Floor Systems for Bridges

1. REINFORCED CONCRETE

Many bridge designs use reinforced concrete slabs for floors. These may be supported by stringers and floor beams of the bridge. When no floor beams are present, the concrete floor is supported directly on top of the primary longitudinal members.

On deck-type bridges, with the concrete floor resting on the top flange or top chord of the longitudinal member, the concrete slab may be anchored to the steel by means of shear attachments. In this manner, the concrete floor becomes an integral part of the steel member in compression.

This composite construction is recognized by most structural authorities as an effective means of insuring economy (particularly in steel tonnage); of promoting shallow depth and more graceful structural lines, and of improving the rigidity of bridges. Typical savings produced with composite construction alone are in the range of 8 to 30% by weight of steel. To be effective, of course, the concrete must always be in compression to prevent cracks in the pavement.

Some types of shear attachments are shown in Figure 1. See Section 4.9 on Shear Attachments for Bridges.

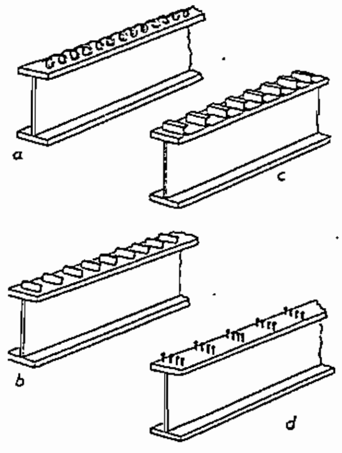

FIGURE 1

2. STEEL GRID

Steel grids may be used for floors for the following reasons:

1. Reduced dead weight of flooring. This reduces the required size of stringers, floor beams, and girders and results in a savings in the amount of steel and cost of the bridge.

2. Snow does not remain on the grid floor; hence, grids greatly lower snow removal cost during the winter.

3. Since snow and rain do not remain on the grid floor, there is no reason for a crown for drainage purposes. This simplifies construction costs.

4. For the same reason, scuppers and drains are not required.

5. The grid flooring can be installed easily and quickly.

Sometimes a light concrete layer is applied to the steel grid.

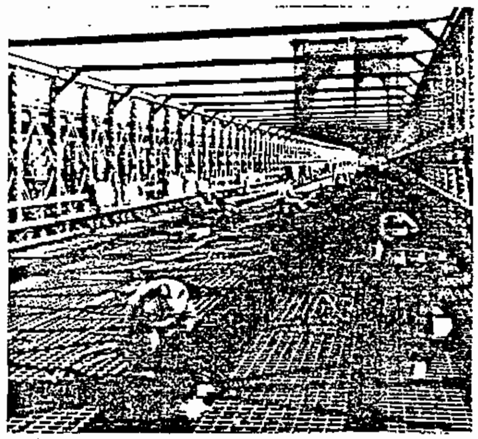

FIGURE 2

3. STEEL PLATE

Steel plate welded to the bridge structure and properly stiffened has been used for flooring. By welding a comparatively thin steel plate to the top flange of longi-

FIGURE 3

tudinal members, a built-up section is produced which greatly increases the strength and stiffness of the member. This has sometimes been called "battledeck flooring".

4. TYPICAL FLOOR SYSTEMS

The design in Figure 4(a) utilizes a steel grid floor in order to reduce the dead weight of the structure. The steel grid rests on the main girders and the longitudinal stringers. The floor beams are set lower so that the stringers, when placed on top, will be flush with the top of the girder. Brackets are shop welded to the girders to receive the floor beams. The top bracket plate is slightly narrower than the flange of the floor beam, and the bottom bracket plate is slightly wider than the flange of the floor beam. This is so that downhand fillet welds may be used in the field connection of the floor beams to the girders.

With a little extra care in shipping and erecting, it would be possible to shop weld the railing and like attachments to the girders and further reduce the field welding.

The floor system in Figure 4(b) is made up of two longitudinal steel girders with a concrete floor attached to the girders by means of shear connections. Although spiral shear connections are shown here, this composite beam could be made by using any type of shear attachments. Shear attachments can also be used on the floor beams.

In the design in Figure 5(a), the top portion of the girders helps to form the curb. For this reason, the floor beams must be lowered, so as to get the bridge floor below the top flange of the girders. To keep this floor level down, the stringers run between the floor beams and their top flanges are flush with the top flanges of the floor beams. Although this produces a very compact and efficient design, it does involve a little more fitting and welding than the previous floor designs.

A very popular design today is the continuous girder deck bridge, Figure 5(b). Several plate girders are placed side-by-side with sufficient cross bracing. A composite concrete floor is attached to the top of the girders by means of shear connectors. For short spans, rolled beams are used with cover plates added

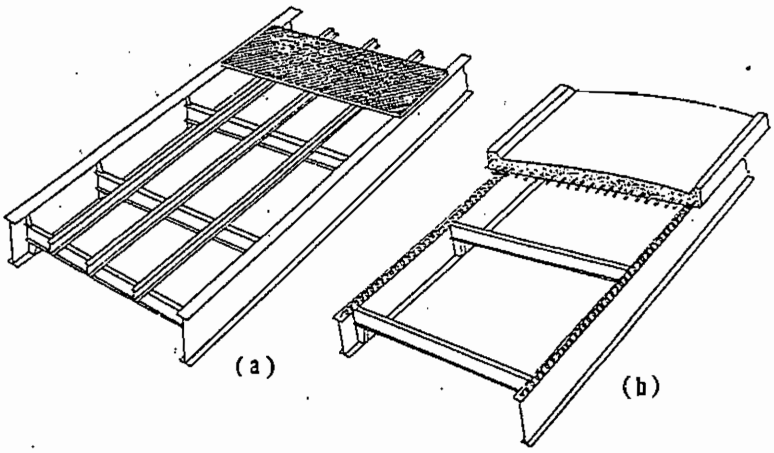

FIGURE 4

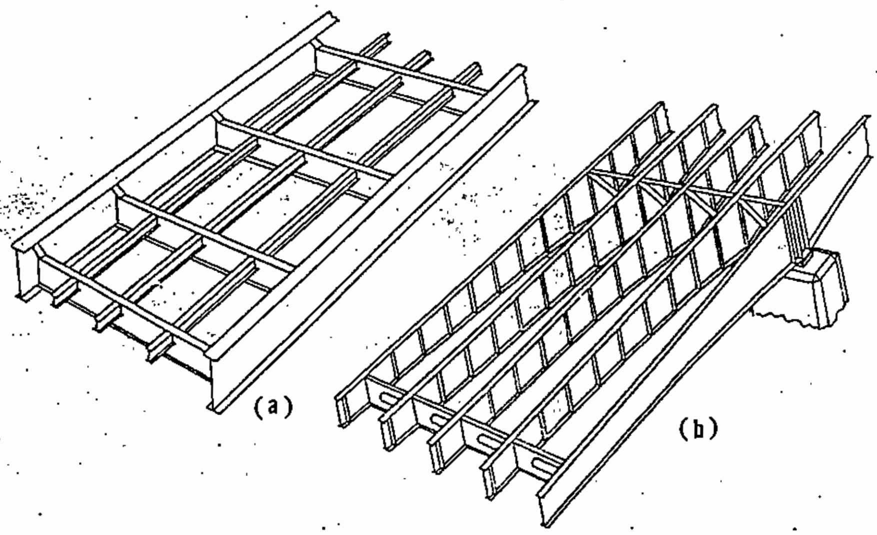

FIGURE 5

at points of high moment. For longer spans, deeper plate girders are fabricated. For a more efficient design, these girders are deeper at points of high moment. The outside girders usually have their intermediate stiffeners placed on one side only, the inboard side, so that they have a more pleasing appearance.

Box girders have been used for bridges; usually two or more are used. They may be joined by several methods. The example in Figure 6(a) uses floor beams flush with the top of the box girder, on which is placed a concrete floor attached with shear connectors.

with floor beams extending outward to support the bridge floor. In Figure 6(b), longitudinal stringers are supported on the floor beams, and the floor rests on these. It has even been suggested that a similar design could be made from a large diameter fabricated pipe section.

5. TORSIONAL RESISTANCE

Designers are coming to realize the importance of designing bridge floors, etc., with more inherent lateral stability and torsional resistance.

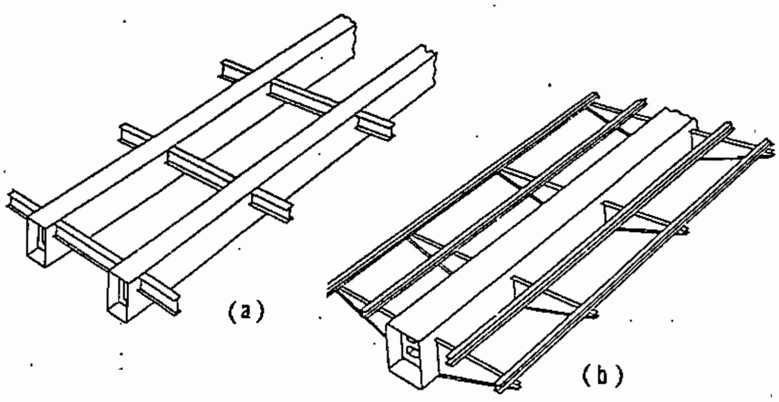

FIGURE 6

Box girder construction has several advantages. It presents a flat surface for other attachments; hence, the floor beams do not have to be coped when they are welded to the girder. There is less of a corrosion problem because of the flat surfaces. Also, since the box girder ends may be sealed off, the inside is protected. Perhaps the greatest advantage is the tremendous increase in torsional resistance offered by the closed box section. It also has good lateral stability. These torsional and lateral stability properties are becoming recognized advantages, and more bridge engineers are making use of them.

Some designs have made use of a single box girder,

When a simple member is subjected to a torsional moment, shear stresses occur; one set being at right angles to the axis of the member and the other set lengthwise. In Figure 7, shear forces (b) act at right angles to the lengthwise member and cause it to twist. A flat section or any open section offers very little resistance to twist. The cross members are subjected to the shear forces (a) and, likewise, twist. If a diagonal member is placed in the structure, both shear forces (a) and (b) act on it. However, the components of these forces, acting at right angles to the diagonal

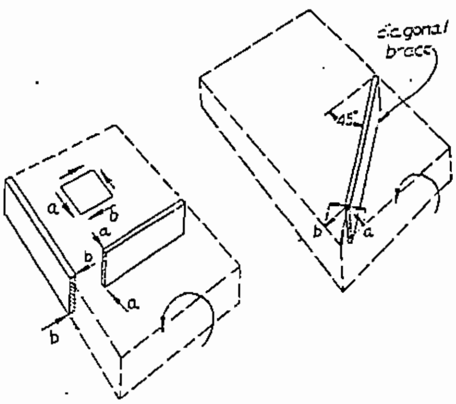

FIGURE 7

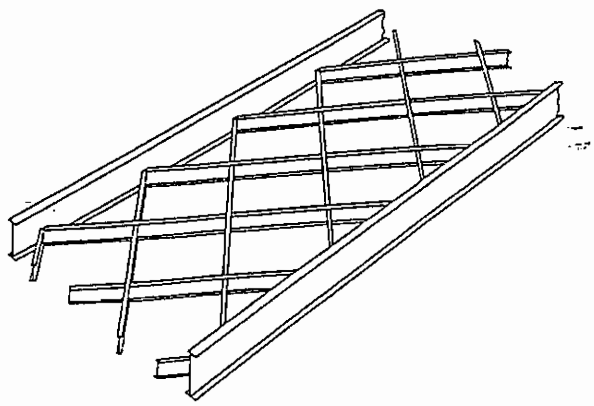

FIGURE 8

member, cancel each other out, so there is no twisting action applied to the member. These forces do combine to place tension and compression in line with the member, thus placing the diagonal member in bending for which it is very rigid. Welding can be used to very good advantage in diagonal bracing.

Figure 8 is from a bridge designed by Camilo Piccone and erected over the Rio Blanco River in Mexico. It is based on an earlier design of Thomas C. Kavanagh. The floor makes use of diagonal members which produce a grid type structure, extremely resistant to twisting and lateral movement.

6. EXPANSION JOINTS

Thermal changes in temperature cause certain physical changes in the size and shape of all construction materials and in their completed structures. The changes are in proportion to the dimensions of the structure, the coefficients of expansion for the materials, and the number of degrees of temperature change.

The structure contracts with the cold and expands with the heat, so a typical bridge might be approximately 1″ longer per 100 linear feet in the summer than in the winter. It will also have daily and short-time changes of a lesser degree in proportion to every change in temperature and it will have additional movements from the elastic deflections of the structure.

These changes in length can be compensated for by corresponding deformations within the structure itself. This is because changing the stress in the structure will also cause it to change in length in proportion to its modulus of elasticity. However, it is usually more economical to use expansion joints since the forces that are required to deform a structure are very large.

Masonry materials such as stone and concrete compress elastically but will not stretch. Therefore, they are likely to crack when subjected to the stresses of temperature contraction.

For these reasons and others, most structures are designed with provision for expansion joints at intervals to take care of the normal movements of expansion and contraction and to relieve the thermal forces. Many types of joints in common use have been designed to do this, varying from open joints, simple planes of weakness, and elastite joints such as are commonly used in pavements, to the long interlocking fingered castings and sliding bar joints used in bridge work.

One Example

The all-welded expansion joint shown in Figure 9 is similar to those in the deck of a large bridge built in recent years. This joint is made entirely from rolled structural plates and angles at a great saving in cost by welding.

It is typical of many cases wherein welding has

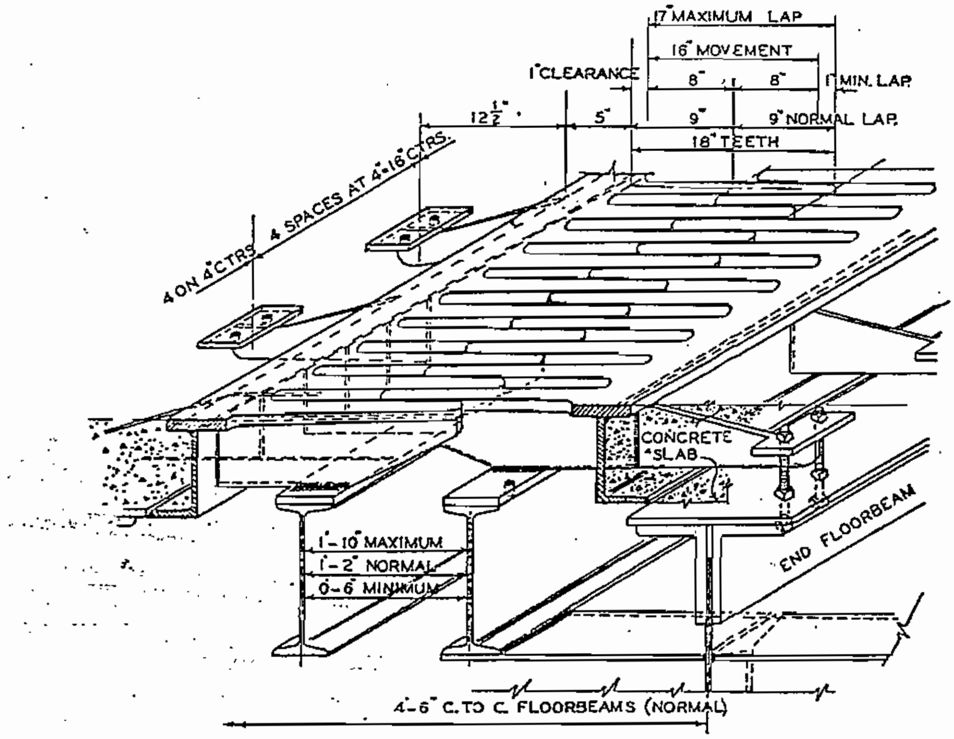

FIGURE 9

not only simplified and improved bridge deck designs but has also reduced the cost of the installation to considerably less than half the estimated cost of conventional type of segmental cast steel fingered joints.

The joint as shown provides for 16″ of movement computed at the rate of 1¼″ per 100′ for the 1200′ length of structure.

The joint (Fig. 9) is made in two halves, each half being symmetrical by rotating 180° with respect to the other half. The joint integral with the curbs, extends the full width of the 24′ roadway in one piece. This teeth. The slight side taper of ½″ in the length of the tooth adds to the clearance as the teeth are pulled apart. The 18″ length of tooth is determined by adding 1″ clearance at extreme expansion movements, plus a minimum lap of 1″ when the bridge is fully contracted to the 16″ of required movement.

The teeth are spaced on 4″ centers. This spacing is as small as practical in order to distribute the loads from the roadway surface over as many teeth as possible. It is also desirable in order to avoid having large holes between the teeth when the joint is open. The

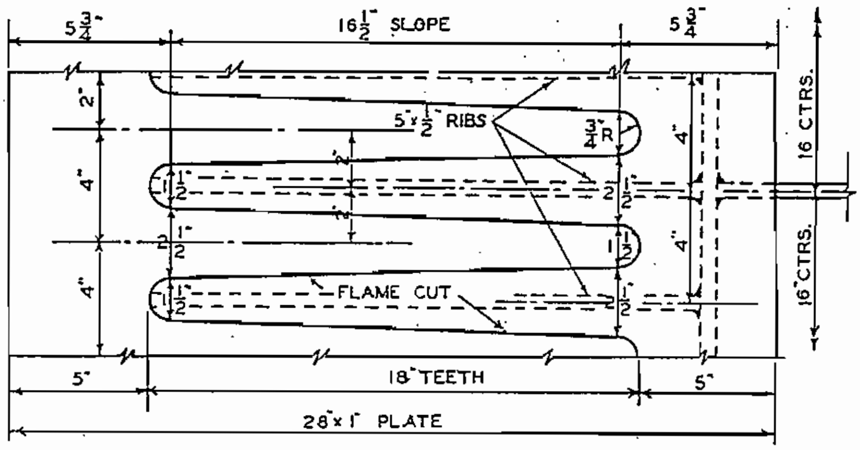

FIGURE 10

LAYOUT OF FLAME CUT TEETH

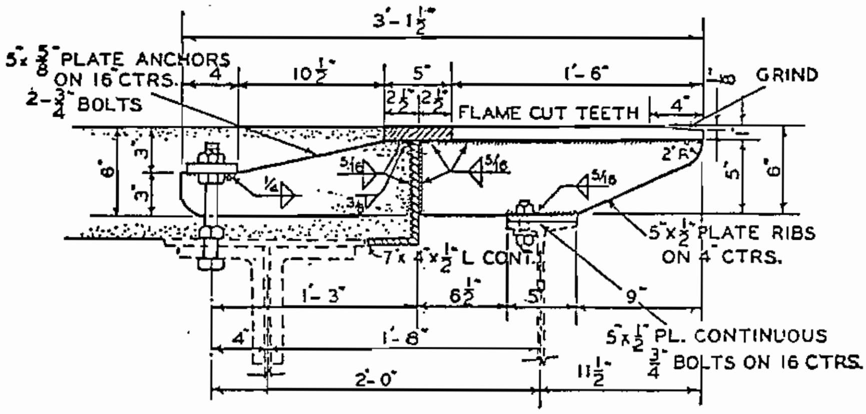

FIGURE 11

is fabricated to fit the curvature of the roadway crown.

The interlocking teeth which form the top surfaces on both sides of the joint are flame-cut in a single operation from a common 28″ x 1″ x 24′ plate as shown in the layout of Figure 10. The cut is made just wide enough to insure finish on both edges of the cut and to give proper clearance for the final meshing of the upper surfaces of the ends of the teeth are ground down and rounded slightly to insure a smooth transition of the loads from one side of the joint to the other.

The joint shown in Figure 9 is designed to support 16,000-lb H-20 truck wheel loads with 100% impact. This load is distributed equally to each of five adjacent teeth and is assumed to be applied on a contact area 3″ long, centered 1½″ from the end of the teeth. While in this extreme position, the teeth on only one side of the joint support the entire load. On this basis the depth of the web, the thickness of the plates, and other proportions are determined to support these load requirements.

The unusually long cantilevered projection of the teeth is reduced by supporting the teeth directly on an auxiliary end cross beam. The cross beams in turn are supported from the end floor beams at 10′-3″ intervals by means of cantilevered stringer brackets. The floor beams span 35′ center-to-center of trusses, and the trusses are supported on expansion rocker or roller bridge shoes.

The strength of the teeth in this case is obtained by continuously groove or fillet welding 5″ x ½″ x 1′-8½″ vertical web plate ribs to the underside of each tooth, as shown in Figure 11. The rear ends of these ribs are anchored for uplift by groove welding to the back of the 7″ x 4″ x ½″ slab closure angle. This angle is continuously welded to the 1″ surface plate, and serves also as a lateral distribution beam between the plate anchors.

Plate anchors composed of 5″ x ⅝″ x 1′-5″ web plates are welded to the rear of the joint opposite the web of every fourth tooth. These plates are spaced at 16″ centers, and each plate engages two ¾″ jacking bolts to the flange of the floor beam. These bolts serve both as erection bolts for setting the joint to elevation and grade, and as anchor bolts to hold down the rear of the joint against uplift caused by traffic. The plate anchors lap with the main longitudinal reinforcement bars in the slab for continuity, and the end of the concrete casts into the pocket formed by the surface plate and the 7″ x 4″ x ½″ angle.

The vertical leg of the 7″ x 4″ angle is flame cut to fit the curve of the roadway crown before welding to the 1″ plate. This helps to hold the joint in proper shape. The ribs are all held together at the bottom by welding to the 5″ x ½″ continuous plate bolted to the auxiliary cross beam.

The entire joint should be assembled in the shop with the cross beams and the field holes drilled to insure a proper fit in the field.

Field erection consists simply of setting the bridge shoes the proper distances apart, shimming the end cross beams to proper grade, and a final adjustment of the jacking bolts and the bolts to the cross beams. The concrete slab is then cast up to the joint around the anchors and cured, and the joint is ready for traffic.

One complete 24′ joint as shown in Figure 9 weighs 6250 lbs. This compares to an estimated weight of 8500 lbs for a conventional cast steel fingered joint.

This comparison indicates that the welded detail accomplishes a saving in metal weight of 26%, in addition to replacing expensive cast steel metal with rolled structural material. The relative cost of rolled metal is much less per pound.

7. ORTHOTROPIC DECKS

A very important type of floor construction is the orthotropic deck, in which all elements of the structure work together. Having principal application in the bridge field, orthotropic construction will be covered separately in the following Section 4.11.