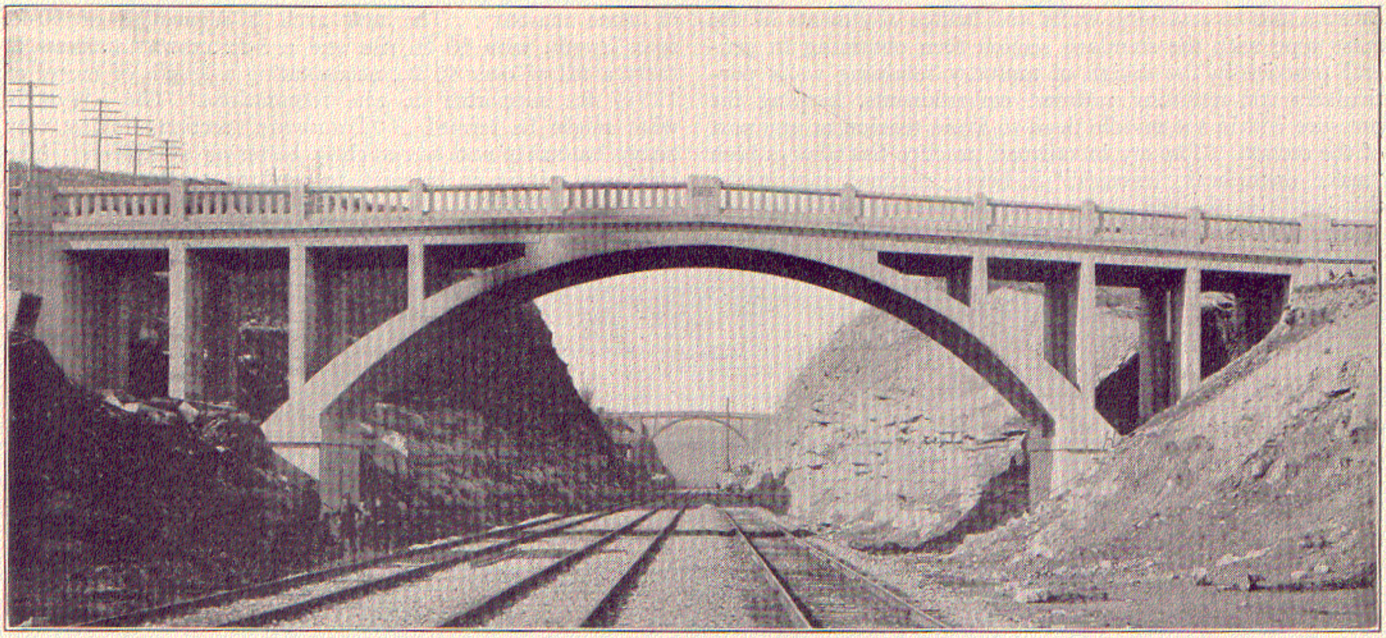

The Gilmore Arch—An Overhead Highway Bridge

Development of Concrete in Railway Construction*

A Review of the Steps in the Adoption of This Material on the Delaware, Lackawanna & Western

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SOMEWHAT MORE than twenty years ago, the Delaware, Lackawanna & Western embarked on a departure from the then current railroad construction practice in the east, by adopting concrete as the material for bridge abutments, retaining walls, etc., for the Newark, N. J., grade

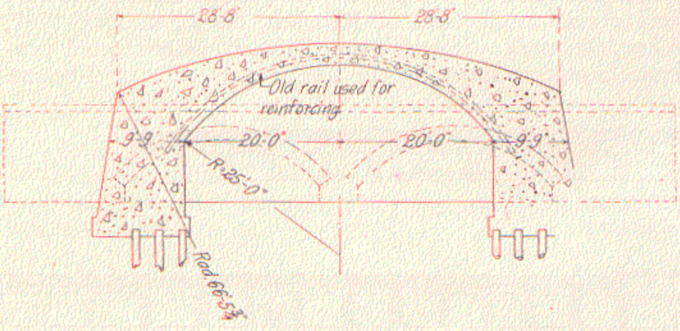


Fig. 1—Forty-foot Arch Over Beaver Brook, Bridgeville

crossing elimination work. Railroad engineers then, as now, enjoyed the reputation of being the most conservative of any in the practice of engineering and this adoption of concrete was considered a bold step forward. Contrary to the normal direction of the progress of civilization, which has been from the east toward the west, the progress in the use of concrete was from the west toward the east as concrete appeared in the construction work of the western railroads several years before it was employed by the eastern lines.

Prior to the advent of W. K. McFarlin as chief engineer of the Lackawanna just before 1900, concrete was not used along the line of the railroad for any purpose other than back-filling or other equally unimportant work not subject to stresses. The remarkable growth of the use of this "new" construction material, both plain and reinforced, in the 20 succeeding years, is evidenced by the monumental structures of concrete all along the line from the lowly drain pipe to the majestic Tunkhannock viaduct. The evolution of the design and construction of concrete structures from the humble beginning became a very interesting process,—at first slow and laborious,—increasing in its momentum and finally becoming almost all-embracing in its scope.

Evolution is defined by Herbert Spencer as a development from the simple to the complex, and the evolution of the use of concrete as a structural material is no exception,—it is the development from the simple gravity sections with pressure lines limited to the middle third of the plane of section, resulting in simple compression throughout, to the highly complex four-way type of reinforcement, and rigid frame structures designed to take stresses of all types and in all directions, complicated by all manner of combinations and conditions of loading pertaining to any particular case.

The following description is an attempt to outline this growth and illustrates the wide usage that concrete enjoys in the construction work of the Lackawanna. The description necessarily partakes somewhat of the nature of a historical sketch due to the fact that each new structure has represented a step forward in the development of the use of concrete for purposes requiring more complicated design.

The Early Uses of Concrete

As already mentioned above, the first use of concrete along the line, and the only use of it for some years, was in the

* This is the first of three articles. The other two will appear in early issues.

construction of retaining walls and bridge abutments of the mass type with the standard section then obtaining in general practice in the design of masonry retaining walls particularly for retaining railroad embankments, keeping the pressure within the middle third to avoid tension at any part of the section. The cry in railroad practice has always been "make them heavy enough," it being assumed that under this condition the soil pressure would take care of itself.

The next use of concrete was in the construction of "rail-top" and "I-beam top" culverts. These were the earliest structures of concrete but were so designed that the rails or I-beams carried the railroad loading while the concrete filled in to form a solid floor as a protection for the steel. There were also a few concrete arch culverts of smaller spans.

The first structure of any size or importance to be built of concrete on the line, was the arch at Bridgeville, N. J., erected in 1903 to replace a double-barreled arch culvert of stone masonry. The new arch is segmental, of 40-ft. span length, with 10 ft. rise and a 3-ft. crown thickness to carry a fill of over 40 ft., necessitating a length of barrel of 123½ ft., supported on pile foundations. The section is what might be termed a "Trautwine" section, having very heavy haunches and but slightly battering abutments. The ring was reinforced by rails to conform to the intrados of the arch, (Fig. 1).

It was also in 1903 that the Keyser Valley and Kingsland shops were built and concrete used in the construction of all of the foundations and floors and subways, and in some instances for the roofs of the various buildings.

Isolated structures of the minor type continued to be constructed of concrete, but the first *reinforced* concrete structure was a coal trestle built at Hoboken, N. J., in 1906-1907. Here, the track stringers were designed as reinforced concrete beams, supplanting the use of steel rails or I-beams.

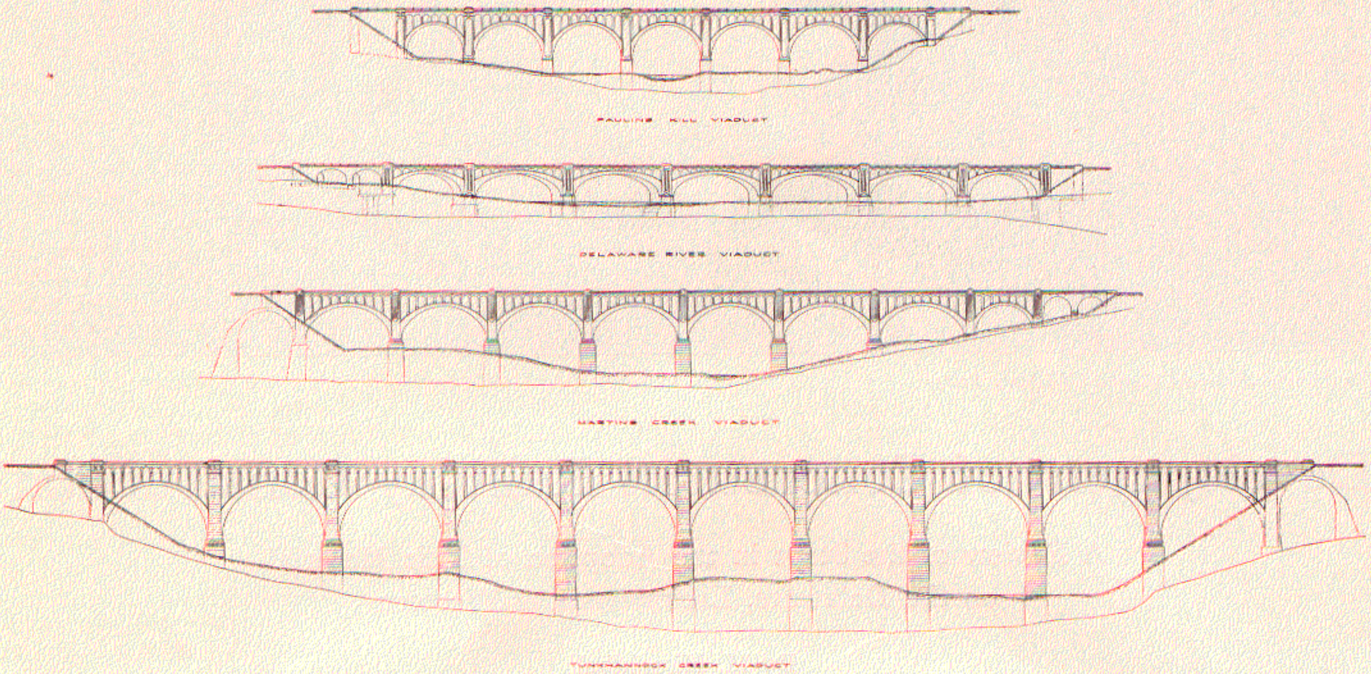


Fig. 2—Four Large Arch Viaducts

Paulins Kill Viaduct, length 1,100 ft., height above water 117 ft.
Delaware River Viaduct, length 1,450 ft., height above water 64 ft.
Martin's Creek Viaduct, length 1,600 ft., height above water 150 ft.
Tunkhannock Viaduct, length 2,375 ft., height above water 240 ft.

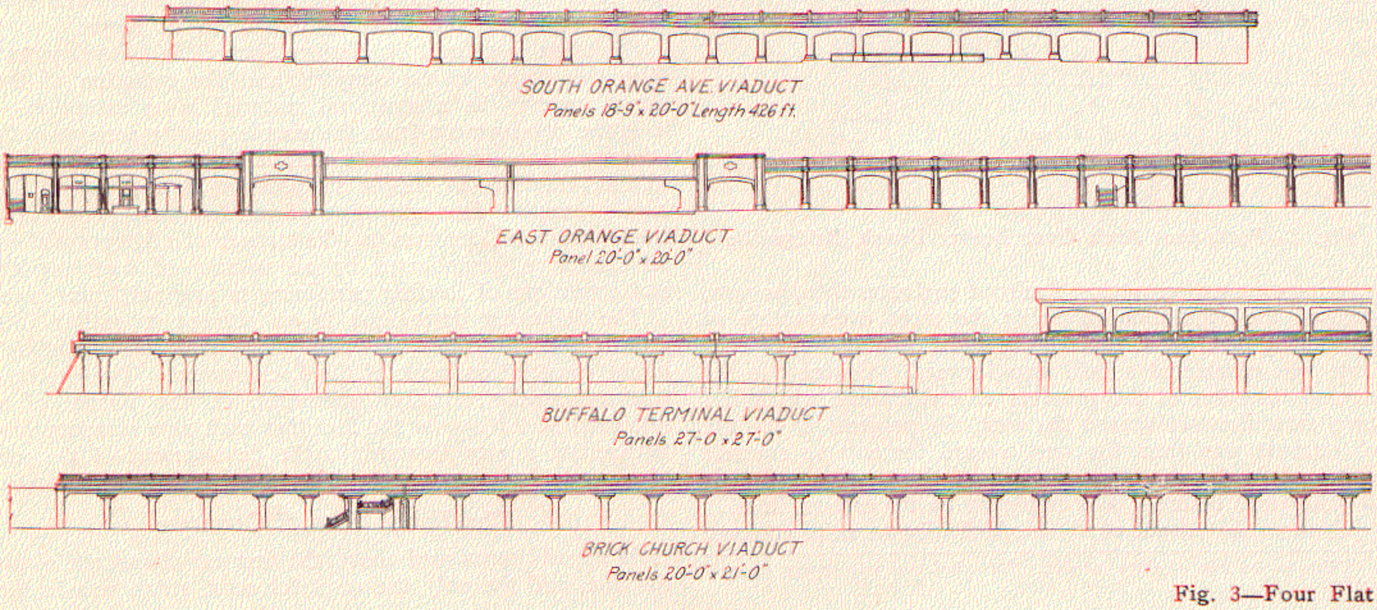


Fig. 3—Four Flat

This trestle of 112 ft. of mass wall aproaches, 226 ft. of reinforced concrete stringers on piers, with temperature reinforcement in each face, and 159 ft. of coal storage bins, entailing the use of reinforced concrete stringers supported on reinforced concrete girders, which in turn are supported by reinforced concrete walls, retaining the coal carried on a reinforced concrete floor, which spans between concrete retaining walls.

At each pier along the open trestle a rail is imbedded transversely, overhanging both sides sufficiently to support a concrete walk. This is evidently a substitute for a reinforced concrete bracket or cantilever, confidence in reinforced concrete not having advanced sufficiently at that time to permit of reinforced concrete cantilevers.

Somewhat later a skew arch bridge was designed and built

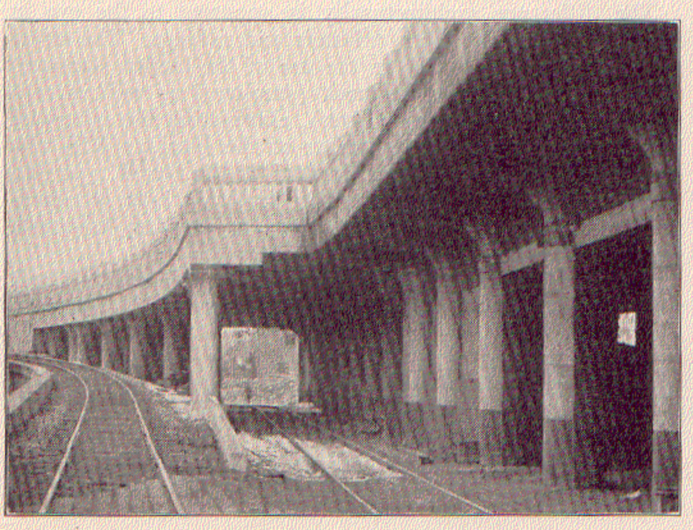


Fig. 4—Showing Flat Slab Construction at Buffalo

over Washington Avenue, Washington, N. J. The right span of this bridge is 44 ft. clear, and as the central angle is 42½ deg. there is a skew angle of 47½ deg. This excessive skew was modified by forming the faces of the bridge to a skew of 25 deg. with the center line of the avenue. This arch is segmental in form with a 10-ft. rise and a 3-ft. crown thickness without any reinforcement, while the elevation of the top of parapet is that of the top of rails. The abutments are supported on pile foundation. One-half of the roadway is carried by the roof of a two-span box culvert, reinforced with rails forming a then typical double rail-top culvert.

At about this time the design and construction of the various shops at Scranton, Pa., was begun and it was decided to use reinforced concrete as the material of construction. This project included a vast program of buildings for many purposes and various conditions of loadings from light office loads to locomotive loading and entailed several years of continuous construction.

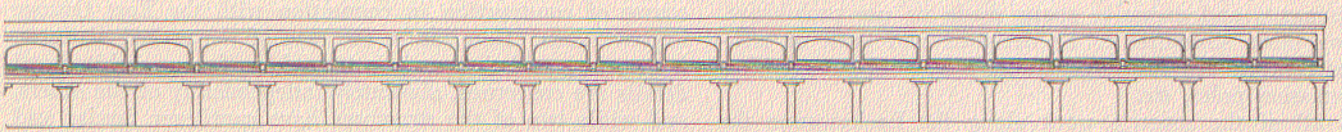
Late in 1907, the preparation of plans was begun for the Hopatcong to Slateford cut-off, now known as the Lackawanna Railroad of New Jersey. The character and object of this improvement have been described so often and thoroughly that no detailed repetition is needed here. However, it was on this improvement that concrete and reinforced concrete were employed by the Lackawanna for the first time on so large a scale and for so many types of construction. There were the two important viaducts, the Delaware River structure of elliptical arches, and Paulin's Kill with semi-circular arches, and while the majority of the bridges, both over and undercrossings were of the arch type, there were a number of flat construction, both of the "T" beam and simple slab type.

Altogether there were 73 concrete bridges and culverts of which about 50 were major structures, concrete construction having attained to sufficient magnitude to justify the organization of a special concrete department to handle the design of all concrete structures. The successful completion of this cut-off, entailing the placing of 260,000 cu. yd. of concrete and 5,000,000 lb. of reinforcing steel, marked an epoch in railroad construction and put concrete in the foreground as the material for consideration in subsequent important construction work. Therefore in the planning of the Pennsylvania cut-off from Clark's Summit to Hallstead and in connection therewith, the projection of the Tunkhannock viaduct, concrete construction occupied a strategic position and had a strong line of defence against the proposed steel structure, despite the advantage of first cost and of established usage which the latter type enjoyed. It is interesting to note that an effective argument for concrete in consideration of the type of structure to be used for the Tunkhannock viaduct, was the striking effect produced by a wooden model of the proposed viaduct so perfect as to all its architectural details, and color as to simulate the completed structure. This model made so favorable an impression that it was shipped to the Leipzig Exposition.

The Pennsylvania cut-off was by far the largest improvement, both in mileage and cost, undertaken by the railroad, and is described in an interesting article by G. J. Ray, chief engineer, appearing on page 1243 of the *Railway Age* of December 24, 1921. With few exceptions all the structures are of concrete, of which, of course, the Tunkhannock and Martin's Creek viaducts are the outstanding features. The total number of structures on this improvement, exclusive of these two viaducts, is 86, of which seven are of structural steel, and 79 are of concrete, 42 of them being major structures. Like the New Jersey cut-off, there have been many articles descriptive of the general scope and details of construction and of the two viaducts, that it is only necessary to summarize by stating that 345,000 cu. yd. of concrete and 6,250,000 lb. of reinforcing steel were placed in the bridges and culverts of this cut-off.

Between the projection of the two "cut-offs" there was begun an ambitious program for the elimination of all

EAST ORANGE VIADUCT
Length 842 ft



BUFFALO TERMINAL VIADUCT
Length 1100 ft.

BRICK CHURCH VIADUCT
Length 1085 ft.

Slab Viaducts

grade crossings in the thickly populated districts along the main line and also on the Montclair branch. The part of this program first to be carried into execution was the elimination of the crossings on the branch from the East Orange city line to the terminal at Montclair and incident thereto the construction of new passenger stations. Embraced in this work are arch construction both overhead and undercrossings, flat construction and, for the larger spans, structural steel encased in concrete. In connection with this improvement, reinforced concrete coal pockets were constructed at Montclair.

After the completion of this first portion of the program of elimination, there were executed at various times the improvements along the main line to Morristown, eliminating successively the grade crossings at Chatham, Madison, South Orange, Morris Plains and Orange, culminating in the East Orange improvements now in progress with the completion of which all grade crossings from Mount Taber, N. J. and Montclair to Hoboken will have been eliminated. In all of these improvements, concrete, both plain and reinforced, is the principal medium of construction, particularly in the East Orange improvement where the only structural steel work occurs at the Main street crossing where the excessive skew of the angle of crossing precluded the use of reinforced concrete as an undercrossing. This street crossing is part of a viaduct, the remainder of which is of concrete.

There were important improvements at other points on the line, notably at the west end at Buffalo where a new terminal was designed and constructed. The tracks there are carried on an elevated structure and the portion under the train shed is utilized as a warehouse and provided with tracks for drilling purposes. There again because of the magnitude and importance of the structure, the question of the type and material of construction had to be considered seriously before a final decision was made. Concrete was selected because of the uniformity afforded by the flat slab construction and the reduction in maintenance costs over those for structural steel.

During all this time and since, isolated grade crossing eliminations and bridge renewals have been executed in concrete at many points along the line, except where clearance requirements and excessive spans made its use prohibitive. Among other structures to be designed and built of reinforced concrete are buildings, cinder pits, sand storage bins, transmission poles, etc.

In all of the concrete work along the Lackawanna the distinctive feature is the attention paid to architectural details to produce artistic effects in harmony with the use and environment of the structure under consideration. It is the writer's opinion that this railroad is one of the few, if not the only one in the country that does not submerge all architectural and' individual effects by the use of standards throughout, with the result that the structures on this line stand out as individual bridges, stations, etc.

The structures herein described have been selected for the purpose of illustrating certain types and to point out particularly interesting examples as indicating divergence from the ordinary.

Several Large Arch Viaducts Have Been Built

Of all the structures, perhaps the best known are the four arch viaducts, because of the interest attaching to their magnitude and because they perhaps best illustrate the individuality of treatment above mentioned. While the Paulin's Kill and Tunkhannock viaducts are similar to each other in so far as they both have sufficient head-room to permit of the use of semi-circular arch spans and spandrel arches, their treatment both architecturally and structurally is absolutely dissimilar.

The difference architecturally is apparent to the eye in the difference of the piers, pilasters and railings. The structural difference is chiefly in the use of the buried abutment arch spans of the Tunkhannock (employed as well in connection with the Martin's Creek), eliminating the otherwise high walls used at the abutments of the Paulin's Kill viaduct, the selection of the rib instead of the barrel type and the provision of a ledge to support centering later ornamentally treated, to obviate the necessity of erecting falsework for arches from the ground.

A comparison of the Delaware River and Martin's Creek viaducts, in both of which the rise is considerably less than half the span, discloses the use of a segmental form of arch in the design of the Martin's Creek as contrasted with the elliptical form in the earlier Delaware river viaduct which is of the barrel type with "U" abutments while the later structure is of the rib type with centering ledges, and submerged arch abutments. Architecturally there is a marked difference in the treatment of the pilasters and railing. Figure 2 shows these four viaducts and the data concerning them.

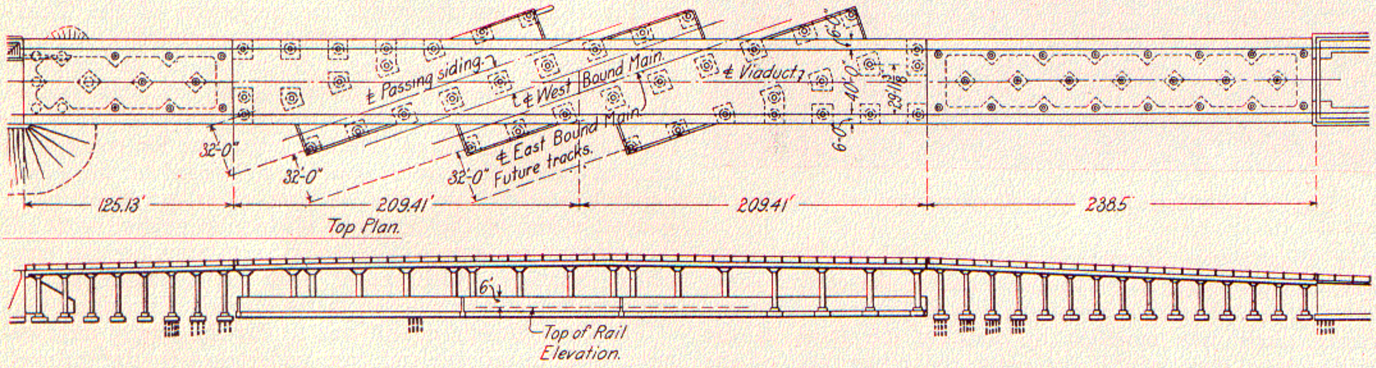


Fig. 5—Flat Slab Viaduct Over the Track at Sanford's Crossing

Flat Slab Viaducts

There are also four long viaducts of flat-slab type, viz: The Buffalo terminal, the South Orange avenue viaduct, and the Brick Church and East Orange viaducts now in the course of construction in connection with the East Orange improvements. Here, as in the case of the arched viaducts, it may be noted that each is treated, so far as architectural details are concerned, absolutely independently of the others, and while two of the structures have cantilever fascias and the other two columns and pilaster fascias, they also differ from each other in architectural details. The structures of the cantilever fascia type are the Buffalo terminal and the Brick Church viaduct, while the South Orange avenue and the East Orange viaducts are of the fascia column type.

The viaduct at the Buffalo terminal is by far the largest, both as regards area and cost, having an extreme width of 154 ft. to accommodate seven tracks at its wide end and narrowing down to a 46 ft. width for three tracks with a total length of somewhat over 1,100 ft.

The columns supporting the structure are cylindrical, reinforced by both longitudinal bars and spirals and are spaced 27 ft. center to center in both directions, the transverse section being completed by 9 ft. 6 in. cantilever spans at each side. The slab, two feet thick, is increased in thickness at the supports to form drop panels and is reinforced with four bands of steel reinforcement, running respectively longitudinally, transversely and in each of the diagonal lines, with bars from each band bent up at the supports to take shearing stresses and those due to negative moment. This slab, beside carrying the tracks and platforms, supports the column concentrations of the train shed roof for the major portion of its length. The train shed columns surmounting this slab are spaced 27 ft. on centers longitudinally to correspond to the spacing of the columns below; transversely, however, the spans are increased sufficiently to permit of spanning over two tracks and center to center of 20-ft. platforms so that some of these columns transfer concentrated loads to the slab which distributes them to the lower columns. The foundations throughout this improvement are on piles surmounted by heavy concrete footings, all connected by reinforced concrete struts in both directions.

The three other viaducts provide facilities for three tracks throughout with station platforms between two of the tracks and on one side of the third, having a width of about 80 ft. in the vicinity of the stations and narrowing down to 46 ft. at the ends.

The East Orange viaduct is complicated by the fact that the crossing at Main street is on a considerable skew and requires long spans, precluding the use of this type of construction and necessitating the use of I-beams encased in concrete with fascia girders supporting the skew ends. This problem was solved architecturally by the use of concrete portals over the sidewalk spans adjacent to the two road spans. This treatment is very effective.

The shortest of the viaducts is the South Orange avenue viaduct, which is 426 ft. long and was built without expansion joints. The others are of very nearly equal length, but while the Buffalo viaduct has but one expansion joint which occurs at the change of section, the Brick Church and East Orange viaducts have joints at intervals of 250 to 300 ft. The columns are spaced 20 ft. center to center longitudinally for the three viaducts, except at the street crossings, of which that at South Orange avenue has the longest spans, these being 33 ft. center to center. The transverse column spacing varies in the three viaducts. At Brick Church the transverse spacing is 21 ft. with two cantilevers of approximately 7½ ft. each while at East Orange and South Orange, where fascia columns are used, the column centers transversely are 20 ft. and 18 ft. 9 in., respectively. Figure 3 shows the four viaducts for comparison with the information concerning each of them.

Overhead Highway Flat Slab Viaduct

While the above mentioned are the only viaducts of this flat slab type to carry railroad loadings, there is also a viaduct over the railroad tracks carrying the highway loads of Newark Turnpike, at Kearney, N. J., known as Sanford's Crossing (Fig. 5). This was an unusually difficult grade crossing elimination, due to the character of the soil, the proximity of the trolley line and the Pennsylvania railroad shops crowding the work. It was further complicated by the extreme skew of the angle of crossing (70 deg. 48 min.) as well as by the inordinately large spans made necessary by the requirement of spanning two tracks with the necessary side clearances, resulting in spans of 32 ft. center to center in both directions. The columns for these spans are supported on four rows of continuous piers acting as guard walls, carried to a height of 6 ft. above the top of rail as a protection against derailment. The approaches are smaller spans of 22 ft. 6 in. center to center with diagonal spacing of columns and sidewalks overhanging on either side. Expansion joints are placed at both ends of the main spans. All the foundations on this viaduct, the length of which is 782 ft. exclusive of retaining walls, are supported on piles, the columns of the approach spans being supported on clusters with individual footings, while those of the main spans are continuous. A peculiarity of the columns on this structure is their octagonal shape which, though attractive in appearance, was found to be excessive in cost of forming and their use was not repeated.

Freight Car Loading

WASHINGTON, D. C.

Freight car loading during the week ended September 30 was the largest for any week since October, 1920. The total showed another increase of 15,000 cars as compared with the week before, to 988,381, which was within 3,902 of the loading during the corresponding week of 1920, when the total was 992,283, and was 83,550 in excess of the loading for the corresponding week of last year. As compared with the week before coal loading increased from 187,896 to 189,349, and there were also increases in the loading of all classes of commodities except grain and grain products and forest products, but the principal increase was in miscellaneous freight which increased nearly 10,000 cars. Increases as compared with 1920 were shown in grain and grain products, livestock, merchandise and miscellaneous. In the Alleghany, Southern, Central Western and Southwestern districts also increases were shown as compared with 1920. While grain loading was less than that for last year the total loading to date in 1922 is in excess, not only of 1921, but also every other year. The summary as compiled by the Car Service Division of the American Railway Association is shown in the accompanying table.

The freight car shortage showed another increase during the last week of September to 130,325, which included 66,529 box cars and 38,954 coal cars, while the surpluses amounted only to 6,593.

The railroads have been furnishing a steadily decreasing percentage of the cars required for coal loading, according to the weekly reports of the Car Service Division of the American Railway Association. For the week of September 23 the percentage of cars placed to cars required was 58, as compared with 63, 73, 78 and 82 in the four preceding weeks, respectively. For the week of September 23 the cars required were 367,616, as compared with only 193,660 in the corresponding week of last year; the cars placed were 212,685 and the cars loaded 181,346, an increase of 21,580 or 13.5 per cent over last year.

The number of locomotives out of service for repairs showed an increase during the first half of September as compared with the last half of August. On September 15 the number requiring over 24 hours for repairs was 16,572 or 25.8 per cent, as compared with 25.3 per cent on September 1, and the number out of service for repairs requiring less than 24 hours was 3,585 or 5.6 per cent, as compared with 3,573 on September 1. The number of serviceable locomotives stored was also reduced from 2,842 to 1,982.

In a circular addressed to the shipping public, asking co-operation to bring about the most economical use of cars, M. J. Gormley, chairman of the Car Service Division, says:

"Prior to the strike of the shop crafts on July 1 the Car Service Division prepared an estimate of car loading for the remainder of 1922 together with probable transportation conditions coincident with the peak of railroad traffic generally reached in October.

"The chart then prepared is attached. It outlines load-