# ENGINEERING NEWS.

# **Reinforced-Concrete Viaduct Between Dallas** and Oak Cliff, Texas.

One of the longest reinforced-concrete arch viaducts ever built is now under construction across a shallow valley between Dallas, Tex., and a suburb known as Oak Cliff. We have received from Mr. V. H. Cochrane, M. Am. Soc. C. E., a member of the firm of Hedrick & Cochrane, Kansas City, Mo., which is in charge of the construction of the bridge, an extensive account of the work. From this account we have prepared the following article.

# General Description.

The Trinity River, ordinarily a small stream not more than 200 ft. wide, runs in a shallow valley between the city of Dallas and its suburb

submitted on or before Jan. 1, 1910. This advertisement contained the following chief requirements:

(1) The structure must be of reinforced concrete, of either arch or trestle construction, and must provide a roadway for vehicular traffic, and two sidewalks. Pro-vision must be made for a double track electric railway to be added at some future time.

(2) The clear width between hand rails must be not less than 50 ft., and should be more if a wider structure can be built at a cost not to exceed the amount available. (3) Conduit spaces easy of access must be provided, having a cross-sectional area of not less than 20 sq. ft. (4) The live loads to be provided for are as follows:

On each electric railway track, two 100,000-lb. cars. On the roadway, 100 lbs. per sq. ft., or a 15-ton road roller having a maximum axle concentration of 10 tons.

On the sidewalks, 80 lbs. per sq. ft.

(5) The design should be more than a mere picture or side elevation; sufficient details should be given to enable the relative merits of the design to be determined. Each designer shall furnish a complete analysis of the

that adopted for construction. These two exceptions were the final adoption of piled cootings instead of spread reinforced-concrete footlags and the widening of the roadway of the bridge from 40 ft., with two 5-ft. sidewalks, to 44 ft., with two 4%. ft. sidewalks. The first of these changes as required by the order of the Advisory Board, which was not sufficiently satisfied with the compact jointed clay soil which was discovered boy. ings to guarantee the 2-ton per sq. ft. rein orced. concrete footings originally designed. The second change was made because it was found that the contract price was enough less than the estimated cost to enable the widening.

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Fig. 1 is an elevation of the structure. Beginning at the Dallas end, it comprises 420 ft. of reinforced-concrete trestle construction; \_\_\_\_\_\_rein-

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of Oak Cliff. At flood stages, however, the river rises sometimes as much as 50 ft. and 'spreads the main city. Some time ago it was decided Soc. C. E., Professor of Civil Engineering, Uni-

that to avoid such interruptions in traffic it would be necessary to build a bridge or viaduct across the river and its valley, and accordingly the County of Dallas about two years ago voted a bond issue of \$600,000 with which to build the structure. These bonds were sold and, after a sufficient amount was reserved to cover the cost of the right-of-way and the Oak Cliff approach, a fund of \$563,000 remained available for the

principal span or spans, and a complete list of working stresses; also sample specifications, an itemized estimate of cost, and a summary of his professional experience. across the whole width of its mile and a half The County Court appointed an Advisory valley, completely shutting off the suburb from Board, consisting of Prof. T. U. Taylor, M. Am.



# FIG. 1. GENERAL ELEVATION AND PART PLAN OF

forced-concrete arches, each 71-ft. 6-in. span; a 98-ft. concrete covered steel plate girder over the river (with 90 ft. clear opening); 21 reinforced-concrete arches of 71-ft. 6-in. span, and 181 ft. of reinforced-concrete trestle-a total length of 5,106 ft. At each end there is a decided angle in the line of the roadway, in the trestle approach portion. It will be noticed that at ordinary river height all but the middle span will be over dry land. At high water, however, the water level will reach to the trestles. The large girder in the middle was required because the U. S. War Department demanded a 90-ft. horizontal clearance and a 60-ft. vertical clearance throughout the entire width of 90 ft. at the river. In order to keep the grade of the viaduct as low as possible, it was therefore necessary to have a girder, and the engineers thought it better that this girder be of steel encased in concrete than of the heavier reinforced-concrete type.

construction of the bridge. The county is undertaking the work alone without the aid of either the city of Dallas or the city of Oak Cliff. Although at one time the railroads whose tracks were being crossed were expected to contribute something towards the cost of construction, up to this time no such contributions have been received.

In November, 1909, the County Engineer, Mr. J. F. Witt, advertised for competitive plans to be

### PLAN OF DALLAS END OF VIADUCT. FIG. 2.

versity of Texas; Mr. Otto H. Lang, M. Am. Soc. C. E., and Mr. N. Werenskiold, to examine the various designs submitted and to report upon them to the court. Out of the 15 designs submitted, the Board recommended the adoption of the arch design submitted by Mr. Ira G. Hedrick, M. Am. Soc. C. E., Kansas City, Mo., with Mr. M. R. Ash, M. Am. Soc. C. E., as associate engineer. With two exceptions Mr. Hedrick's preliminary design was substantially the same as

# Foundation.

The specifications and drawings call for concrete piles for all piers except the two river piers, where long timber piles are used. For the concrete piles the following tests were prescribed:

The safe load assumed for each concrete pile is 30 tons and the contractor will be required to test four piles. Each of the test piles shall first be loaded with 30 tons for 48 hours and must show no settlement. Each pile shall then be loaded with 60 tons and shall show not more than 1/4-in. settlement after the load has been applied for 48 hours. Should the test piles fail to sustain the load specified, the contractor must increase the size and length of piling or increase their number, without extra charge, so that in the opinion of the engineer



# March 30, 1911.

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# Unbalanced live load condition.

# Extreme soil pressure, tons, per sq. ft.... 20 Extreme soil pressure, tons, per sq. ft.... 1.6 Several tests of the soil were made and fairly uniform results were arrived at. This soil is a hard, compact black or yellow clay underlaid by sand or sand and gravel in places. As the clay is very dry, owing to the long drought which has prevailed at Dallas, the bearing capacity of the soil was tested by pouring water into the pits the tests, it appeared that under a constant load, settlement continues for a few hours and then practically ceases. When the load was increased to ten tons about, water was added to the pit and was kept standing 3 ft. deep. On the whole, the settlement was proportional to the load, vary-

of driving and forming the piles. It was de- plates, the lower being imbedded in the cross cided that it would be safe to assume that the girder and the upper sliding on it, as also shown piles would carry an average load of 20 tons in Fig. 7. each so the subcontractor agreed to increase the size of the bases of the piers at his own expense so as to make good the deficiency in the carrying capacity.

# Piers.

special design to carry the horizontal thrust of the second column from each pier, and the sec-

remedy these defects by changing the methods lower copper plate is replaced by two cast-iron

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# Arches.

Each arch is 71 ft. 6 ins. clear span and 79 ft. 6 ins. c. to c. of piers with a rise of 17 ft. It consists of a solid arch span, reinforced, as shown in Fig. 6, in upper and lower planes and There are several types of piers in the bridge. carrying a flat slab floor by means of vertical and allowing it to stand. According to most of The standard arch pier is shown in Fig. 3. cross walls pierced by openings so as to make Every fifth pier in the arch span (Fig. 4) is really three columns carrying the transverse made sufficiently large to resist the deadload girder. The roadway is so arranged as to allow thrust of one adjacent span in case the arch on for a future railroad track, but at present only the other side of the pier should fail. The two a macadam roadway has been placed. Expanpiers on either side of the river span are of sion joints are provided in the floor slab over



# THE DALLAS-OAK CLIFF CONCRETE VIADUCT.

timber.

The concrete piles were made in place by by driving a core into the ground and then withdrawing it. The average penetration was about 14 ft. The following table gives the results of two groups of typical tests on concrete piles in place. One is a hammer test and the other a load bars are placed just above them. test.



31/2-in timber bearing on the soil, but the same the arch span was carried down to bed rock. are supported from a cantilevered bracket. results practically were given with a  $12 \times 12$ -in. The other abutment pier was founded on piles, one-half of which are driven on a slope of  $4\frac{1}{2}$ ins. to 1 ft. to care for the horizontal thrust. pouring a 1:2:4 concrete into holes prepared Both the ordinary piers and the so-called abutment piers are pierced longitudinally by two openings 9 ft. wide spanned at the top by arches. The distance from the springing line to the top of these openings is 4 ft.; the reinforcing

## Trestle.

ing in one typical case from 1/16-in. under six the arch spans in bending (Fig. 5). The tension tions are separated from each other by a strip tons to 14-in. under 10 tons per sq. ft. A maximum side of each pier is reinforced with corrugated of asbestos board. It will be noted that the load of 20 tons produced a permanent settlement bars. These piers will be founded on 168 timber roadway slab, the curb and the sidewalk slabs of about 3/2-in. This test was made with a 31/2 × piles. The abutment pier at the Dallas end of are in one integral piece, but that the sidewalks

# **Concrete-Encased** Girder.

The span over the river consists of four steel girders 98 ft. between supports, connected by steel cross girders, the whole to be encased, as shown in Fig. 8, in concrete. The steel girders carry in direct compression the horizontal thrust of the adjacent arch spans. This thrust is carried into the bottom flanges of the girders by means of the special cast-iron shoe shown in Fig. 8. The upright portion of the shoe bears against the concrete of the pile on one side and against the cast-steel wedge on the other, the wedge being driven between the cast-steel shoe and the end of the bottom flange angles. In all other details the girders are of the usual type of

# VIADUCT.

cracks were caused by the vibration of the ground while the adjacent piles were being driven, and were made while the concrete was green. In a few cases the cracks had opened 2-in. showing that the soil had risen and had lifted the upper portion of the pile. In some cases the cross-sectional area of the pile had been reduced owing to the pressure of the surrounding soil caused by driving adjacent piles. It was found to be impossible to tamp the concrete into the soil so as to increase the diameter of the piles. The subcontractor who was driving the piles was not willing to undertake to

# Longitudinal Section.

each longitudinal girder rests on a socket formed by two bent copper plates extending the full width of the girder, the lower plate resting on the cross girder and the upper being fastened to the longitudinal girder. The longitudinal girders on either side are connected by means of reinforcing bars just above the socket, but a cleavage plane is left between them extending through the floor slab so that the girder which rests in the socket is more or less free to rotate. The the grades of concrete are as follows: girders are thus discontinuous and are designed as simple beams. At suitable intervals expansion joints are introduced. At these joints the

# Half Transverse Section.

with Dallas gravel and Jacksboro stone, the only crushed stone available in the vicinity, it was decided that the gravel concrete was quite as strong as broken-stone concrete for 1:2:4 mixtures, though for leaner mixtures the broken stone showed up better. Consequently, a sand and gravel concrete of 1:2:4 mixture was prescribed, with the proportions to be modified if the engineer so decided. The specifications for

For the arch rings, girders, cantilevers and spandrel walls (above a plane through bottom of cantilevers), and for girders, bents, floor slabs and arch piers (above a plane 3 ft. 6 ins. below the springing line of arches), and

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for encasing the metal work for the steel span over the Trinity River, the concrete shall be composed of one part Portland cement, two parts sand, and four parts stone or gravel to pass in any direction through a 11/2-in. ring. Concrete in all cross spandrel walls (below the plane of bottom of cantilevers), in the arch piers (below a

a 11/2-in. ring.

The reinforcing bars are of round corrugated shape and of medium open-hearth steel, having ment without being stressed in tension above its an ultimate strength of 60,000 to 68,000 lbs. per elastic limit. sq. in.; elastic limit not less than the ultimate The total cost of the structure, including enstrength; elongation of 22%; and the capacity

necessary, be carried through the adjacent arch rib to the next pier, thus leaving an unbalanced live load thrust of 5,000 lbs. per lin. ft. of width of arch rib to be taken care of by the pier, or

arches, excluding temperature cluding stresses due to 80° F. vari-

steel reinforcement takes the entire bending mo-

# Lighting The Double-Hump Yard of the Missouri Pacific Ry. at Dupo, 111.\*

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At Dupo, Ill., about 13 miles southea of St. 195,000 lbs. altogether. Louis Union Station on the St. Louis, Iro. Mounplane 3 ft. 6 ins. below springing line of arches), and in the two end abutments and retaining walls shall be comtain & Southern R. R. of the Missour Pacific WORKING STRESSES. posed of one part Portland cement, three parts sand, and Maximum compression on concrete in Ry. system, is located one of the largest louble. five parts stone or gravel to pass in any direction through hump freight yards in the West, desined to Concrete for curbs, wheel guards, sidewalks and para-Maximum compression concrete in girhandle both north and south-bound traffic, each pets or copings shall be composed of one part Portland ders ..... 600 " " " " " cement to three parts of a mixture of clean sand and hump having a capacity of 120 cars pr hour. Maximum compression on concrete, ingravel to pass a 1/2-in. screen. The yard is about three miles long and about The bases of all piers, columns and abutments shall be composed of concrete mixed in the proportions of one Maximum shear on concrete, plain.... 30 " " " 800 ft. wide at the classifying yards, with conpart Portland cement, three parts sand and five parts Maximum shear on concrete, reinforced nections to the railroad company's Ill nois digravel to pass in any direction through a 21/2-in. ring, or if broken stone be used the proportions shall be one No tension in concrete will be allowed. vision, East St. Louis, Ivory Ferry, the Terminal part Portland cement, three parts sand and six parts of Railroad Association, and other system The broken stone to pass a 2½-in. ring. When temperature stresses are included, the yard is divided into receiving, classification, forwarding, storage, caboose and repair yards. The two humps, the roundhouse, repair yards, coal and water stations, and the power house, togineering and all incidentals, will be about gether with a hotel and other facilities are lo-

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FIG. 6. DETAILS OF ARCH SPAN.

the bend.

# Loads and Stresses.

The live loads for the final design were the same as required in the case of the competitive plans. The electric railway loads were increased to allow for impact, 50% for floor slabs and about 13% for arch ribs. No impact allowance was made for the road roller concentrations or the uniformly distributed loads on roadways and sidewalks. The piers were designed for two conditions of loading; first, four 100,000-lb. cars, 80 lbs. per sq. ft. on a width of 22 ft. of roadway outside of the car tracks, and 60 lbs. per sq. ft. on sidewalks, all symmetrically disposed on the two adjacent spans so as to produce balanced horizontal thrusts; second, four 100,000-lb. cars, 40 lbs. per sq. ft. on a width of 22 ft. of roadway, and 30 lbs. per sq. ft. on sidewalks, all on one of the two adjacent spans and producing an unbalanced horizontal thrust of 7,000 lbs. per lin. ft. of width of arch ring. For the latter condition, which is considered quite unlikely to occur, it was computed that 2,000 lbs. could, if

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to bend cold 180° to a diameter equal to the \$570,000, or about \$2.10 per sq. ft. of floor. The piece tested without fracture on the outside of contract is held by Corrigan, Lee & Halpin, Kansas City, Mo., who are doing the work, and the concrete piles are being put in place by the Gulf Concrete Construction Co., Houston, Tex. Field work is being carried out under the supervision of Hedrick & Cochrane, Consulting Engineers, Kansas City, Mo., and J. F. Witt, County Engineer. E. N. Noyes is Resident Engineer, representing the Consulting Engineers. Work was begun October, 1910, and should be completed by Dec. 1, 1911.

cated at practically the longitudinal center of the yard, making it very nearly symmetrical.

Under the direction of the Construction Department of the Missouri Pacific Railway Co., Westinghouse, Church, Kerr & Co. in 1906, acting as Engineers and Constructors for the Railway Co., designed, constructed and equipped their Dupo power house. The following year the Engineers were instructed to investigate and recommend a system of artificial illumination for the yard. All of the commercial systems of out-door arc lighting were investigated, but as the power house contained alternating-current equipment, the direct-current systems could not be given serious consideration. Owing to business conditions, all work in the yard was suspended from 1907 to 1909, in the Fall of which year the subject was again taken up, and as many improvements had been made in the different lighting systems, another investigation and report was made which included flaming arcs, in addition to the systems previously considered

THE LARGEST CANTILEVER CRANE in the world, according to London "Engineering," was recently installed in the Imperial Japanese Navy Dockyard, Yokosuka, by Messrs. Cowans, Sheldon & Co., Ltd., Carlisle, Eng. It is designed for a working load of 200 tons, carried at the end of a 95-ft. radius, and has been tested with 250 tons at that radius. The same firm has under construction for the Japanese navy yard at Kure, a similar crane, designed for a safe load of 200 tons at 105-ft. radius. The capacities of some large cantilever cranes now in existence are as follows: Kure, 26,250 ft. tons; Yokosuka, 23,750 ft. tons; Devonport, Eng., 22,800 ft. tons; Clyde, Eng., 18,750 ft. tons.

Several installations of flaming arcs were visit-

\*Description prepared by Mr. W. S. Austin, for West-inghouse, Church, Kerr & Co., 10 Bridge St., New York

#### THE DALLAS-OAK CLIFF VIADUCT.

By Victor H. Cochrane, M. Am. Soc. C. E., of Messrs Hedrick & Cochrane, Consulting Engineers, Kansas City,

The Dallas-Oak Cliff viaduct, now building in Dallas, Tex., will be a structure of unusual magnitude. It will be 4778 ft. long between the end abutments, and from end to end of approaches, more than a mile long. It will have a roadway 44 ft. wide between curbs, and two sidewalks each  $4\frac{1}{2}$  ft. wide in the clear. It will be of reinforced concrete construction throughout.

The city of Dallas, including the residence district known as Oak Cliff, has a population of 93,000. Oak Cliff has a population of about 20,000 and is separated from the main portion of the city by the Trinity River valley. Oak Cliff is built up mainly of residences. The Trinity River is a small stream a wider structure can be built at a cost not to exceed the amount available.

3. Conduit spaces easy of access must be provided, having a cross-sectional area of not less than 20 sq. ft.

4. The live loads to be provided for are as follows: On each electric railway track, two 100,-000-lb. cars; on the roadway, 100 lb. per square foot, or a 15-ton road roller having a maximum axle concentration of 10 tons; on the sidewalks, 80 lb. per square foot.

5. The design should be more than a mere picture or side elevation; sufficient details should be given to enable the relative merits of the design to be determined. Each designer shall furish a complete analysis of the principal span or spans, and a complete list of working stresses; also sample specifications, an itemized estimate of cost and a summary of his professional experience.

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Grade Point. Elev. 436.55

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side of Houston street on an ascending grade of 2.8 per cent to a point near the tracks of the Missouri, Kansas & Texas Railway, the Dallas Terminal Railway, the Gulf, Colorado & Santa Fe Railway, and the Chicago, Rock Island & Pacific Railway, a distance of 567.7 ft. From this point the viaduct swings to the right through an angle of 47 deg. 44 min., crosses the railway tracks overhead and runs on a level grade in a southwesterly direction to the south bank of the Trinity River, a distance of 2529 ft. Thence it proceeds in the same direction on a descending grade of 0.74 per cent to the west side of Lancaster avenue, a distance of 2009.4 ft.

The approaches will consist of U-abutments having wing walls of the ordinary buttress type, retaining earth fill. Next to the north abutment there will be 439 ft. of trestle construction consisting of longitudinal girders resting on bents. Next to the south abutment there will be 181 ft. of similar construction. The main portion of the viaduct will consist of 51 arches having a span 711/2 ft. between springing lines or 791/2 ft. center to center of piers, and a rise of 17 ft.

The Trinity River is being improved by the Government so as to make it navigable, and it was required that the river span should provide a transverse clearance of 90 ft. between piers, and a vertical clearance above low water of 60 ft.



ordinarily confined between steep banks not more than 200 ft. apart, but at flood stages it rises as much as 50 ft. and spreads out all over the valley, which is from 1 to 11/2 miles wide. At such times the traffic between Dallas and Oak Cliff is suspended for days at a time, causing great loss and inconvenience. It was accordingly decided to build a viaduct to do away with such interruption of traffic, and the County of Dallas voted a bond issue of \$600,000 with which to build the structure. Neither the City of Dallas nor the City of Oak Cliff furnished any money. It was expected that the railroads whose tracks are to be crossed overhead at the Dallas end of the viaduct would contribute toward the cost, but up to this time they have not done so. After the bonds were sold a sufficient amount was reserved to cover the cost of the right-of-way and the Oak Cliff approach, thus leaving a fund of \$563,000 available for the construction of the viaduct.

On Nov. 19, 1909, Mr. J. F. Witt, county engineer, advertised for competitive plans to be submitted on or before Jan. 1, 1910, the chief requirements to be observed by designers being given as follows:

1. The structure must be of reinforced concrete, of either arch or trestle construction, and must provide a roadway for vehicular traffic and two sidewalks. Provision must be made for a double track electric railway to be added at some future time.

2. The clear width between hand rails must be not less than 50 ft., and should be more if

Designs were submitted by 15 different engineers and engineering firms. The County Court appointed an advisory board of engineers to pass on the plans, consisting of Prof. T. U. Taylor, M. Am. Soc. C. E., professor of civil engineering in the University of Texas; Mr. Otto H. Lang, M. Am. Soc. C. E., and Mr. N. Werenski-The board recommended the adoption of old. the arch design submitted by Mr. Ira G. Hedrick, M. Am. Soc. C. E., consulting engineer, Kansas City, Mo., and Mr. L. R. Ash, M. Am. Soc. C. E., associate engineer.

Mr. Hedrick's preliminary design was substantially the same as the final design except that in the former all the piers but a few near the river were carried on reinforced concrete footings designed for a soil pressure of 2 tons per square foot. The borings showed the soil to be compact jointed clay, and since the river bottom is not subject to scour it was thought that it would be unnecessary to use piling. The advisory board, however, recommended that all the main piers be founded on piles. The preliminary design provided for two 5-ft. sidewalks and a 40-ft. roadway paved with creosoted wood blocks. In order to compensate for the extra cost due to the use of piling throughout, it was decided to pave the structure temporarily with macadam instead of creosoted blocks. The contract price, however, was enough less than the estimated cost to enable the viaduct to be widened 3 ft., thus making the clear width between balustrades 53 ft.

The structure begins near the south line of Arlington street and proceeds along the east

#### Details of Abutment Pier.

throughout the width of 90 ft. Accordingly, in order to keep the grade of the viaduct as low as possible, the span over the river is to be of steel plate girder construction. All the metal work is to be incased in concrete so that the span will conform in appearance to the remainder of the structure. The horizontal thrust of the adjacent arch spans will be transmitted through this span, and the adjacent arch ribs will have to distort sufficiently to take care of the expansion and contraction of the steel span.

Live Loads .- The live loads for the final design were the same as required in the case of the competitive plans. The electric railway loads were increased to allow for impact, 50 per cent for floor slabs and about 13 per cent for arch ribs. No impact allowance was made for the road roller concentrations or the uniformly distributed loads on roadways and sidewalks. The piers were designed for two conditions of loading: First, four 100,000-lb. cars, 80 lb. per square foot on a width of 22 ft. of roadway outside of the car tracks, and 60 lb. per square foot on sidewalks, all symmetrically disposed on the two adjacent spans so as to produce balanced horizontal thrusts; second, four 100,000-lb. cars, 40 lb. per square foot on a width of 22 ft. of roadway, and 30 lb. per square foot on sidewalks, all on one of the two adjacent spans and producing an unbalanced horizontal thrust of 7000 lb. per lineal foot of width of arch ring. For the latter condition, which is considered quite unlikely to occur, it was computed that 2000 lb. could, if necessary, be carried through

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the adjacent arch rib to the next pier, thus leaving an unbalanced live-load thrust of 5000 lb. per lineal foot of width of arch rib to be taken care of by the pier, or 195,000 lb. altogether.

Working Stresses.—Maximum unit compression on concrete in arches, excluding temperature stresses was taken as 500 lb.; maximum unit compression on concrete in girders, 600 lb.; maximum unit compression on concrete, including stresses due to 80-deg. variation in temperature, 750 lb.; no tension in concrete will be allowed; maximum unit shear on concrete, plain, 30 lb.; maximum unit shear on concrete, reinforced for shear, 100 lb.

When temperature stresses were included the steel reinforcement was figured to take the entire bending moment without being stressed in tension above its elastic limit.

Foundations.—The specifications provided that the concrete piles might be put in place by any method which would meet with the approval of the engineer. The requirements in regard to the supporting power of piles were as follows:

"Each of the test piles shall first be loaded with 30 tons for 48 hours and must show no settlement. Each pile shall then be loaded with 60 tons and shall show not more than ½-in. settlement after the load has been applied for 48 hours. Should the test piles fail to sustain the load specified the contractor must increase the size and length of piling or increase their number, without extra charge, so that in the opinion of the engineer the piling used will carry safely a load equivalent to 30 tons for each pile shown on the plans."

allowed to stand. Several tests were made, giving fairly uniform results. The results of a typical test are shown in the accompanying diagram. It will be noted that the settlement under a load of 6 tons was only about 1/16 in.. while under a load of 10 tons it was about 1/4 in. It appears that under a constant load the settlement continues for a few hours and then practically ceases. When the load was increased to 10 tons water was added to the pit and was kept standing 3 ft. deep. On the whole the settlement was proportional to the load. The maximum load applied was 20 tons per square foot and after this load was removed it appeared that the permanent settlement of the soil was 3% in. This test was made with a  $3\frac{1}{2} \times 3\frac{1}{2}$ -in. timber bearing





Sections Showing Dimensions of Arch Span.

The work of construction had not proceeded far when it appeared from the tests made that the piling would not comply with this provision of the specifications, and accordingly at a conference of the county court, the county engineer. the advisory board, the consulting engineers and contractor, it was decided that the working load per pile be reduced from 30 tons to 20° tons each, and that the bases should be correspondingly increased in size. The contractors agreed to stand the extra expense involved. The piers were then redesigned for the following working loads: Under balanced live-load condition, extreme load per pile, 20 tons, extreme soil pressure, 1.0 ton per square foot; under unbalanced live-load condition, extreme load per pile, 20 tons, extreme soil pressure, 1.6 tons per square foot.

The soil as shown by the borings and excavations is hard, compact, black or yellow, clay, underlaid in places by sand or sand and gravel. At the present time the clay is comparatively dry owing to the long drought which has prevailed in the vicinity of Dallas. Accordingly in testing the bearing capacity of the soil water was poured into the pits in some cases and

on the soil. Other tests made with a 12 x 12-in. timber gave practically the same results.

The piles were made in place by pouring 1:2:4 concrete into holes prepared by driving a core or former into the ground and then withdrawing it. The average penetration was about 14 ft. The aggregate used for some of the test piles was gravel and for others Jacksboro stone. All concrete was mixed wet and tamped as it was poured into the holes. The accompanying table gives the results of two groups of typical tests:

#### SETTLEMENT OF TEST PILES.

Pile No.	Pe trat Ft.	ne- ion. In.	Blows per In. Last 6 In.	Tons.	tlement 20 Tons.	in ins. u 22½ Tons.	nd	er a lo 25 Tons.	ad of ¬ Tons.
52	13	o	40	0	0				0
5.5	11	6	54	0	0				3/8
82	13	6	40	0	0			<b></b>	3/8
85	14	0	28	0	0				0
39	14	10	42		9/16	11/16	I	1/16	1 3/4
4.2	14	0	48	0	9/16	11/16	1	1/8	1 11/16
Ġo	14	0	6o	0	3/8	3/8		5/8	1 7/16

Weight of hammer, 7,000 lbs.; stroke, 36 in. Weight of ram, 3,000 lb. Weight of former, 4,700 lb.. Diameter of pile, at top, 14 in.; at bottom, 34 in.

Some of the piles were exposed after being tested and it was found that several were cracked

in one or more places. It appeared that these cracks were caused by the vibration of the ground while adjacent piles were being driven, and that they were made while the concrete was green. In a few cases the cracks had opened  $\frac{1}{2}$  in, or more, showing that the soil had risen and had lifted the upper portion of the pile. In some instances the cross-sectional area of the pile had been reduced, owing to the pressure of the surrounding soil caused by driving adjacent piles. Evidently the soil was so compact that it would not compress to any great extent. The sides of the piles were very smooth. It was found to be impossible to tamp the concrete into the soil so as to increase the diameter of the piles.

The subcontractors who were driving the piles were not willing to undertake to remedy these defects by changing their methods of driving and forming the piles. It was decided, as indicated



above, that it would be safe to assume that the piles would carry an average load of 20 tons each, so the subcontractors agreed to increase the size of the bases at their own expense so as to make good the deficiency in the carrying capacity of the piles. The amount of load carried by the piles and the soil respectively depends upon their relative rigidity. The diagram shows the variation in the soil pressure under the unbalanced live-load condition as the assumed extreme pile load varies from 0 to 20 tons.

Every fifth pier is large enough to resist the dead load thrust of one adjacent span in case the arch on the other side of the pier should fail. Thus in case of the accidental failure of any portion of the structure not more than five spans would fall.

Both the ordinary piers and the so-called abutment piers are pierced by two openings 9 ft. wide, at the top of which are semi-cylindrical surfaces. The distance from the springing line to the top of these openings is 4 ft., and reinforcing bars are placed just above the openings. The three pier shafts are each 7 ft. wide. The pier bases are reinforced as shown in one of the drawings. The batter of the ordinary pier is  $\frac{1}{2}$  in, to I ft. and that of the abutment pier is 3 in. to I ft.

The abutment pier at the Dallas end of the arch spans was carried down to bed rock, the lower portion being of cellular construction. The abutment pier at the Oak Cliff end of the arch spans is to be founded on piles, and one-half of these will be driven on a slope of  $4\frac{1}{2}$  in. to the foot in order to take care of the horizontal thrust.

The two piers on either side of the river are of especial interest because they must carry the horizontal thrust of the arch spans in bending. The tension side of each pier is reinforced with 104 corrugated bars  $1\frac{1}{6}$  in. in diameter. These piers, unlike all the others, will be founded on timber piles. There will be 168 piles in each.

Approach Trestle Construction.—The roadway will be carried by reinforced slabs integral with the longitudinal girders, which are spaced about



5 ft. apart. Thus the girders act as T-beams. The span lengths vary from about 24 to 50 ft. The ends of the girders rest on cross girders 21/2 ft. in width. The longitudinal girders are rigidly connected to the cross girder at one end by means of a reinforced corner bracket. At the other end each of the longitudinal girders rests in a socket formed by means of two bent copper plates of the full width of the girder, the lower resting on the cross girder and the upper being fastened to the longitudinal girder. The two abutting longitudinal girders are connected by means of reinforcing bars just above the socket but a cleavage plane is left between them, extending through the floor slab, so that the girder which rests in the socket is more or less free to rotate. The girders are thus discontinuous and are designed as simple beams. At suitable intervals expansion joints are introduced.







River Pier and Thrust Shoe.

At these joints the lower copper plate is replaced by two cast-iron plates, the lower being embedded in the cross girder and the upper sliding on it.

In general, the cross girders are carried on three columns, and are designed as beams continuous over three supports. They are heavily reinforced for shear. The columns rest on reinforced spread footings of the ordinary type.

Arch Spans.-A cross-section through an arch span is shown herewith. The floor slab is carried on eight crosswalls 8 ft. 10 in. apart, center to center. These crosswalls rest on the arch ribs, which are of the barrel type and are 39 ft. wide. The crosswalls have two openings, thus making them virtually a bent having the cross girder resting on three wide columns and cantilevered outward on either side to support the sidewalks and a small portion of the road way slab. Over each pier there is a heavier wall having a T-shaped section at either end of the pier, the head of the T being 4 ft. wide and I ft. 6 in. thick.

The floor slab is 10 in. thick under the electric railway tracks and 7 in. thick between the tracks and the curbs. The sidewalk slab is  $3\frac{1}{2}$ in. thick and spans from the curb to the fascia girder under the handrail. There is a conduit space provided under each sidewalk slab. The roadway slab has a longitudinal recess or depression deep enough to permit of the laying

of the tracks at some future time. This depression is drained by means of a 3-in. tile drain, and the slab is water-proofed. The roadway slab, the curb and the sidewalk slabs are integral. At the second transverse wall from the pier an expansion joint is provided in the floor slab. The free end of the slab rests on a strip of asbestos board.

The arch ribs are 1 ft. 4 in. thick at the crown and 3 ft. thick at the springing lines. The nominal span and rise are 71 ft. 6 in. and 17 ft. respectively. The radius of the intrados is 46.09 ft. and that of the extrados is 52.75 ft. The arch rib is reinforced with 35 lines of 11/8-in. round corrugated rods in both intrados and extrados. The splices are arranged to stagger, and the rods extend 4 ft. into the tops of the piers. The two arch spans next to the Trinity River span are of course subject to greater temperature stresses than in the ordinary case, but these stresses will not be excessive.

Concrete.-Gravel is to be used throughout for

the broken stone concrete is the stronger for the leaner mixtures.

It is specified that the proportions of sand and gravel, as found in the pits will have to be modified, if required by the engineer, in order to produce the different grades of concrete specified.

Trinity cement, manufactured by the Southwestern States Portland Cement Company, is being used. The cement is furnished to the contractors by the County. The specifications for cement are substantially the same as recommended by the American Society for Testing Materials.

The specifications for the grades of concrete are as follows:

"For the arch rings, girders, cantilevers and spandrel walls (above a plane through bottom of cantilevers), and for girders, bents, floor slabs and arch piers (above a plane 3 ft. 6 in. below the springing line of arches), and for encasing the metal work for the steel span over the Trinity River, the concrete shall be composed of I part



More than Width of Orr Details of Rocker Bearing Details of Expansion Joint Expan

Details of Expansion and Rocker Bearings of Trestle Approaches.

the aggregate. It is found in the vicinity of Dallas in natural beds mixed with sand. In some places there is an admixture of clay, so that considerable care must be exercised to secure gravel of good quality.

The only satisfactory broken stone obtainable in the vicinity of Dallas is that produced at Jacksboro, Tex., known as Jacksboro stone. It costs considerably more than the gravel. An elaborate series of tests was made by Prof. T. U. Taylor to determine the relative merits of Jacksboro stone and Dallas gravel. The following table gives the average results of over 100 compression tests made with two different brands of cement, "Trinity" and "Lone Star."

COMPRESSION TESTS OF CONCRETE MADE WITH JACKSBORO STONE AND GRAVEL.

				Average				
				Strength, Lb. per Sq. In.				
Concret	te — Ag	gregate -	7	14	28			
Mixtur	e.Kind.	Size, In.	Cement.	Days.	Days.	Days.		
1:2:4	Stone	11/2	Trinity	1347	1972	2255		
"	"	41	Lone Star	1278	1589	1813		
"	Gravel	64	Trinity	1788	1908	2097		
"	**	64	Lone Star	1520	1949	2103		
1:3:5	Stone	- 11/2	Trinity	1253	1319	1707		
ĩ. °	44	41-	Lone Star	695	938	1105		
"	Gravel	"	Trinity	794	1061	1215		
**	**	"	Lone Star	826	1083	1289		
	~		- • •			i		
1:3:6	Stone	21/2	Trinity	939	1119	1293		
"	- "	"	Lone Star	1251	1431	1633		
"	Gravel	**	Trinity	500	715	797		
"	**	"	Lone Star	555	630	789		

In view of these results it was decided that the gravel concrete is as strong as the broken stone concrete for the I:2:4 mixture, but that Portland cement, 2 parts sand and 4 parts stone or gravel to pass in any direction through a 1½-in. ring.

"Concrete in all cross spandrel walls (below the plane of bottoms of cantilevers), in the arch piers (below a plane 3 ft. 6 in. below springing line of arches), and in the two end abutments and retaining walls shall be composed of I part Portland cement, 3 parts sand and 5 parts stone or gravel to pass in any direction through a 11/2in. ring.

"Concrete for curbs, wheel guards, sidewalks and parapets or copings shall be composed of I part Portland cement to 3 parts of a mixture of clean sand and gravel to pass a 1/2-in. screen.

"The bases of all piers, columns and abutments shall be composed of concrete mixed in the proportions of I part Portland cement, 3 parts sand, and 5 parts gravel to pass in any direction through a 21/2-in. ring, or if broken stone be used the proportions shall be I part Portland cement, 3 parts sand and 6 parts of broken stone to pass a 21/2-in. ring."

Steel Reinforcement .- The specifications require the use of round corrugated rods or other deformed bars of a type satisfactory to the engineer. After the contract was let it was decided to use round corrugated rods throughout. The material for reinforcing bars is medium open hearth steel having an ultimate strength of 60.000 to 68,000 lb. per square inch, an elastic limit not



less than one-half the ultimate strength, elongation of 22 per cent, and the capacity to bend cold 180 deg. to a diameter equal to the thickness of the piece tested without fracture on the outside.

Trinity River Span.-This span has four steel girders connected by steel cross girders. All metal work is to be encased in concrete. The steel girders carry in direct compression the horizontal thrust of the adjacent arch spans. This thrust is carried into the bottom flanges of the girders by means of special cast steel shoes shown herewith. The upright portion of the shoe bears against the concrete of the pier on one side and against the cast steel wedge on the other, the wedge being driven between the cast steel shoe and the end of the bottom flange angles. The girders are otherwise of the ordinary type of construction and the material specified is medium steel except for rivets, which are to be of soft steel.

Lighting System.—At each pier on either side there will be a cement lamp standard on which are to be placed three 40 cp, 50-watt series Tungsten lamps. Each lamp will be encased in a heavy to-in. R. I. glass globe. The wiring system is to be so arranged that the center light on each post will be on one circuit and the two side lights on another circuit, so that either one, two, or three lights in each group can be used, as desired. At the Houston Street stairways the lamp standards will have a single lamp only.

The total cost of the structure, including engineering and all incidentals, will be about \$570,000. The cost per square foot of floor is about \$2.10. which is a remarkably low figure for a structure of this height. The contract was awarded to Messrs. Corrigan, Lee & Halpin, of Kansas City, Mo. The concrete piles are being put in place by the Gulf Concrete Construction Company, of Houston, Tex. The field work is being carried out under the supervision of Messrs. Hedrick & Cochrane, consulting engineers, Kansas City, Mo., and Mr. J. F. Witt, county engineer. Mr. E. N. Noyes is resident engineer representing the consulting engineers. The work was begun in October, 1910, and is to be completed by Dec. 1, 1911.

TRACK PANS for railway water stations are having their usefulness extended, being now adapted to freight train service, whereas their former application has been almost entirely to fast passenger train service on long runs between regular stops. The advantages claimed for freight train service are saving in the cost of stopping and starting, in the wear and tear on the equipment, and in elimination of the danger of breaking draft gear. An extensive study of this subject has been made during the past year by the committee on water service of the American Railway Engineering and Maintenance of Way Association, and a general review of present designs and operations is given in the committee report to the annual convention. A summary of the principal factors entering into the installation of track paus includes first cost. interest, depreciation, maintenance, operation, including cost of water, loss of energy expended in drawbar pull overcoming the dynamic pressure of the water from pan or scoop, speed of trains. ruling grade, loss of time and cost of stopping and starting, including the wear and tear on equipment. Location on tangent and level grade are considered desirable, with approaches such as to allow the minimum speed over the pan required to take water properly. It is believed that the future development of the design of the track pan will depend to a large extent upon the scoop, which affords more principles of design than the pan, and it is considered possible that the general arrangement will be entirely changed to obtain greater efficiency. The development of the design of scoop is receiving consideration from several railroads.

#### THE DESIGN OF PASSENGER TER-MINALS.

The principal considerations entering into the design of passenger terminals of medium size are summarized in the report of the committee on yards and terminals of the American Railway Engineering and Maintenance of Way Association, presented at the annual convention. The fundamental idea, according to the committee, is to provide such arrangement of tracks as to permit the greatest freedom of movement with the least interference, to the end that incoming and outgoing trains may be handled without serious interruption or delay. Thus the maximum of efficiency of tracks and facilities is secured and a resulting minimum expenditure for installation.

Where it is necessary to provide for trains arriving or departing, or both, in rapid succession it is very important that the track layout be such that inbound and outbound movements will not conflict to any great extent. This permits trains to enter the station while others are departing, and also makes possible the use of vacant tracks in the minimum time after outgoing trains have left them, reducing the number of tracks required.

The train capacity of tracks depends largely on the facilities provided for rapid handling of baggage and express matter to and from the trains at the platform. These facilities should therefore be the best and should interfere as little as possible with the movement of passengers. Wherever possible, baggage and express should be received, delivered and handled below the train floor, and raised and lowered by elevators near the baggage and express cars. Both time and discomfort are saved by this plan over trucking long distances on the passenger platform.

The time required to load and unload passengers, baggage and express varies widely with the character and volume of the business handled by the different trains and with the facilities provided. Much less time is usually required on long-distance trains to load the passengers than to handle the express and baggage, but on short distance and suburban trains the conditions may be reversed. In any case the time required for these operations and for the necessary shifting must be considered the interval between the departure of trains on any tracks, so it is advisable to provide for loading express and heavy baggage before making up a train and placing it at the platform. Investigations made by the committee show that an average of 4.1 trains per hour are now handled on one track during the busiest hours and that an average of 6.5 trains per hour can be readily secured with full consideration of the factors mentioned. The maximum estimated is about 12 trains per hour.

Typical track layouts for both dead-end and through passenger terminals of medium size are presented by the committee. In the dead-end station an eight-track layout is considered. A double-track arrangement at the entrance is preserved as far as possible to give practically continuous use of station or platform tracks. Results are thereby secured close to the best obtainable in a through station with the same length of platforms. A double-track ladder extends across the entrance to the station, connecting each pair of station tracks directly with the main-line tracks. A third ladder track, having end and intermediate connection with the station tracks, serves the coach-cleaning yard. In the outer yard the arrangement depends on local conditions.

In the station a two-level platform is shown, as described, with elevators for baggage and express. A platform for this purpose is also provided along either side of the station with four passenger platforms between. Where many passengers arrive in quick succession, as in the case of surburban traffic, inclined floors are recommended instead of stairs in the egress passages,

to prevent congestion. Grades not greater than 10 per cent and roughened floors are considered advisable.

The track layout for a through station provides two platforms, one for the movement in each direction, with a station track on either side of each platform and the main-line tracks between the inner station tracks. Each train making the stop is switched to one or the other of the two tracks for its direction, thus clearing the main track. Four trains of ordinary size can stand at such a station, at the same time leaving the through tracks open. Each platform has two levels, with baggage elevators and undercrossing for passengers. Such a station has a very large capacity.

The committee recommended the design of terminals to meet economically the needs of the greatest periods of activity which may reasonably be expected in about twenty years.

#### Depth of Ballast in Track.

During the past year a study leading toward the determination of the proper thickness of ballast in track has been made by the committee on ballast of the American Railway Engineering and Maintenance of Way Association. Data on the kind of ballast and on the dimensions of the ballast section have been collected from a number of railroads, but on account of the complicated conditions which govern the proper depth, no definite conclusion has yet been reached. A summary has been made of the functions of ballast and of factors determining its depth preliminary to a recommendation.

Primary functions of ballast which were named in the report of this committee to the annual convention are, I, to provide drainage which will lead water away from the ties, or to protect the subgrade from water, as in the case of cementing gravel; 2, to distribute the load from the ties more uniformly over the subgrade; 3, to provide a material which can readily be worked in all kinds of weather and which will not materially lose carrying power or change position as a result of the action of the elements.

Factors determining the depth of ballast are made to include first the character of the subgrade, whether rock, firm material, such as firm gravel, or soft material, such as gumbo. It is believed that the softer the subgrade the deeper the ballast required, between certain limits, for uniform distribution of pressure. The kind of ballast is another factor, which affects the depth only slightly, however, as compared with the others. It seems to be the general practice to provide a less depth of stone ballast than of gravel, probably largely due to difference in cost.

The size of ties and number per rail length determine the bearing surface on the bottom of the ties in a given length of track. Where the roadbed is soft this factor materially affects depth.

The stiffness of rail is an element, varying greatly between such heavy sections as the 135-lb. rail used on parts of the Central Railroad of New Jersey and the 40-lb. rail used on sidings. With stiff rails the wheel load is distributed over a greater number of ties, thus influencing depth of ballast. The magnitude of the wheel loads and their frequency of application also influence the depth directly, as an increase in either requires greater depth for proper distribution.

FILTERED WATER AT TOLEDO, OHIO, has cost \$6.74 per million gallons. This cost is distributed by Mr. D. H. Goodwillie, chief chemist of the water-works department, among the following items: Coal and electricity, \$1.75; chemicals, \$3: labor, \$1.95; repairs and supplies, \$0.04 About. 15.500,000 gal. per day are now being filtered.

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