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THE NEW OHIO RIVER BRIDGE OF THE SOUTHERN RAILWAY AT CINCINNATI, OHIO

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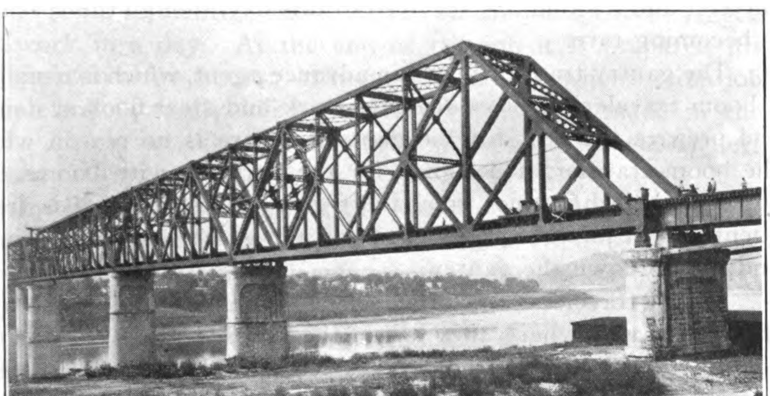
Those of you who have read Andrew Carnegie's autobiography will remember that he devotes one chapter of that very interesting book to the beginning of the iron bridge industry. While he was still a division superintendent of the Pennsylvania railroad, Mr. Carnegie saw that the day of wooden bridges was beginning to wane; and in 1862, with four others, he organized the Keystone Bridge Co. for the manufacture of bridges of iron. The five partners were all connected with the Pennsylvania railroad. One was a technical engineer, two were practical mechanics and two were executives. Each contributed $1250 to the capital of the firm, Mr. Carnegie borrowing his share from the bank.



Southern Railway Bridge over the Ohio River at Cincinnati

This was a modest beginning, but almost immediately they began to build spans of unprecedented length, crossing such streams as the Ohio and the Mississippi rivers. One of their notable bridges was built for the Cincinnati Southern Railway, now a part of the Southern Railway system, across the Ohio

river at Cincinnati, in 1877. The channel span, 519 ft. in length, was the longest span of any kind known up to that time. I consider myself fortunate in possessing a photograph of that bridge in course of construction.

In those days it was not only customary to use falsework under the bridge to carry its weight until it became self supporting, but also to erect a timber scaffold as high as the trusses and as long as the span, known as top falsework, from which lines and falls were hung to raise the iron members. The hoisting equipment consisted of either hand winches or steam engines.

This bridge was completed in 1877 and served until the present year, when the bridge which is the subject of this talk was erected in its place. It will not be out of place to touch hastily on some of the developments in bridge erection during the 45 years' interval.

In the late seventies there was an important change. Some practical bridge builder, instead of building his top falsework for the full length of the span, made it just long enough to cover two panels and put it on wheels. This was the first gantry traveler and its kind has survived to this day, though the species is becoming rare.

The gantry traveler needs an advance agent, which is usually a boom traveler, to place the falsework and steel floor system, and prepare the way for the gantry. There is no reason why the boom traveler, if designed for the purpose, with booms of sufficient length, cannot erect the trusses as well, and it is frequently used for that purpose, saving the great cost of erecting and taking down the gantry.

Boom travelers are often placed on the top chords of through spans, where they erect the trusses ahead of them, panel by panel. Many of the largest bridges have been erected in this way, but as the traveler has to be made to fit the bridge, and as there is so much variation in the dimensions of different bridges, it is generally necessary to build a special traveler for each job. These big special travelers can rarely be used after their first job, almost never after the second.

The Wabash railroad's cantilever bridge over the Ohio at Mingo Junction was built with special travelers. It took a small army to man these immense travelers with their hundreds of lines, and the travelers were never used again. Compare this

with the cantilever bridge of the Labelle Iron Works, a short distance up the river from the Wabash crossing, but erected ten years later with locomotive cranes. These cranes had been used on many jobs before they came to this bridge and have been on many more since, for they are suitable for bridge work, building work, in fact any work to which railroad tracks give them access. Steel erectors began to use locomotive cranes about 15 years ago and now few structures of any size, if accessible by rail, are erected without them. On the Southern bridge just completed, although nearly all of the steel was actually placed in the structure by derrick cars, we employed 6 locomotive cranes for some months for auxiliary work such as unloading and reloading steel in the yard and other duties that will appear later.

On the Paducah and Illinois railroad bridge over the Ohio River at Metropolis, the trusses were 110 ft. high and some of the top chord sections weighed nearly 50 tons. They were erected by a locomotive crane with a boom 130 ft. long. The same crane was used later with a 200-ft. boom to erect a very high building with roof trusses weighing 25 tons.

When a locomotive crane arrives on the job it can be rigged for work in a day. At the end of the job it is prepared for shipment in a few hours. It moves on its own wheels from job to job and is rarely idle. Ordinary repairs are made in the field. The crane, like the men who work with it, seldom gets a chance to go home.

In this sketchy review of the evolution of erection methods I have not spoken of the derrick car, but will come to it shortly, as it reached its highest development to date in the job that I am now going to talk about.

The new bridge is on the same alinement as the old one and has the same length, 3,240 ft. from abutment to abutment. The grade is higher than the old grade by from 4 ft. to 7 ft. As the old piers were retained wherever possible, the span lengths are unchanged except where girders take the place of through truss spans in the Cincinnati approach.

Besides the increase in carrying capacity, which is always expected when a new bridge takes the place of an old one, there are three striking differences between the structures. In the first place, the new trusses are continuous for three spans from pier 3 to pier 6; second, a vertical lift span replaces the old pivot

pier draw. The third difference is not apparent to the eye, as it is due to 45 years' progress in metallurgy. Except in secondary members the new material is silicon steel in riveted members and heat treated carbon steel in eye bars and the allowable unit stress in both is 24,000 lb. per sq. in. I do not know what unit stresses were used in the old bridge, but this is an increase of 50 per cent as compared with ordinary structural steel and, of course, results in a corresponding decrease in the sections. So the difference in size of members of the two bridges, conspicuous though it is, does not fully reveal the great increase in loading capacity.

In widening the piers to take the double track superstructure, a combination of structural steel and concrete was used. The stone at the tops of the starlings was cut away to provide a level shoulder. Steel columns were set on these shoulders and concrete was poured around them up to a certain height. The new trusses rest on these columns. After the old spans had been taken down, the stone was removed between the columns down to the top of the concrete and steel girders erected between the columns. Finally the girders and the rest of the columns were encased in concrete.

Erection of the bridge was made difficult by the great volume of railroad traffic which had to be maintained and the congested condition of the site. At each end of the bridge there is a busy railroad yard. Under it are railroad tracks, city streets and the Ohio River. Fortunately, new bridges are often enough wider and higher than the old ones that it is possible to build them around the old ones. Such was the case here. Then, if the erection equipment can be placed on top, out of the way of traffic, the only serious problem remaining is what military men call the service of supply: how to get material to the front.

The new bridge, like the old one, has a sidewalk on one side, outside the trusses. As pedestrian traffic was discontinued during erection, it was possible to bring the steel out on the sidewalk. It was desirable to have two such material tracks, so temporary brackets and stringers were manufactured for the other side.

Of the four river spans, the two at the shores were erected on falsework and then served as anchor arms while the other two were erected by the cantilever method. Span 4, being only 300 ft. long, was extended as a cantilever for its full length,

but the 519 ft. span was built out from both ends and connected at the middle. Operations on the river spans, therefore, were started on both sides of the river at about the same time.

Only one storage yard was provided, however, for the steel and falsework lumber. It was located on vacant railroad property in Cincinnati about half a mile from the end of the bridge. Double gage tracks were required because the railroad company furnished narrow gage locomotives for moving the material out on the material tracks, while the cars were standard gage.

Material for the south end was first taken from the yard over the main line to the Kentucky side in small quantities as needed, or as railroad traffic permitted, and then held on cars for short periods until the raising gangs were ready for it, when the narrow gage locomotive took it out on the sidewalk.

As the natural place for the hoisting equipment was on top of the trusses, the logical conclusion according to precedent would have been to use travelers. The disadvantages of travelers, as compared with locomotive cranes, have been referred to. But in one respect the crane is found wanting. For work at close range, it is unrivalled, but because of its necessarily short wheel base, it cannot handle heavy loads at long reaches and therefore is not suitable for erecting long girders ahead of itself or for cantilever work unless the panels are short and the weights moderate.

For long reaches ahead, nothing is superior to the derrick car. In the picture a steel derrick car is traveling with one of the 110-ft. girders of the Cincinnati approach. This girder weighs 38 tons. The car itself is not heavy enough to balance the load, so wire rope guys are run back to the water-ballasted tank car.

These girder spans had to be placed slightly out of their proper alinement to clear the old truss spans and in this temporary position were partly supported on timber bents erected as pier extensions. Material for the river spans was brought on the new girders while traffic occupied the old bridge.

But to return to the derrick car: it is not as adaptable as the crane and is seldom used for anything but railroad bridge work, but it is much more versatile than any traveler and, therefore, can be kept almost constantly employed. This gives it a distinct economical advantage in that it reduces the amount of capital tied up in idle and obsolescent equipment. But that is

not all. Every new machine is an experiment. Its faults and weaknesses are only exposed by using it; many of them do not appear until it has been used a long time. Through long years of constant service the derrick car has been slowly but steadily developed to a state approaching perfection, and the men have become so familiar with it that its operation is conducted with great efficiency. It takes fewer men to run a derrick car job than a traveler job.

So, although the boldness of the idea was somewhat startling, when it was proposed to lift two of these heavy steel cars to the top of the river spans, 70 ft. above the deck, it seemed a very desirable thing to do, and investigation proved it to be entirely practicable.

The new double track spans, of course, have four lines of stringers. The two inner ones were placed in the floor system where they belong. The other two were placed temporarily on top, resting on the top struts. These struts were made somewhat heavier than the requirements of the completed bridge would demand and were reinforced by a temporary arrangement of the sway bracing, which provided knee braces. They were only made strong enough, however, to carry the unloaded derrick car. To take care of the heavy reaction under the front end of the car when lifting a load with the boom, wings were added to both sides of the A-frame which would carry the load directly to the top chords. The car never traveled with a load. When it was traveling, the wings, or outriggers, were clear of the top chords by an inch or so. Wedges were provided for taking up this clearance and relieving the load on the car truck and the top strut when the car was spotted for a lift, and this was always with the front end over a panel point, so that no bending strain would be induced in the top chords. These wedges were driven and withdrawn by hydraulic pressure. A high pressure pump was placed on the car to control the wedges. It was operated by the engineer and it was the work of a moment to wedge the car up for business.

The side wings contributed greatly to the stability of the car, an important feature, since the side reach from the center of the bridge to the material track was 23½ ft., and although figures indicated that with these wings the usual side guys, or quarter falls, could be dispensed with, they were retained as an extra precaution against overturning. The car has four engines,

all of which, as well as the hydraulic pump, received steam from one boiler and were operated by one engineer. There is, 1st, the main hoisting engine; 2nd, the propelling engine; 3rd, a swing line engine for swinging the boom and 4th, an auxiliary hoisting engine for comparatively light loads. The boom was 71 ft. long and the topping lift falls consisted of two ten-sheave blocks, 2 six-sheave blocks and 31 parts of ⅞ in. wire rope, which gave the engineer perfect control of the boom. Oil was used for fuel.

All bridge builders with experience on the Ohio have a wholesome respect for that river in flood. So from the time that the contract was made in 1920, the principal objective was to complete the two spans which had to be erected on falsework before the high water season in the latter part of 1921. To fail in this would have meant serious risk of not only the loss of the new steel erected but of the old structure as well, and a tie-up of the Southern Railway for an indefinite period. The shop said that it could deliver the approach girders and the floor systems for the two shore spans by July 1, but would not promise the trusses, which had to be assembled and reamed at the shop, before October 1. An examination of the records of the weather bureau showed that high water before Dec. 1 would be almost without precedent and that floods before Jan. 1 were rare. So we were reasonably sure of 8 or 10 weeks of good river after the arrival of the trusses and plans were made to proceed with the work.

The flood menace made it imperative that everything possible be done before the arrival of the trusses. So the falsework was placed with a crane at the shore end of the span, aided by lines hung from the old bridge, and the floor beams and stringers were placed on this falsework by the crane and skidded out to their position. Meanwhile, temporary towers, made up principally of spare booms, were erected at each end of the bridge. The derrick cars were knocked down into pieces that could be handled by two cranes and reassembled on top of the towers. When the trusses arrived everything was ready for completion of the spans in the minimum time.

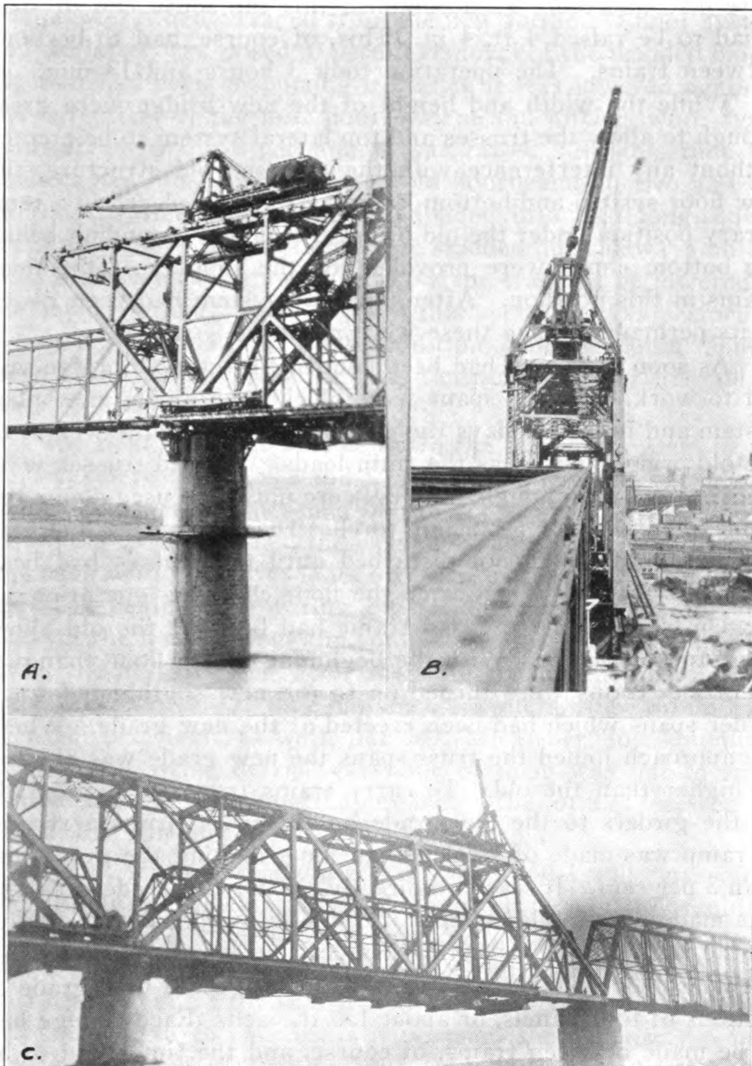
Before this, the pier columns had been placed. Our locomotive cranes were heavier than the limit loads established by the railroad company for the old bridge, so these pier columns were placed on a barge and erected from the river.

By Oct. 1 a good start had been made on span 2 at the Kentucky end. Two weeks later 8 of the 10 panels in that span had been erected. Both spans were self supporting before Oct. 25 and all falsework was removed shortly after the first of November. Incidentally, the river rose to a high stage in the latter part of November and carried a great quantity of drift, an occurrence without precedent at that time of year, justifying the precautions that had been taken against such a contingency.

After that, the north derrick car, working on the continuous trusses, had plain sailing, building the cantilever structure before it and advancing without noteworthy incident to the middle of span 3. But before the south car could start on span 3, it had to erect the temporary steel tying that span back to span 2. The principal element in these tie-backs consisted of four girders each about 120 ft. long and weighing 38 tons. Eventually they became part of the Cincinnati approach, but they were adapted to this temporary service by adding somewhat to their length and providing pin holes in the ends. The surplus ends were afterwards burned off. These were our heaviest pieces and were handled at a front reach of 67 ft.

The north and south halves of span 3 met on Dec. 17. On Dec. 21 the final connecting operation was performed. The joining of a span that has been erected from both ends by the cantilever method is getting to be a rather common occurrence and I suppose that most of you are familiar with it. While there is a great variety in the details, the essence of the method is always the same, at least so far as my experience has gone. The cantilever arms are erected with an upward inclination. This provides end clearance for the closing top chord member. After that member is erected the arms are lowered by some device, usually hydraulic jacks, and the top chord comes to a bearing. More lowering tends to put compression in the top chord, but usually one of the arms has been erected in advance of its normal position and at this stage of the proceedings, is on rollers free to move, so the pressure of the top chord forces it back till the bottom chord is ready to take tension, at which time the truss has assumed its proper shape and all members in the closing panel can be connected. A common method of lowering the cantilever arms is to jack up the far ends of the anchor spans, and that method was used on this bridge, but as the north

anchor span in this case was part of a 3-span continuous structure, a new feature was introduced in the provision that only the south arm should be lowered in the connecting operation. Accordingly, the south arm was given the upward inclination



Span No. 4, Cincinnati Southern Bridge

A,—Nov. 5, (1921) started. B,—Nov. 13, setting batter posts. C,—Nov. 23, completed. These views illustrate how the new bridge was built around the old, with derrick car on top of new bridge. Old bridge single track. New bridge double track.

during erection, but the north arm was not. The south end of span 2 was jacked up until the chords straightened out and all members could be bolted up, then jacking was continued until the tension was relieved in the temporary tie-backs, when they were disconnected. To accomplish this the south end of span 2 had to be raised 4 ft. 4 in. This, of course, had to be done between trains. The operation took 3 hours and 18 min.

While the width and height of the new bridge were great enough to allow the trusses and top lateral system to be erected without any interference with the enclosed old structure, the new floor system and bottom laterals had to be placed in a temporary position under the old bridge. Hangers extending below the bottom chord were provided for the support of the floor beams in this position. After the floor system had been raised to its permanent place these were removed.

As soon as span 3 had been connected, the new bridge was put to work. The old spans were blocked up on the new floor system and for a few days the new bridge carried the weight of the old bridge as well as the train loads. The old trusses were quickly removed, though, as they were not to be used again and could be cut up with a burning torch. The old floor system, still carrying traffic, was not disturbed until the trusses had been entirely removed. Then came the floor changing operation.

Up to this time railroad traffic had been on the old alinement and old grade. With the beginning of the floor changing operation, trains were turned on to the new southbound track girder spans which had been erected at the new grade. Where the approach joined the truss spans the new grade was about 4 ft. higher than the old. To carry trains from the high grade on the girders to the low grade on the truss spans, a run-off or ramp was made of steel, 150 ft. long, making the grade less than 3 per cent. It was laid directly on the low grade rails and was made with guides so that it could be skidded ahead quickly on the rails to a new position as occasion demanded.

The floor of the truss spans was changed to new grade in sections of four panels, or about 150 ft. each. Each change had to be made between trains, of course, and the times had to be selected so as to disturb traffic as little as possible. The operation was as follows: As soon as we got the track, a work engine was coupled to the ramp and pulled it four panels ahead to the new position. The falls from the two derrick cars on top were

then hitched to the four floorbeams. The floorbeams were disconnected from the trusses and the new floor system, with the old floor system and track on it, was raised to the new position and bolted in place. Meanwhile men with burning torches were cutting the old floorbeams in two in the middle. The hitches were then changed from the new to the old floor system and the latter was raised to permit removal of the wooden blocking that had been supporting it. Then it was lowered again to the bare steel of the new floor system and hitches were again transferred to the track, and it was raised. By this time the burners had finished cutting the old floorbeams in two and the old floor system was therefore divided into two longitudinal sections. These two sections were skidded out sideways on the new floorbeams far enough to allow the track to be lowered to the new stringers. The first time this operation was performed it took 3 hr. and 17 min., the second time 2 hr. and 2 min. There were 11 operations, and the best time made was 1 hr. and 15 min.

The next step was to take down the temporary steel in the tie backs between spans 2 and 3. As there was now a continuous track on top, it was possible to use both cars for the removal of the big girders. Then the cars made their final trip over the top, each working towards its own end of the bridge, taking up its track behind it, lowering the stringers to their permanent place in the floor system and completing the sway bracing; and about the first of April, after spending six months on top, they were taken down. If they had been travelers, they would have been shipped home to wait, like Mr. Micawber, for something to turn up. Being derrick cars, one of them was put to work completing the Cincinnati approach. The other received an urgent call for duty in western Pennsylvania.

Just a few words about the lift span and I will close. The act of Congress which authorized the first bridge in 1877 required a movable span near the Kentucky shore where boats ply in high water to avoid the swifter current in midstream. The act is still in effect. Provision was therefore made for raising the new span 12 ft. to pass boats if occasion should arise. A permanent hydraulic jack with a 12-ft. runout was placed under each end of the span, but to reduce the power required, the span was partially counterweighted. The short distance that the span must be raised suggested a convenient method of reducing the

counterweight. The wire rope cables to which the counterweights are connected are rove in falls of five parts. The towers were built high enough to allow the counterweights a movement of five times the movement of the bridge, or 60 ft. Consequently, the four counterweights of about 50 tons each, or 200 tons total, produce the same effect as 1,000 tons would on a single line.

From beginning to end this job was carried out with remarkable smoothness. The designers must be given credit for the great care with which every detail of the scheme was studied. It must be admitted, however, that some very complicated problems were frankly put up to the erection foreman, Mr. Frantz, to get out of as best he could, and he never failed to justify the confidence imposed in him. Much is due to the high degree of coöperation attained among the various parties concerned. To mention by name the persons who had an important and responsible share in the work would be almost like calling the roll of a company of infantry, because there were five organizations working together and all of them had to make individual sacrifices for the general good of the undertaking; (1), the organization of Ralph Modjeski, consulting engineer; (2), the engineering department of the Southern Railway Company, headed by T. H. Gatlin; (3), the operating department of the railway, represented by C. E. Rickey, superintendent of the Cincinnati terminals, to whom we are all especially indebted for the way train movements, when necessary, were arranged to conform to the desires of the construction gangs; (4), the Foundation Company, contractors for the masonry; and (5), the American Bridge Co., contractors for the super-structure.