THE AURORA, ELGIN & CHICAGO THIRD-RAIL ELECTRIC INTERURBAN RAILWAY.

Among the numerous interurban electric railways now in operation or under construction, one of the most important and most interesting is the Aurora, Elgin & Chicago Ry., which has recently been completed, and which was opened for traffic on Aug. 25. The line is designed for high-speed service, has a double track for a large portion of its length, and is operated entirely on the third-rail system. This system was adopted as being an improvement upon the trolley system for railways of this class, being better adapted for high-speed service, and more economical in maintenance than the ordinary overhead construction.

As railways of this class have developed from the electric street railway there is still a general tendency to speak of them as street railways, even when built upon private right of way. As a matter of fact, they may be fairly considered as forming a special class of themselves, and the line in question conforms very closely to ordinary steam railway practice in its location and construction. The railway is built entirely upon its own right of way, and its construction has involved some heavy cuts and embankments to give the easy grades and curvature demanded by a high-speed line. It is of substantial construction, with steel and concrete structures throughout and a heavy track.

The road will have about 82 miles of main line, of which 21½ miles are double track. The distance from Chicago (52d Ave. and Harrison St.) to Wheaton and Aurora is 33.3 miles; the line from Wheaton to Elgin, 16.5 miles; and the Batavia branch, 6 miles. It will serve a population of about 80,000 outside of Chicago. The same interests own the Elgin, Aurora & Southern Traction Co., with 70 miles of track. Of this length, 37 miles comprise the interurban line between Carpentersville and Yorkville, while the balance consists of city or street lines in Aurora and Elgin. Fig. 1 is a map of the railway.

The line will be operated mainly by trains instead of single cars, the multiple unit system being adopted, in which each car has its own motive power, but all the motors are controlled from the head of the train. There will also be trail cars without motors, to be attached to motor cars for two-car trains.

There are trains in both directions every half hour. At present the time allowed for the run between Aurora and Chicago or Elgin and Chicago is 1 hr. 15 mins., but this will be reduced to 45 minutes as soon as everything is in good running order. This will give an average speed of about 45 miles an hour from start to finish, which will necessitate actual running speeds of 50 to 60 miles per hour. The traffic is handled by the telephone train dispatching system, the head dispatcher at Wheaton communicating with the men at the substations, or with the conductors, who report at these stations. The cars are equipped with portable telephones, and means for connecting these with the telephone wires are provided in small iron cabins at all turnouts and crossovers; while at intervals along the road the wires are brought down the poles so that the telephones can be attached. Block signals may be introduced later.

ROADWAY AND TRACK.

The width of right of way is mainly 66 and 100 ft. The lighter grading was done with plows and scrapers, while the heavier work was done with steam shovels and locomotives and side dump cars, temporary trestles being used for building the center of the large banks, which were then widened out as required. Narrow-gage construction tracks were used at some points, and standard-gage tracks at other points. Along the Fox River, on the Elgin line, the bank is built in the shallow water along the east shore. On single-track portions of the line the cuts are excavated to a width sufficient for double track. The maximum grade is one of 1.8%, a mile in length, entering the Fox River valley, but on the rest of the system the aim has been to limit all grades to 1%. The ordinary curves connecting long tangents are of 1° and 2°, and the maximum on high-speed portions of the line is 4°. Near the Chicago terminal two reverse curves of 16° (with a short tangent between) are required to avoid interference with cemetery property, but as these are between two railway grade crossings (at which all cars must stop) they do not affect the question of speed. The superelevation on curves is about 1 in. per degree, with a maximum elevation of 5 ins.

The width of roadbed is 16 ft. for single track (13 ft. over toe of ballast), and 28 ft. for double track (26 ft. over ballast), as shown in Fig. 2. The track is laid with 80-lb. rails of the Am. Soc. C. E. section, 60 ft. in length, and having about 0.6% of carbon. They are laid with broken joints and spliced with angle bars and four 1-in. bolts with lock nuts. Bolts of this size are rarely used on steam railway track, except for frogs. In tracklaying, the 60-ft. rails are unloaded from the cars by hand, being run out over two timber horses or "dollies" placed on the subgrade, ahead of the car. The first of these is a little lower than the floor of the car, and the second is considerably lower, and each has at the top an iron roller. On double track, the tracks are 13 ft. c. to c., and are connected by crossovers at intervals of three or four miles. On single track there are passing sidings at similar intervals; these sidings are 700 ft. to a mile in length, long sidings being provided at curves so as to provide practically double track, and thus give greater safety for high-speed running at some points. There are 32 oak and cedar ties to a 60-ft. rail, and the ballast is of gravel, with a depth of 9 ins. under the ties. The rail joints are fitted with the electric bonds of the Protected Rail Co., of Philadelphia, Pa., or with the 12-in. "United States" rail bond of the American Steel & Wire Co., of Chicago. The rails are cross-bonded at intervals of 500 ft. The switches are of the split pattern, with 15-ft. reinforced switch rails; and No. 10 spring-rail frogs are used for main track turnouts. High switchstands are used, except in yards. The switch and crossing work was built by the Morden Frog & Crossing Works and the Ajax Forge Co., both of Chicago.

The conductor or third rail is of the 100-lb. Am. Soc. C. E. section, in 33-ft. lengths, and is of much softer steel than the track rails, having only about 0.1% carbon. The object of this is to give greater conductivity, but as the softer steel rusts and corrodes much more quickly than the harder steel, the third rail is painted with a cheap asphalt paint thinned with gasoline. This rail is carried by insulating supports on the ties (every fifth tie being of extra length), as shown in Fig. 2. These supports are blocks of wood boiled in paraffine. The joints of the third rail are spliced with two-bolt malleable cast-iron splice bars, and are fitted with the Protected Rail Co.'s rail bonds of U-shape. The holes in the rail flanges for attaching the bonds were made after the rails were laid; some were punched by a portable hydraulic press, and others were drilled (either by hand or by a gasoline machine mounted on a hand-car). At grade crossings, the third rail is cut; the last rail is dropped 2 ins. in its length and has its end fitted with an incline 24 ins. long to raise the contact-shoes of the cars into place. At switches a "drop rail" is used, as shown in Fig. 3, so as to clear the shoes of cars on the turnout, the sides of which would otherwise strike the side of the rail. The ends of the rails are connected by cables laid under the crossings. Single cars will drift over the crossings, but trains (and even single cars at short crossings) will have the front shoe again in contact before the rear shoe has left the rail.

All highway grade crossings are planked and

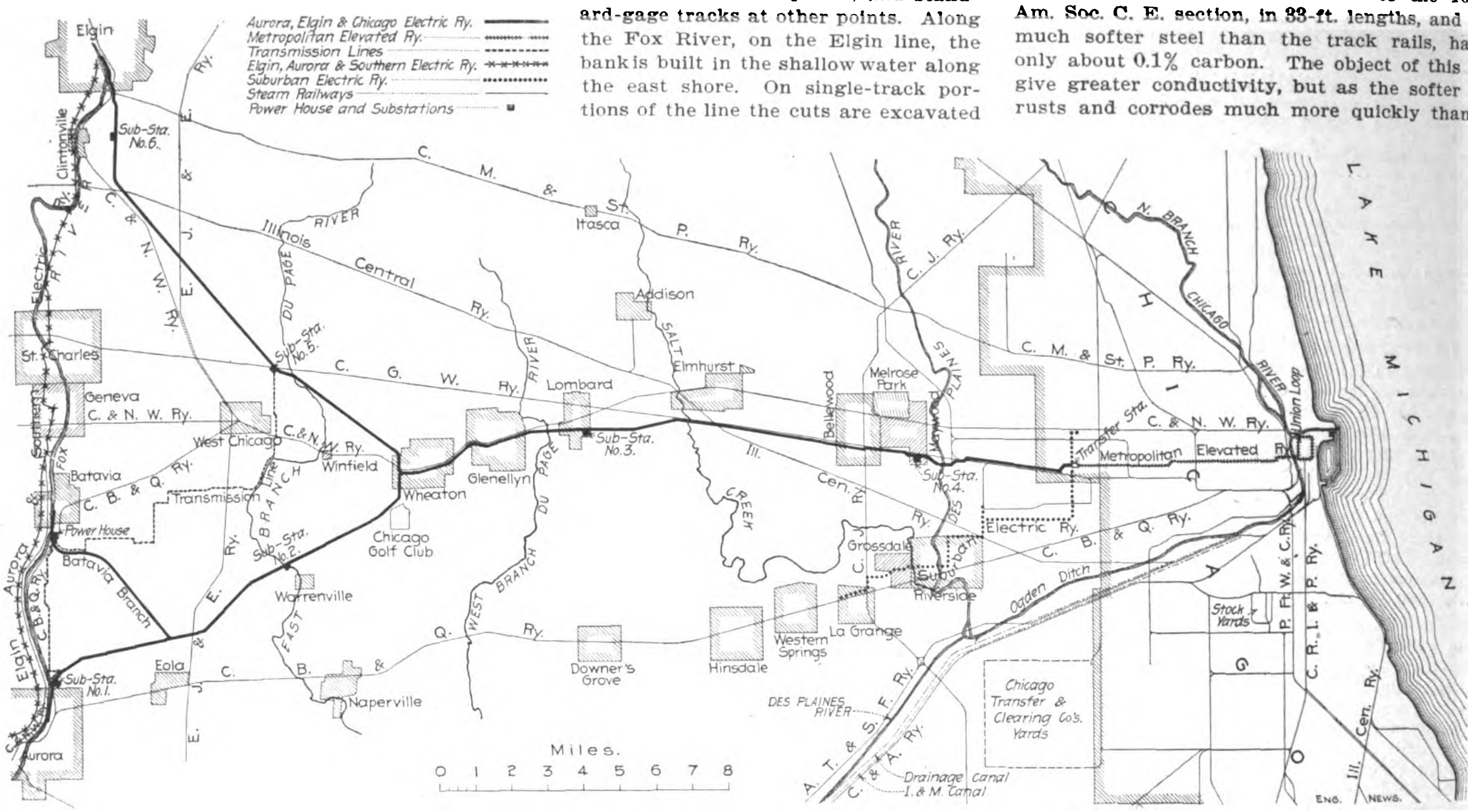

FIG. 1. MAP OF THE AURORA, ELGIN & CHICAGO RY. CO.'S THIRD-RAIL ELECTRIC INTERURBAN RY.
Charles Jones, Chief Engineer, Wheaton, Ill.

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fitted with cattle-guards of vitrified clay blocks, made by the Climax Stock Guard Co., of Chicago, and bell or other warning signals may be installed later at important highways. There are only four railway grade crossings, one of which is a crossing of an electric line operated by only one car per hour. The other three (one of which comprises three parallel steam roads) are protected by interlocking plants.

the West branch of the Du Page River, and on the Elgin branch, has two 30-ft. arches (with a rise of 1 in 10). The smaller structures have arches of 10, 12 and 15-ft. span, and one of these has two 15-ft. spans. Old 60-lb. rails are laid in all the arches, except those of 12 and 15-ft. span. They are placed about 36 ins. apart, near the center line of the arch ring, and extend into the haunches. The standard cattle-pass, Fig. 5, is

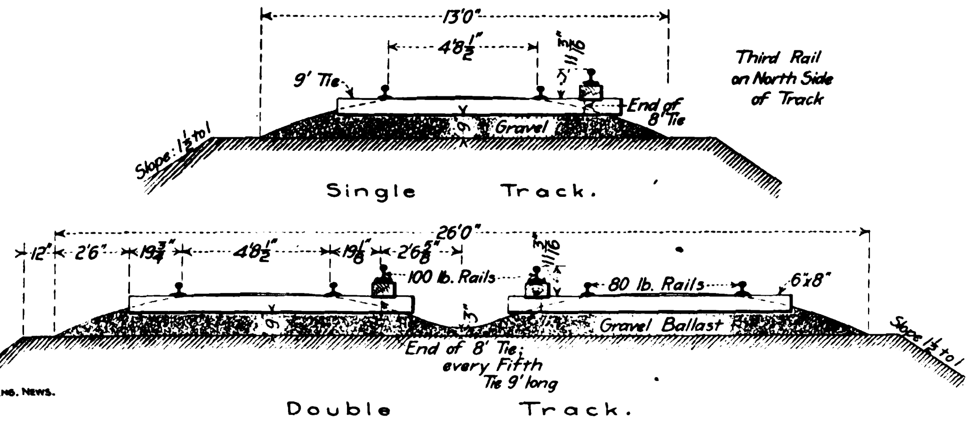

FIG. 2. CROSS-SECTIONS OF ROADBED AND TRACK OF THIRD-RAIL ELECTRIC RAILWAY.

BRIDGES.

All steel bridges were designed in accordance with Cooper's specifications, with his Class E-40 loading. Mr. W. M. Hughes, M. Am. Soc. C. E., of Chicago, was Consulting Engineer for the bridge work, and all these structures were built by the King Bridge Co., of Cleveland, O. There is only one truss bridge, crossing the Chicago & Northwestern Ry., at Elgin, on a skew. This has a span of 158 ft. 7 ins., with shallow floor construction, and one end rests on columns, connecting with a steel viaduct 363 ft. long.

All the other steel bridges are of plate girder construction. There are two 100-ft. spans (arranged for three tracks) over the Des Plaines River, and a double-track deck bridge of 70 ft. span over the East branch of the Du Page River. At Warrenville there is an 89-ft. span over the West branch of the Du Page River with a 24-ft. cattle-pass and culvert at one end. Besides the Chicago & Northwestern Ry., already noted, the line passes over two other railways, by girder spans of 69 and 80 ft., respectively. It also passes under five railways, which are carried by girder spans of 36 to 60 ft. There are 12 plate-girder bridges carrying the line over streets and roads, and four carrying roads over the railway. The latter have 45-ft. main spans (to allow for future double tracking), with 20-ft. I-beam approach spans. Besides these there are a number of small openings spanned by I-beams with concrete filling. The steel bridges have open floors, but with closely-spaced ties and a substantial floor system. All piers and abutments are of concrete.

There are four concrete bridges, besides a number of concrete culverts and cattle-passes. The Salt Creek bridge, Fig. 4, has two 35-ft. arches (with a rise of 1 in 6); the Poplar Creek bridge at Elgin has one 30-ft. arch, and another bridge over

10 ft. wide and 7 ft. high, with 10-in. I-beams 14 ins. c. to c., embedded in concrete. One of these, with two openings, is shown in Fig. 6. The beams are embedded in concrete, but are figured to carry the entire load unaided by the concrete. This beam construction enables much lighter abutment walls to be used than for an arch culvert, as there is no thrust to be resisted. The cost is also about 20% less than for an open-floor bridge with I-beams on concrete abutments, since the latter

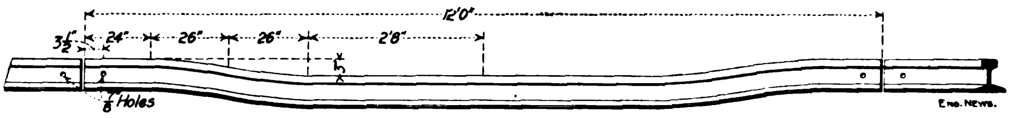

FIG. 3. DROP RAIL AT SWITCHES.

would require heavier abutments than where the beams are embedded in the concrete.

In one cattle-pass, Fig. 7, concrete jack arches are turned between the I-beams, but instead of the ordinary removable wooden centering, arches of wire netting were fitted on the lower flanges and the concrete placed on these, being filled in from both sides towards the crown. The end of each I-beam rests on a vertical 60-lb. rail embedded in the abutment, and a diagonal rail is embedded in each wing wall. This arrangement enables lighter walls to be used, with an economy in concrete, and a saving of about 30% in cost as compared with a structure having concrete abutments and an open I-beam floor. All concrete work is made with Portland cement supplied by the Wabash Portland Cement Co., of Detroit, Mich., with works at Stroh, Ind.

STATIONS AND BUILDINGS.

The Chicago terminal is a transfer station for connection with the Garfield Park line of the Metropolitan West Side Elevated Ry., as described in our issue of Aug. 14. The cars run between two platforms, on the outer sides of which is the terminal loop of the elevated railway, which is reached by an incline from the elevated station at 48th St., as described in our issue of July 31. At Elgin and at Batavia the line runs on its own right of way up the river bank to a terminal station in the center of the town. At Aurora the cars run for about half a mile along a street, but the tracks are adjacent to the right of way of the Chicago, Burlington & Quincy Ry. There are about 30 stopping places in all, most of these having simply open platforms at road crossings. Each of the six brick substation buildings has a waiting room and platform for passengers, and there are a few small frame stations. The main repair shops and car sheds are being built at Wheaton, and are of fireproof construction throughout.

CAR EQUIPMENT.

The road has about 30 cars, and others will be added as the traffic requires. Those now in use were built by the Niles Car & Mfg. Co., of Niles, O., and were all run to Chicago on their own wheels. One of these is shown in Fig. 8, which also shows the track and third rail. They are 47 ft. 3 ins. long over all, 8 ft. 8 ins. wide, and weigh 74,000 lbs. empty. They are of substantial construction, with steel underframes stiffened by truss rods, and steel-framed trucks. The wheels are 36 ins. diameter, and the axles 6½ ins. diameter, with journals 5 × 9 ins.; the axles, boxes, etc., conform to the M. C. B. standards. There is a motor of 125 HP. on each axle, and nearly all the cars are thus equipped, the line being operated mainly by trains of three to five cars; the electrical equipment is on the multiple-unit system, in which all the motors are controlled from the controller on the front car. There will, however, be some trail cars without motors. Contact shoes are fitted on both sides of each truck, and there are two trolley poles on the roof for use on the short piece of street line in Aurora. The cars have transverse seats, upholstered in rattan, and have seating accommodation for 56 passengers. They are equipped with telephones, Christensen air brakes, electric heaters and electric interior lights and headlights. At one end is a smoking room. The platforms are vestibuled and have side and end doors in the vestibule, the latter allowing for access between the cars when coupled up in trains. Hinged sections of the floor cover the steps when the doors are closed, and when the car reaches the 52d Ave. transfer station (which has a high platform). The dimensions of the cars correspond very closely with those of the cars on the Chicago elevated railways, and the trucks are so arranged as to enable the cars to

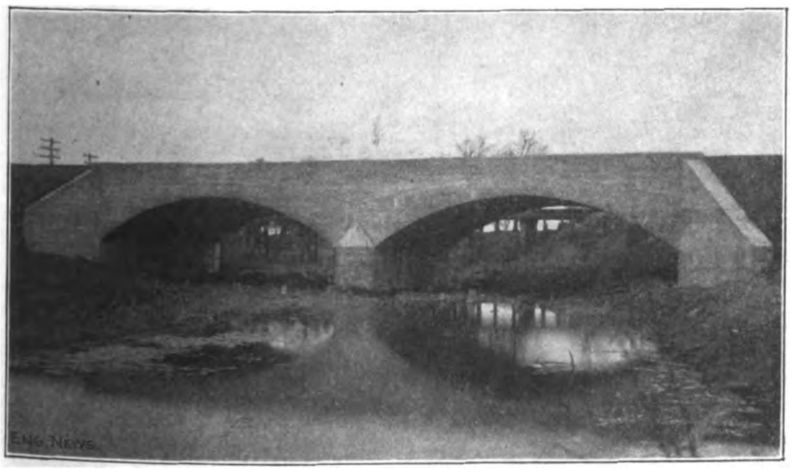

FIG. 4. CONCRETE-STEEL BRIDGE OVER SALT CREEK; AURORA, ELGIN & CHICAGO RY.

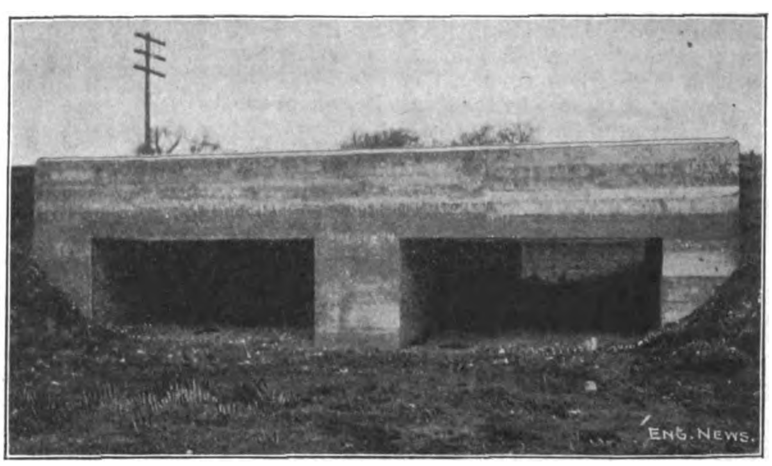

FIG. 6. CATTLE-PASS WITH DOUBLE OPENING.

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readily pass the 90-ft. curves on these lines. This is in view of the possibility of eventually running the cars over the elevated railways into the city.

POWER PLANT.

The current for operating the entire line is generated at one power house, at Batavia, Ill.; this will also supply current for the line from Elgin to Aurora, and for the street cars in these cities. This will not only give greater economy than the present small power stations on these older lines, but the city traffic will tend to equalize the load on the power station and prevent the high peaks which occur when only interurban traffic is operated. The power house is 202 x 160 ft., of steel frame construction, with a simple but handsome exterior of limestone and common pale brick, and a roof of tar and gravel composition on plank sheathing. The concrete foundations and the masonry were built by the company, while the steel work was built and erected by the Variety Iron Works, of Cleveland, O.

There are three Corliss cross-compound condensing engines of 2,200 HP., built by the C. & G. Cooper Co., of Mount Vernon, O. These have cylinders 32 x 60 and 64 x 60 ins., with a piston speed of 750 ft. per minute at the normal speed of 75 revolutions. The receiver is in the basement, and contains a heater coil. On the shaft of each engine, between the cranks, are mounted a revolving field General Electric generator of 1,500 KW. and a 20-ft. 80-ton flywheel. Space is provided for a fourth engine and generator. There are also two horizontal engines of 200 HP., built by the Phoenix Iron Works, of Meadville, Pa.; each of these drives an exciter of 160 KW. The lubrication is effected by the Siegrist pressure circulating system, the pumps of which are arranged in duplicate for three independent sets of circulating pipes for engine oil, high-pressure cylinder oil, and low-pressure cylinder oil. The oil room in the basement has two tanks for each of these oils, so that one can be filled while the other is in service; in this room also are two Cross filters for the waste oil, made by the Burt Mfg. Co., of Akron, O.

All piping is exposed and within view, instead of being concealed in tunnels or a basement. The main lines of pipe are carried horizontally along the wall of the engine room, the valves being made accessible by an iron L-shaped ladder which travels along the whole length of the wall. With this arrangement all the principal pipe connections, valves, etc., are in full view of the men in the engine room. This room is served by a 50-ton electric traveling crane built by Alfred Box & Co., of Philadelphia, Pa., and a railway track enters one end of the room so that material can be handled directly from the cars by the crane.

Steam is supplied by eight water-tube boilers of 500 HP., built by the Edge Moor Iron Co., of Wilmington, Del., and space is provided for two more boilers. The boilers carry a pressure of 180 lbs. They are fitted with superheater tubes, and have the traveling chain-grate of the McKenzie Furnace Co., of Chicago, driven from eccentrics on a shaft placed beneath the floor. The plant also includes Green economizers and Worthington condensers and pumps, the main circulating and feed pumps being driven by induction motors. The power station is close to the Fox River, and the water supply for the boilers and condensers is taken from the river by a conduit which passes through the building, while the waste water is discharged into a culvert which leads back to the river. At the intake is a screen house, with two intake chambers, each fitted with three wire screens, which can be raised by means of a trolley hoist running on the I-beams of the roof. To prevent trouble from ice at the intake, an 18-in. cast-iron pipe is run to it from the condensing plant so that some of the warm water from the condensers can be discharged at the intake instead of into the culvert. The 240-ft. chimney, of brick and stone, is placed at the middle of the building, and the top of its 11-ft. flue is 225 ft. above the grates.

The coal-handling plant is of rather novel design, no continuous conveyor being used. The coal is dumped or shoveled from railway cars into a masonry storage bin parallel with the boiler room, and divided into 18 pockets, each of which has a capacity of 3,771 cu. ft., the total storage capacity being about 2,000 tons. The bottom of each pocket has two steel hoppers, the two rows of hoppers being separated by a stone wall pierced with archways. Under each row is a track of 21½ ins. gage, the rails being embedded in the concrete floor of the basement (below the boiler room floor), and arranged for outside-flanged wheels, so that the concrete between the rails is made flush with the rail heads and the floor is easily kept clean. A transverse track runs to an Otis elevator, and has turntables at its intersection with the two tracks under the coal hoppers. On these tracks run steel cars of 1 ton capacity, fitted with ball bearings. A car is loaded by a gate at one of the hoppers, and then run to the elevator, the floor of which carries a turntable with automatic weighing device. This raises the car to the level of a track running along the tops of hoppers of 5 tons capacity above the stokers, and it is run to the right or left along this track and dumped into any one of the hoppers, as required. From these hoppers, spouts lead to the automatic stokers or chain grates. Under the ashpits passes another track of 21½ ins. gage, on which are run similar cars, which are raised by the elevator and then run over a storage bin above the coal car tracks (above the coal bin), from which the ashes may be dumped into railway cars and hauled away for filling, etc. One man can handle a ton of coal from the storage pocket to the boiler hopper in eight or ten minutes, and two men can easily handle all the coal and ashes. This coal and ash-handling plant was designed by the engineers, and built by the Variety Iron Works, of Cleveland, O.

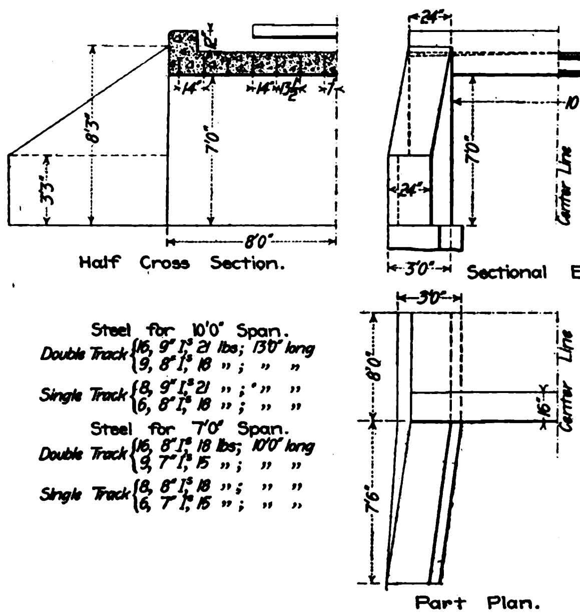

FIG. 5. STANDARD CATTLE-PASS; AURORA, ELGIN & CHICAGO RY.

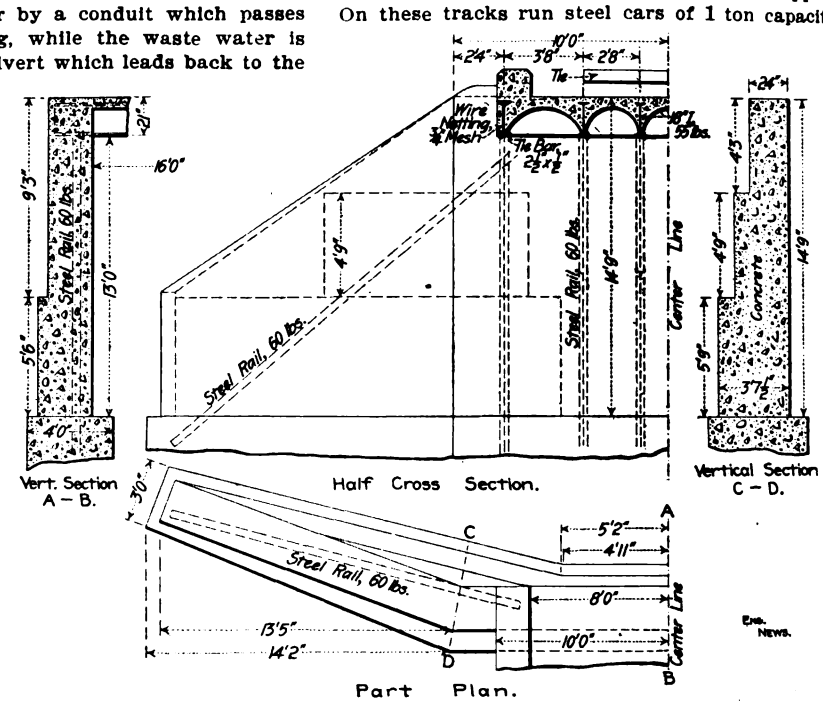

FIG. 7. CONCRETE-STEEL BRIDGE WITH CONCRETE JACK-ARCH FLOOR.

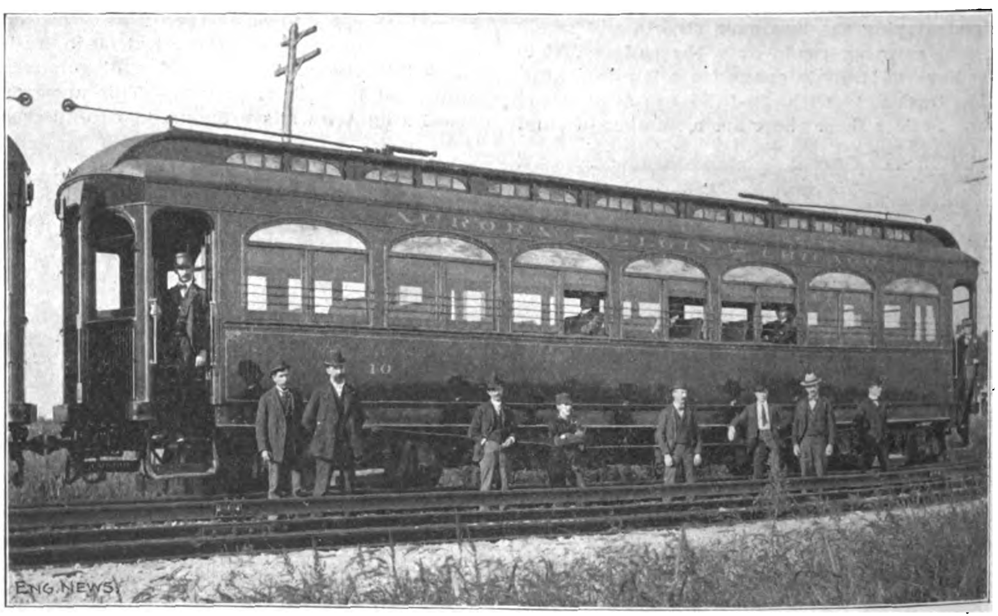

FIG. 8. CAR FOR HIGH-SPEED THIRD-RAIL ELECTRIC INTERURBAN SERVICE; AURORA, ELGIN & CHICAGO RY. Niles Car & Mfg. Co., Niles, O., Builders.

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The transformers are on the engine room floor, and are cooled by a current of air passing up through them. Two fans deliver the air into a blast chamber, or bus-bar room, in the basement, which is a long room under the transformers and containing the connections for the outgoing high-tension wires. This room is entered by means of an air lock, formed by double doors having openings fitted with shutters.

The power plant generates an alternating current of 26,000 volts, which is sent out over the high-tension cables to the substations. Stationary transformers reduce this to a 420-volt alternating current; this enters the rotary transformers, which deliver a 600-volt direct-current to the third rail. The arrangement of the high-tension current is shown in Fig. 9, from which it will be seen that provision is made for alternative circuits in case of failure in emergency. Each circuit consists of three aluminum cables, arranged in a triangle, 20 ins. c. to c. These are transposed at intervals of a mile. The high-tension cables do not extend to the ends of the line, the end sections (indicated by dotted lines) having the third rail fed directly from the substations, so that the poles carry only the telephone wires. The poles carrying the high-tension cables are 40 ft. long and 80 ft. apart, and the telephone wires are carried on the same poles, below the cables. On the end sections of the line the telephone wires are carried by smaller poles 100 ft. apart. The telephone wires are transposed on every fourth pole.

There are six substations, the location of which is shown in Figs. 1 and 9. They are approximately 10 miles apart, feeding the third rail for five miles in each direction. All these are fireproof buildings

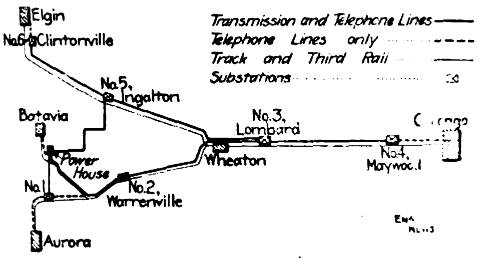

Fig. 9. Plan of Electric Distribution System; Aurora, Elgin & Chicago Ry.

of brick and stone, with Monier concrete-steel floors; and they have waiting rooms and platforms to serve also as passenger stations. Each substation has six stationary air-cooled transformers, two rotary transformers, and a fan with induction motor (supplied by the Buffalo Forge Co., of Buffalo, N. Y.) for supplying the air blast to the transformers.

ENGINEERS AND CONTRACTORS.

The railway is owned by the Aurora, Elgin & Chicago Ry. Co., 100 Washington St., Chicago. The officers of the company are as follows: President, L. J. Wolff, and Treasurer, M. J. Mandelbaum, both of Cleveland, O.; Secretary, Warren Bicknell. The Chief Engineer is Mr. Charles Jones; Construction Engineer, E. H. Arnold; Electrical Engineer, E. Gonzenbach. The headquarters of these officers and for the operation of the line are at Wheaton, Ill. The contractors for grading were the Pound Construction Co., of Chicago, for the line from Chicago to Aurora and Batavia; and the Bracey, Howard & Foster Co., of Chicago, for the Elgin line. The latter company also did all the tracklaying and ballasting. The power plant and electrical engineering work was designed by the Cleveland Construction Co., of Akron, O.; Will Christy, President; W. E. Davis, Vice-President and Electrical Engineer; and W. L. Morris, Mechanical Engineer. The General Electric Co., of Schenectady, N. Y., had the contract for all electrical equipment. The other principal contractors have already been mentioned.

SPECIFICATIONS FOR CONCRETE WORK; AURORA, ELGIN & CHICAGO RY.

The use of concrete for railway bridges, culverts, bridge piers and abutments, retaining walls, and other structures has been increasing very rapidly within recent years, and this is especially true of the electric interurban railways which are now becoming so numerous. On the third-rail interurban line of the Aurora, Elgin & Chicago Ry., concrete has been used very extensively, the structures ranging from small box culverts to 10-ft. flat-top I-beam and concrete culverts, and arches of 12, 15, 30 and 35-ft. span. Some of these arches are of concrete alone, while others have old 60-lb. rails (36 ins. apart) embedded in the arch, being curved to about the radius of the center line of the arch ring. Some further particulars of the concrete structures are given in our article upon this railway in the preceding pages. It may be noted that all these structures were built of Portland cement from Stroh, Ind., supplied by the Wabash Portland Cement Co., of Detroit, Mich.

As so much of this class of work is now under construction, and as the specifications were carefully drawn up, we give these specifications below, in the belief that they will be of interest to many of our readers. These specifications were drawn up by Mr. Charles Jones, Chief Engineer of the Aurora, Elgin & Chicago Ry., and Mr. E. H. Arnold, Constructing Engineer, both of Wheaton, Ill.

Some of the provisions of the specifications are worthy of special attention, and perhaps the most notable of these is in regard to the measurement of cement. There is considerable difference of opinion not only as to how the cement should be measured, but also as to the actual meaning of the terms of some specifications in this respect. At the annual convention of the American Railway Engineering and Maintenance of Way Association in March, the late Prof. J. B. Johnson started an animated discussion on this point, showing that in very many cases it is not stated whether cement is to be measured loose or in the original package, while a difference of nearly 50% may be made in measuring the same quantity by the two methods. Some of the speakers favored specifying the cement to be measured "loose," and others favored specifying "in the original package," while others specified a certain weight per cubic foot of cement. In the specifications quoted below it will be seen that the proportions are expressed as units of volume, a quarter-barrel sack of Portland cement as packed by the manufacturer being taken as a cubic foot.

In building walls with sloping tops, the practice of the Illinois Central Ry. was first followed. Under the specifications of that road (Eng. News, July 18, 1901), the work is built in horizontal sections, and the slope finished in short sections of 3 to 4 ft. in length and bonded into the horizontal sections before the concrete of the latter has become set. At each junction of adjacent sections of the slope there is a groove across the top of the wall. This plan, however, was not found to work satisfactorily on the Aurora, Elgin & Chicago Ry., and the method described below was adopted. This consisted of marking off the slope on the inside of the form and building the wall in steps, which did not come within 6 ins. of the slope. This being completed, the space between the steps and slope line was filled in with concrete and finished off with a mortar surface, thus giving an even and unbroken surface for the top of the wall.

As to the consistency of the concrete, it is required that the concrete should be wet enough for water to flush to the surface after thorough ramming, and a slight excess of water is considered preferable to a deficiency. The method adopted for facing the work is to have an iron plate fitted with angle irons which keep it 1½ ins. away from the surface of the mold. This space is filled with fine mortar, while the ordinary concrete is filled in behind, the plate being then drawn up and the whole mass tamped so that the facing will be thoroughly incorporated with the backing.

With this introduction we give the specifications below, practically in full, with certain modifications from the original form which have been introduced as the result of experience with the work done under these specifications:

SPECIFICATIONS FOR CONCRETE WORK.

1. Concrete masonry will be constructed in three grades:

2. Class A. Will be composed of 1 part Portland cement, 2 parts sand and 4 parts stone. This grade will be used in arch sheeting, bridge seats, parapet walls, and such other parts of structures as may be required by the engineer.

3. Class B. Will be composed of 1 part Portland cement, 3 parts sand and 6 parts stone. This grade will be used in abutments, bench walls for arches, retaining walls, or such other work as directed.

4. Class C. Will be composed of 1 part Portland cement, 4 parts sand and 8 parts stone. This grade may be used in foundations and other work as directed by the engineer. This class of concrete will permit the use of irregular shaped rubble stone of about 1 cu. ft. in size and less, laid in each course, and so arranged as to leave a space of not less than 8 ins. between adjacent stones, and no stone to be within 8 ins. of the face of the wall.

5. The proportions above expressed are units of volume, a quarter barrel sack of Portland cement as packed by the manufacturer being accepted as a cubic foot. The sand must be measured loosely.

6. The proper quantities of sand and stone for each batch must be measured in a manner satisfactory to the engineer, so that there can be no doubt that the required proportion of each kind is delivered. The use of barrels or boxes without heads and bottoms, into which the sand and stone may be cast, the containing vessel then being removed, will be deemed satisfactory, or preferably the use of square and uniform sized wheelbarrows built specially for this service. The use of the ordinary shallow wheelbarrow will not be permitted.

CEMENT.

7. The cement will be an American Portland and must be of a manufacture approved by the chief engineer, and the contractor will not be allowed to make concrete with any other brand. Contractors will be required to provide a suitable storehouse at the several structures in which the cement may be stored so as to be protected from the weather and from dampness from the ground. A sufficient quantity shall be kept in the vicinity of the work so as to allow ample time for tests without delay to construction. In addition to the usual tests the inspector will be required, from time to time, to make small pats of pure cement, and of cement mixed with sand, in order to satisfy himself that the cement going into the work is uniform in character and has not been injured by exposure. He shall reject all cement that is lumpy, or fails to set in proper time, and the contractor shall remove the same from the work.

SAND.

8. All sand must be clean, coarse and sharp; sand from bank or pit preferred. It must be free from loam or clay. If necessary to meet these requirements, it shall be screened and washed as directed by the engineer.

STONE.

9. The crushed stone used in the concrete must be made from hard, clean limestone, free from earthy or clayey matter, or rotten stone. It must be the entire product of the crusher passing through the screens up to and including stone of 1½ ins. size. The screenings, or all that passes through the ½-in. screen, must not exceed one-sixth of the whole, and be reasonably free from dust.

10. The water used must be fresh and clean.

MIXING.

11. A suitable platform must be prepared of convenient size and so constructed as to keep the ingredients entirely free from mixture with all foreign matter. Not more than 1 cu. yd. of concrete shall be made at once. In preparing a batch by hand, the measured quantity of sand must first be spread upon the platform, 2 or 3 ins. thick. Upon the sand the proper quantity of cement will be evenly spread. The sand and cement shall then be thoroughly mixed dry by turning and re-turning with a shovel at least three times, or oftener if required by the inspector. The proper amount of broken stone, having previously been wet, shall then be spread uniformly upon the mixed sand and cement; the whole shall then be turned over by shovels at least twice before loading into wheelbarrows for depositing in the molds. During the turning of the stone with the dry sand and cement, the mixture must be wet by a spray or sprinkler; water must not be dashed or thrown upon the mass in quantities to wash.

12. The contractor must see that the resultant mixture is uniform in character, and that all the stone is covered on all surfaces with the mortar. The contractor must see that the proper amount of water is used; that the concrete is neither too wet, nor too dry; a slight excess of water, however, being preferred to a deficiency. It should be wet to that degree that after thorough ramming the mortar will flush to the surface. Concrete mixed by machinery must correspond in all respects to that above described; special care being taken that the ingredients are so delivered to the machine that the resultant mixture is uniform in character, each shovel full having the prescribed proportion of the different materials, and of the desired consistency.

PLACING THE CONCRETE.

13. Immediately after the mixing, the materials must be deposited in the molds in layers not exceeding 4 ins. in thickness; these layers must be carried up level and no wavy or irregular lines will be permitted to show on the face of the work. Concrete which has begun to set before being placed and rammed will not be allowed to remain in the work.

14. After being placed, each layer must at once be thoroughly rammed and consolidated so that no void spaces are left. The contractor must insist upon the thorough ramming and compacting of all concrete, as the value of the work largely depends upon the completeness with which this highly important part of the work is done. He must see that a sufficient number of men are provided with suitable rammers so that each batch is spread and well compacted before another batch is delivered within the molds, and when this labor is specially severe, the contractor should require the changing of men so employed in order that this part of the work may be thoroughly performed.

15. Layers should not be tapered off, but be built with square ends and when from any cause it becomes impracticable to complete a layer, a plank of convenient width should be secured to the mold against which the concrete shall be rammed, thus making a vertical joint. Should it be necessary to start a second layer at once, it should stop short of the first plank at least 12 ins., when a second plank must be secured in the same manner as the first, and the concrete rammed against it, the layers being carried up full thickness to the board, and left rough. No loose stones or porous places should be left on the surface of any layer, but such places must be filled with mortar, and the ramming repeated until wet mortar flushes to the surface. The top surfaces and also the sides of all stepped footing courses in foundations must show smooth

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mortar faces, and if necessary to secure this, sufficient mortar of 1 part cement to 3 parts sand shall be made and applied.

ARCH CULVERTS.

16. In the construction of long arch culverts the work may be divided into sections of 20 to 25 ft. in length by temporary partitions extending from the top of the footing course through the bench wall and arch sheeting; against this temporary partition the concrete must be rammed. After the completion of a section and the setting of the concrete, the temporary partition will be removed, and the next section started against the concrete, but no mortar must be used to flush the joint, or bind it to the section first built, in order that any contraction may open the joint, or settlement of the foundation may cause sliding without breaking the concrete.

17. In similar manner in large arches, sections shall be set off by partitions parallel with the axis of the arch (the size of these sections to be determined by the engineer), the temporary partitions to be on truly radial lines. Against these partitions the concrete shall be well rammed. After the concrete is well set the partition shall be removed, and another section started, no mortar being used at the joints. The object is to construct the arch of clearly defined sections, capable, should occasion require it, of some slight sliding adjustment without fracturing the mass.

18. The backs of all arches must be covered with a layer of motar not less than ½-in. in thickness, composed of 1 part cement to 2 parts sand.

FORMS.

19. In constructing all forms of concrete masonry, the casings or molds shall be substantially built of planks sufficiently heavy (in general 2 ins. thick) to hold the concrete. These planks must be surfaced on two edges, and one side so as to be of uniform thickness. They must be neatly fitted together so that the mortar face shall be as smooth as possible, without showing the ends or edges of the planks. In order that the faces of the masonry may be true, the sides of the forms must be firmly braced and secured by rods or wire extending through the concrete. On the removal of the forms, all such wire and tie rods must be cut off at least 1 in. beneath the surface, and the holes neatly filled with mortar. A competent carpenter must be employed in the erection of the forms, and all work must be done in a workmanlike manner. The molds for bridge seats and projecting copings, when such are ordered, shall be constructed in a first-class manner so as to make smoothly finished work. When edges of wing walls, bridge seats, or tops of parapets, or other parts of the work are required to be beveled or rounded, molds of proper shape shall be used, and all forms so constructed that the resultant work shall be finished true and in a workmanlike manner.

20. Where sloping walls are used, as in the wings of abutments, the casings must be built to full height; then upon the inside a line will be drawn at the top surface of slope. The wall will next be built up in steps of convenient size from 18 ins. to 36 ins. on the horizontal, with risers of 12 to 24 ins., care being taken that no part of the step is nearer than 6 ins. to the slope line. Immediately after the wall has been built up in steps, concrete will be filled in to near the top line so that the finishing surface of mortar will bring the sloping face to the height indicated by the line. The mortar will then be floated to a true surface and worked off with a sidewalk finish. This sloping surface above the steps must be built continuously in one operation.

FACING.

21. For all concrete work in abutments, arches, piers, retaining walls, or in other construction required by the engineer, a facing mortar of 1 part cement and 2 parts sand shall be used on all surfaces exposed to the weather, or which may be exposed, also the intradoes of all arches and the upper 12 ins. of wing walls and parapets. This mortar facing shall be 1½ ins. thick, and secured in the following manner: pieces of sheet iron of convenient width and length, with suitable handles attached, and having angles with a projection of 1½ ins. riveted at intervals of 24 to 30 ins., shall be furnished by the contractor. The angles being placed against the molds, the space between the plate and the mold shall be filled with the mortar described above, which must be mixed in small batches as it may be needed; it must be of such a consistency as to readily fill the space, without being so thin as to allow the stone in the concrete to be forced through it. When the space is filled with the mortar and tamped with a suitable tool to insure complete filling of the entire 1½-in. space, and the ordinary concrete is filled against the plate, this last must be withdrawn, and the whole tamped as described, so that the face and the back are built up together. The contractor must see that this mortar face does not follow nor precede the concrete mixture, but must be built up with it. Bridge seats and the top surface of parapet walls must be finished as described in Paragraph 20; that is, floated to a true surface and worked off with a sidewalk finish.

22. For the backs of abutments and retaining walls, it will be sufficient in forming their back surfaces that the concrete be forcibly cast against the forms, thus working the finer portions of the mixture against the casing, and then thoroughly tamping it. The top 12 ins. of wing walls, abutments and parapets, however, to be finished as described in paragraph 21.

23. No concrete surface with pores or open spaces shall be covered with earth; such open work must first be pointed.

GENERAL.

24. When it becomes necessary or expedient in the judgment of the engineer to use I-beams, or steel rails, or iron in any form in the concrete, an allowance equal to the actual cost of handling such iron shall be made to the contractor and the volume of iron shall be estimated as concrete.

25. After the work is well set the forms shall be removed by the contractor. Concrete shall have at least 48 hours to set after the completion of the work, or longer in cold weather.

26. No concrete shall be laid in freezing weather except upon the order of the engineer, with special instructions as to the conduct of the work, and its protection from the frost. In hot, dry weather the contractor must see that the crushed stone is frequently wet, and that the concrete is wet from time to time in order to prevent drying before hardening. In dry weather all exposed surfaces of new work must be kept moist at least three days.

27. The contractor will be required to furnish all plank, timber, braces and tie rods, or other material required in construction of forms for concrete masonry, for which no allowance will be made, nor for any scaffolding, nor centering on arches (except when necessary to use trusses) nor other timber used in masonry construction, except such as is necessarily left in the work, the cost of all such material being included in the contract price per cubic yard of completed work.

28. All walls when finished must present a smooth uniform surface of cement mortar, and all disfigurements must be effaced, and if there are any open, porous places, they must be neatly filled with mortar of one cement and two sand, well rubbed in, which finishing must be done immediately upon the removal of the forms. Compensation for all labor and material required in such finishing, including the mortar facing when required, with the finishing of bridge seats and other parts, is included in the price per cubic yard for concrete work.

COLLAPSE OF A 200-FT. HIGHWAY BRIDGE OVER THE COLORADO RIVER AT GONZALES, TEX.

We illustrate in the accompanying cuts the wreck of a highway bridge crossing the Colorado River at Gonzales, Tex., which collapsed on Aug. 1, 1902, owing to the failure of one of the double-cylinder piers on which it was carried. The bridge was a through pin-connected truss span of 200 ft.; the width between trusses being 20 ft., and the trusses being divided into ten 20-ft. panels. The total weight of the span was about 100 tons, and it rested upon two steel tubular piers each made up of a pair of steel tubes 54 ins. in diameter. The tubes of the pier at the town end, which were the ones that failed, were about 50 ft. long, and they were sunk to a cemented gravel stratum some feet below the bed of the river. The tubes failed by tipping over toward the stream, they being ridden over the bank and crushed down by the span, the pier seats of which sunk into the ground some 10 ft. The opposite end of the span remained in place on the far pier.

Fig. 1 is a view of the wrecked bridge, showing the wrecked pier at the far end, and Fig. 2 is a near view of the end which fell. The four pyramidal structures shown underneath the bridge in Fig. 1 are old I-beam and concrete piers which supported the 140-ft. King arch, built some 30 years ago and which were left standing when the old arch was replaced by the new steel span built last June. These old piers, as is clearly shown by Fig. 2, did considerable damage to the falling bridge by crushing up through the metal work; three panels of the steelwork were pretty badly mutilated by them. They, however, served a good purpose by catching and supporting the span and thus preventing it from turning over or sinking further into the mud. On the whole this bridge seems to have been of fairly good design, except that the hip verticals are not what good modern practice demands, and that no bracing seems to have been used between the pier cylinders. The information available does not show, however, whether or not the latter defect contributed in any way to the failure.

Immediately after the wreck the local authorities awarded a contract for repairing the bridge to E. P. Alsbury & Son, of Houston, Tex. The contract price for the work was $5,700 and included the repairing and replacing of ruptured members, the construction of a new pier and the addition of a 54-ft. span between the new pier and the river bank. The fallen tubes weighed about 60 tons and had to be taken out from under about 30 ft. of soil and caving banks. The falseworks used was of framed bents and two 40-ft. gallows frames were used in taking out the span. The wrecked span stood on an 18% grade and the falseworks and gallows frames were built to suit this grade. Within twelve days after work was commenced the entire wreck, including the pier and falsework, were entirely removed and on the shore ready for repairs and replacing. It was expected on Sept. 2 that the bridge would be re-erected and ready for traffic in about three weeks.

During the work of reconstruction the temporary structure, shown by Fig. 3, was employed to accommodate the traffic. This structure is described as follows, in a letter to us from the contractors:

The good citizens of Gonzales attempted to give the people a quick and temporary crossing by making two 40 x 15-ft. barges and connecting them with aprons. The point selected for this temporary structure is the swiftest point on the river, the current running fully 20 miles an hour, and for a width of 50 ft. this rapid current is 10 to 12 ft. deep. When the boats were put into the river they turned over and sank. No nose or rake being built on the upstream side, the force of the water pressed the upper side under and coming over filled and sank the boats. The boats were not properly constructed, only a 10-in. gunwale being used, and they were roughly jointed and not calked. We suggested a temporary log trestle, but they desired to use these flats which they had built, and the only way we could see to use them, was to pick them up and hold them in place; first putting a rake on the upstream side. The boats are carried and held upstream by four stationary gallows frames built of 6 x 8-in. timbers and resting on the bottom of the river. There is a 15-ft. space between the barges and in case of a small rise this apron can be removed and drift guided through. The barges are allowed to settle two-thirds of their depth in the water so as to cause the displacement to carry part of the load, the rigging carrying about one-third of the traffic. The work was put in place and traffic opened within 14 hours after our foreman and a few of the boys started, and has given a crossing on some days to 1,000 bales of cotton coming in from the country. About 6,000 ft. of line is in use and should the river rise the barges can be pulled up accordingly. The people are well pleased with the result and the town is saved a loss of $1,000 country trade a day, which would have drifted to the adjoining towns.

We are also indebted to the contractors for the information and the photographs from which this description has been prepared.

FIG. 1. GENERAL VIEW OF WRECKED BRIDGE OVER COLORADO RIVER AT GONZALES, TEX.

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