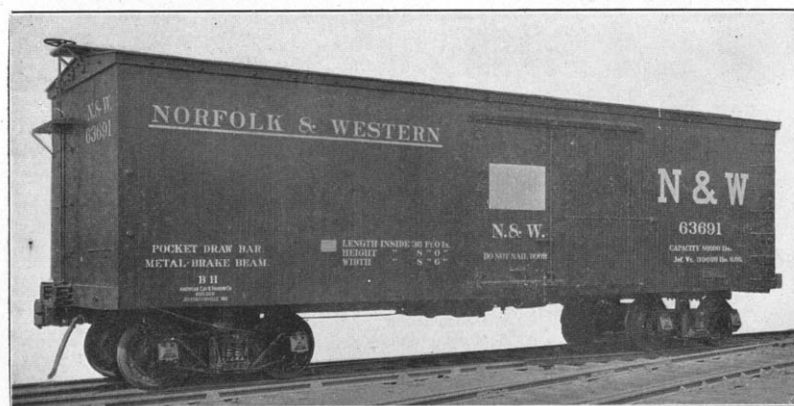
so as to require their replacement would in most cases merely bend or distort a steel one, which may be readily straightened and returned to service. A badly wrecked steel-frame car

looks rather discouraging to one not accustomed to handle such matters, but experience has shown this not to be as bad as it seems. Hand methods have been found most available in handling work of this character, as machinery is of little avail, except in manufacture.

Freight cars get very rough usage and have to stand severe shocks, and oftentimes these are cornering or diagonal which at the time may not break the wooden car but result in its springing back and concealing the damage.

The steel-frame car under these conditions will sometimes yield and stay bent laterally and act as a tell-tale of unfair usage. There is a considerable question as to how far to go in providing

FIG. 14.



lateral strength and stiffening in a car frame. If we consider the strength required for the vertical stresses of loading and impact, we naturally get a proportion of lateral stiffness from the flanges of the channels or other sections used for sills. The crossbearers, bolsters, and fastening of the floor serves to bind the bottom framing so as to give considerable lateral strength. There has been some criticism as to lateral weakness of some steel-frame box cars which are amply strong for carrying their load in normal operation, but will not stand severe cornering shocks without distortion, which occurs between the bolsters. It has been found that in most cases these distorted cars can be jacked back to straight lines without the necessity for cutting them apart, and in view of the cheapness of this class of repair



FIG. 15.

it would seem to indicate a desirable economy in the original construction rather than a justification for an additional expenditure for stiffening the frame.

For instance, if these cars are built with a steel side frame and with two-channel centre sills not cover-plated but spacer-bolted and riveted to bolsters, crossbearers, and end plates, if the centre sills by calculation show sufficient strength for carrying their proportion of load, a cover plate would only give an advantage of a certain amount of lateral stiffness. Such a cover-plate would cost say \$12 per car, and if we are to build 1000 cars it amounts to \$12,000 for a partial insurance against lateral distortion, as it would not be a complete one.

If we should have a dozen distortions a year, and that would be a large proportion for 1000 cars, they could be repaired for a hundred dollars or so. We can afford to do this each year for the life of the 1000 cars and still save a large proportion of the cost of the cover-plating. During the consideration of a certain design it was proposed to splice the sills at the bolsters as this was thought to favor repairs in the case of end damage. It was found that it would cost \$2 more per car than if the sills were run through solid to the ends. On 1000 cars this would cost \$2,000 and the number of these cars receiving end damage, the repair of which would be facilitated by a splice in the sills, would be so small as to be insignificant and the expenditure almost a total loss.

It is our conviction, therefore, that simple, direct methods of design, looking towards such strength as may be required for normal operation, with such reserve as may be necessary for waste, wear, and corrosion to cover average life will give best economic results, and to provide for more than that, adds unnecessary weight and cost for which there is not adequate return.

The question may be raised that if steel is such a good thing for the frame of a car why not cut out the wood altogether and have a complete steel car. This is undoubtedly true in regard to some classes of cars and in some localities. Results so far obtained with all-steel box cars are not favorable. They are excessively hot in hot weather and to an extent that will damage some classes of lading, and as box cars are required to carry all classes of commodities, this feature is prohibitive of all-steel

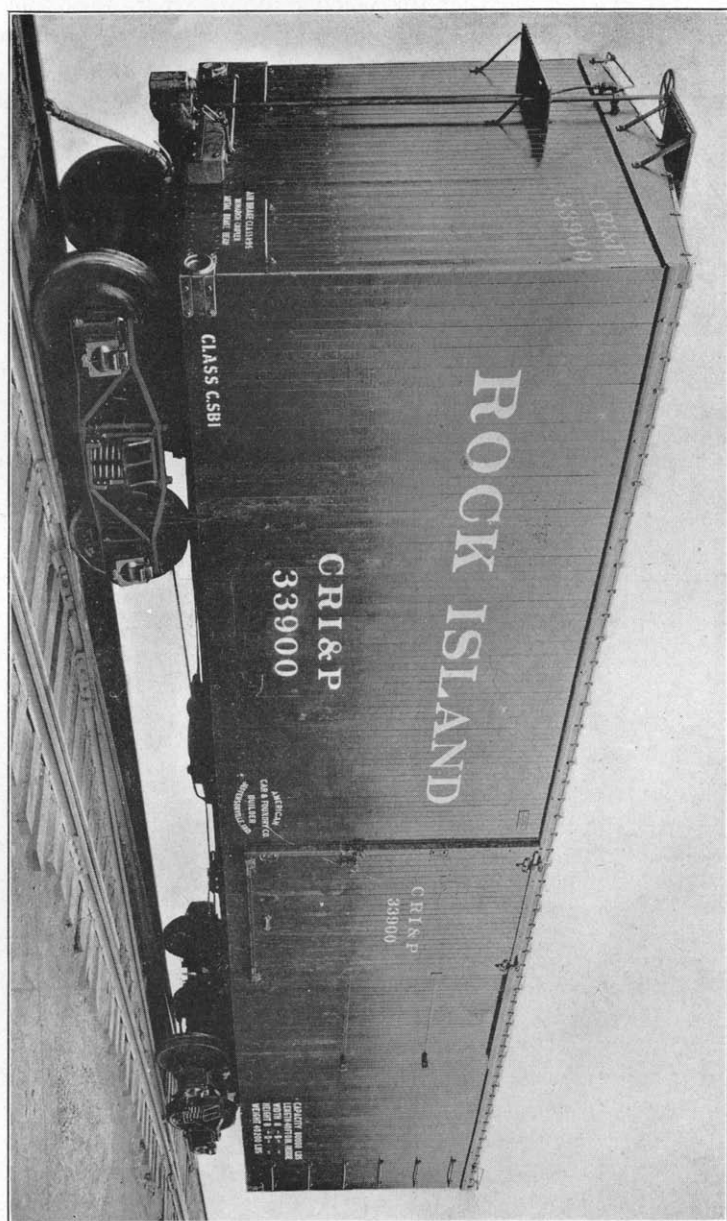
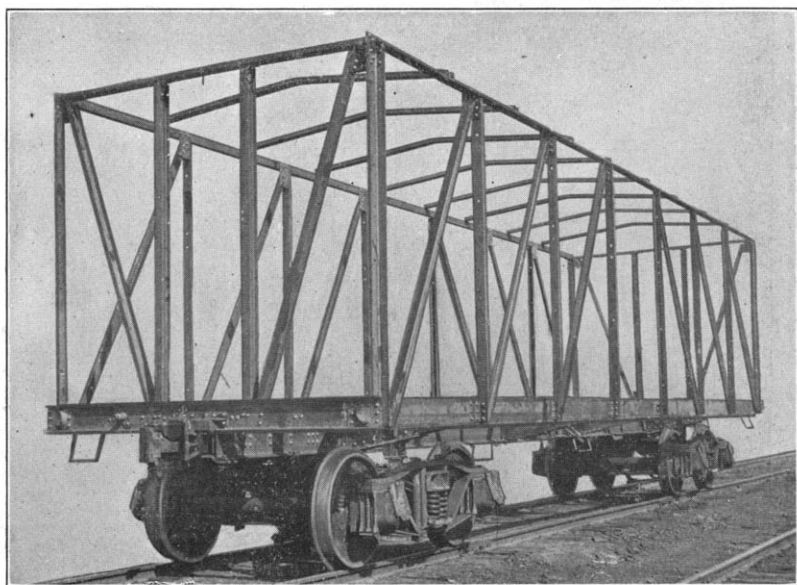


FIG. 16.

box cars. In cold weather, or when exposed to great changes of temperature, steel cars will condense the atmospheric moisture and cause the condition called "sweat," and this is also prohibitive on account of many classes of lading, which require clean, dry storage when in transit.

For open cars to which the above objections do not apply, the choice of all-steel or composite construction is governed by service and cost conditions. On roads serving industries where

FIG. 17.

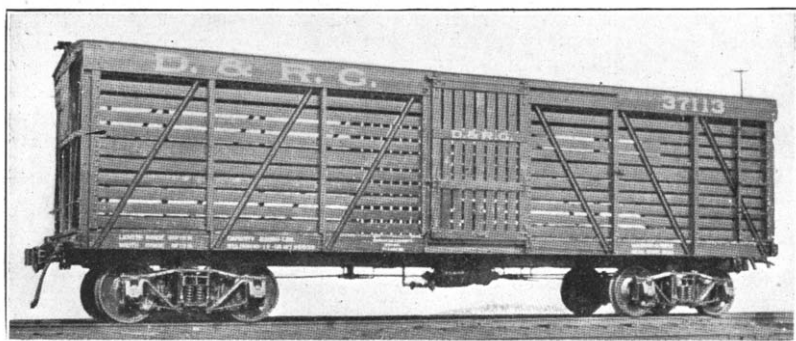


there is a large proportion of hot lading, as at rolling mills, smelters, etc., when hot materials are frequently loaded direct into cars, all-steel construction is the better proposition. If such conditions do not prevail, then the comparative cost of all-steel and of composite construction together with consideration of repair facilities may be taken into consideration. It has been amply proven that the questions of weight, percentage of revenue load, cost and facility of repairs, durability, and general reliability can be as strongly claimed for composite construction as for all-steel when both have an equal weight of other factors affecting the question. Many designs of all-steel cars have given

magnificent results, and it is not the intention to detract from their merits. At the same time, having been concerned in the development of the composite construction of freight cars that has grown to considerable proportions, the writer has welcomed this opportunity to present for your consideration some of the features of a very interesting development in railway transportation.

Neither the writer nor any one connected with the N. & W. Ry. made any attempt toward patenting the car designs made by him. It is now several years since they have been public property, and they have been very extensively copied by railroads, car companies, and others, the only returns to the writer being a

FIG. 18.



sense of satisfaction and pride of achievement as a successful designer. Papers describing and illustrating these theories of car construction have been contributed to the railway press or to railway clubs, some of these being as follows: Paper read before the Richmond Railway Club, May 8, 1902; Paper in the *American Engineer and Railroad Journal*, Jan., 1903; Paper read before the Western Railway Club, March 15, 1904; Address to students of Purdue University, April 11, 1905.

It is now nearly ten years since the first developments on the lines described above, and while the freight equipment of the country is still largely of wooden construction, the new cars that are being built are mainly with steel used to a very considerable extent in their framing and the tendency is very considerably on the lines which have been indicated of composite construction.