systems building for steel bridges

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This paper describes component bridges used in Europe and South America. These bridges are designed on the sectional principle wherein individual parts are standardized and are fabricated with such accuracy that they can be interchanged and used on any point of the bridge. Three types of component bridges are discussed: fast-assembly bridge of the Rheinhausen type, D (from the German word for triangle) bridge, and SKB bridge. Discussion of both design and erection of these bridge types is presented.

Basically, there are two types of construction in steel bridge building: (a) bridges designed for clearly defined, unchanging conditions, built only once, and normally having a certain amount of time available for design, procurement, shop fabrication, and field erection; and (b) bridges designed for several purposes and varying conditions, for multiple reuse in different locations, for quick delivery and short erection time. Examples of the latter type are

1. Temporary road or rail crossover above a subway construction pit;
2. Temporary parallel diversion of road or railroad traffic while a permanent bridge is being built or replaced;
3. Temporary relief of brief traffic peaks during a trade fair, exhibition, or sporting event;
4. Quick elimination of danger points such as level crossings between road and rail traffic; and
5. Emergency replacement of bridges destroyed or damaged by a disaster.

Such tasks can only be fulfilled by bridge equipment that is kept in store, is quickly supplied, erected, and dismantled, and is suitable for reuse without loss in material.

COMPONENT BRIDGES

The first question is, What features must bridging equipment have in order to meet these requirements? The bridge must be designed on the sectional principle with maximum standardization of individual parts. By means of jigs and fixtures, the elements must be fabricated with such accuracy that they can be interchanged and used at any point of the bridge. Elements must connect and disconnect in the simplest way. This is best achieved by fitted bolts. The holes for fitted bolts have to be shop-drilled to the final nominal size. It must be possible to combine the individual elements into overall structures for many uses. The overall structure must have variable cross section, span length, bearing arrangement, and vertical and horizontal curvature.

After these general considerations, the next questions are, Where have bridges of this type been used? Have they performed well?

Various countries have developed and tested different kinds of bridge systems. The following are three types developed and tested by Krupp in West Germany:

1. The fast-assembly bridge of the Rheinhausen type, a bridging system for road traffic;
2. The D bridge, a bridging system for road traffic; and
3. The SKB bridge, a bridging system for rail and road traffic.

Fast-Assembly Bridge of the Rheinhausen Type

The dimensions of the fast-assembly Rheinhausen bridge system are based on bridge class 30 of DIN 1072. The standard lower chord design of the main girder permits span lengths of up to about 30 m. If the lower chord and possibly the roadway plate are specially strengthened greater span lengths can be obtained without difficulty. The Rheinhausen fast-assembly bridge is a deck bridge of all steel construction, with a lightweight steel deck. The completed bridge is formed by a beam grillage rigid in longitudinal and transverse directions and continuous over all supports. In operation, the roadway panel is jointless over the total bridge area. Web spacing of the structure is 3 m. Cross girders are provided at 6-m intervals. The fast-assembly bridge can be erected with or without walkways. Although the fast-assembly bridge is designed for temporary use, its design fully corresponds to that of permanent bridges.

The basic elements of the fast-assembly bridge are the main girders. They have an open cross section and consist of the top roadway panel with roadway ribs in transverse arrangement, the web plates, lower chords, and a welded-in cross beam in the center girder. Four variations are available: two-web or one-web design, each 12 m long, and two-web or one-web design of 6-m length. Main girders 6 m long are mostly installed at the bridge ends. They can be delivered with a uniform web height and also with raised web. A raised web design is advantageous in the case of a low ramp height. For all main girder types the web plate height is uniformly 1 m.

For a single-lane cross section, a two-web main girder element is used. If the useful lane width of 3 m is not sufficient, the roadway can be widened to about 3.20 m by enlarging the element and widened further to 3.80 m by the addition of a special curb. Two-lane and multilane cross sections are achieved by combining the necessary number of one-web main girder and two-web girder elements. In this manner useful roadway widths of 3, 6, 9, 12 m, and more are produced. In-between roadway widths are possible, too. For the fast-assembly bridge at Hannover, two-lane widths of 7.50 m were required. They were built by arranging two 3.20-m-wide two-web main girders at the outer borders of the cross section, with an intermediate plate of 1.10-m width. This cross-sectional design also offers the advantage of a two-lane cross section 7.50 m wide, which can be divided into two 3.20-m-wide single-lane roadways.

The main girder elements are normally straight units. If bridges are to have curvatures in the plan view or elevation, this curvature is approximated by a bent polygonal course with bends at the joints spaced 12 m apart. Its accuracy is sufficient for practical purposes. Curvatures in elevation have large radii, and the bends at the joints can be achieved by wedge-shaped drilled web butt straps. Curvatures in the plan view, however, may have very small radii. In this case, a wedge-shaped drilled butt strap arrangement may no longer be enough. Special wedge plates will have to be arranged at 12-m intervals to form the curvature needed. The dimensions of these wedge plates are variable, and they can be adapted to any curvature. As compared with a main girder uniformly curved, the design of a polygonal approximation of the curvature as stated would offer a great benefit so that, in many uses of the equipment with considerably different conditions of curvatures, only butt splices and wedge plates would have to be exchanged, whereas all main girder elements and cross girders would be used without any modification.

The versatility of this fast-assembly bridge design may be seen from the following five examples.

In Barcelona, a fast-assembly, 144-m-long, four-lane bridge was delivered. It had a useful roadway width of 12 m. The spans ranged from 13 to 18 m. In its plan view the bridge was straight. The maximum gradient was 10.6 percent. A synthetic coat was applied to the roadway. The weight of steel was 330 tons. This fast-assembly bridge served to cross a railroad line where the previous level crossing had resulted in interruptions of traffic.

A fast-assembly, 131-m-long, four-lane bridge with a useful roadway width of 12 m was erected in Caracas. The span lengths range from 27 to 37 m. In its plan view the bridge is straight, and its maximum gradient is 7.85 percent. The fast-assembly bridge crosses a small river and a highway and is intended to be in use for a long time. An asphalt coat was chosen for the roadway.

In Rotterdam a fast-assembly bridge was temporarily used to cross a road-building site. Its total length was 53.60 m, and it had a useful roadway width of 9 m and a span length of 26.80 m. Because of its short-term use, a synthetic coat was applied.

The most convincing example of the versatility offered by the fast-assembly bridge system in many locations is the bridge across the Aegidientorplatz in Hannover. This fast-assembly bridge has a central two-lane part of 7.50 m of useful roadway width and separate single-lane descents of 3.20 m useful width. The total length of the bridge is 726 m, 504 m allotted to the single-lane descent branches and 222 m to the two-lane central bridge. The span lengths range from 11 to 28.50 m. The maximum gradient is 6 percent; the crossfall of the deck ranges from 1 to 3 percent. In its plan view the bridge is greatly curved. The center angle of the arc is about 80 deg, and the radius of curvature is about 90 m. Because of its great length and the horizontal curve, the bridge length was subdivided into three independent sections separated by expansion joints. The roadway coating is a 1-cm-thick layer of mastic and a 2-cm-thick melted asphalt layer. The steel superstructure weighs 1.023 tons and the supporting structure 175 tons.

The fast-assembly bridge was erected to relieve the overloaded Aegidientorplatz during rush hours by a parallel overpass route in the second plane for the main flow of traffic. Another factor contributing to the bridge design was the subway construction site planned for the Aegidientorplatz region in the near future. The scheduled time of bridge use is at least 10 years. Erection work was carried out on 5 consecutive weekends. Road and tram traffic was interrupted on these weekends only in the actual erection area, whereas in the remaining sections the traffic was maintained. The bridge has been in service successfully for 4½ years. It is used with great frequency by all traffic including trucks and buses, although the at-grade routes are still available. The melted asphalt coat suppresses most of the traffic noises. Although the roadway is elevated to the window level of adjacent flats, there have been no complaints from residents about any noise nuisance.

The last example of this series is the fast-assembly bridge at Duisburg, Marientorplatz. It is 144 m long and is of two-lane design with 8.50 m of useful roadway width. Individual span lengths vary from 21 to 30 m. In its plan view the bridge is straight. The gradient ranges from 0.8 to 5 percent. The one-sided deck crossfall is 1.6 percent. The roadway coating is a 2-cm mastic layer and a 3-cm melted asphalt layer. The steel superstructure weighs 380 tons and the supporting structure 30 tons. The fast-assembly bridge is used as a temporary descent ramp from a permanent elevated roadway system in the second plane to the existing roadway level. The scheduled time of use is 5 years. Afterward the structure will be used at another location. Erection was carried out without any appreciable traffic impediments. Tram traffic below the bridge only had to be interrupted for a few hours on a Saturday night.

The D Bridge

The name D bridge is derived from the word Dreieck, i.e., triangle. The D bridge is designed for road and tram traffic. It can be of single- or double-story design. Its concept has been based on span lengths up to 95 m having a roadway width of 6 m, with loads based on bridge class 30 of German DIN 1072. The D bridge is a through bridge with trussed main girders. Its principal elements are the main girder triangle formed by two diagonals and the associated chord member and the loose single chord. The roadway main girder is built up from these elements. It may be single-story with a system height of 2.135 m, two-story with a system height of 4.27 m, or three-story with a system height of about 6.5 m. In all types of the D bridge design, one or even two bearing trusses per main girder may be arranged side by side. Additional chord reinforcements permit another increase in the allowable span length.

Except for the bridges equipped with a flat roadway, D bridges are provided with a lower wind bracing, whereas through bridges have an additional upper bracing, if necessary.

Several deck types have been developed for the D bridge: (a) timber decking on longitudinal and cross girders, (b) hollow structural steel plates on cross girders, and (c) flat steel decking without cross girders, of extremely low overall depth, extending from main girder to main girder. For the last type of roadway, special lower wind bracing is unnecessary.

The D bridge can be installed by the usual erection methods of structural engineering. A particularly advantageous and quick method is the launching of the D bridge. The total bridge can be completely assembled on one side of the obstacle and then launched into place. The launching nose required for this procedure can also be assembled from D bridge elements. About 50 D bridges have been placed in service in West Germany since 1960.

The SKB Bridge

The last example for standard bridge types is the so-called SKB bridge. It is a bridging system for single-track railroad traffic. Because the bridge has a deck cover that can also be used by road vehicles, it can simultaneously serve for road traffic. The SKB bridge is a further development of the SKR bridge, which was designed by Krupp in cooperation with the pre-war Deutsche Reichsbahn. Since May 1945, 39 SKR bridges have been set up in the present territory of the German Federal Railways. The SKB bridge, too, was developed by Krupp jointly with German Federal Railways.

The standard design of the SKB bridge is the through bridge with trussed main girders. Truss panel length is 6 m. The trussed main girders can be single-story with 6-m system height or double-story with about 12-m system height. As a single-span girder design, single-story bridges are used up to a span length of 84 m in railroad traffic (in road traffic up to 120 m), and two-story bridges up to a span length of 120 m in railroad traffic (in road traffic up to 162 m) in accordance with German specifications. The main elements of the roadway main girder are the chords, diagonals, and posts, all available in lightweight or heavy construction.

The roadway of the SKB bridge consists of the cross girders arranged in the panel points at 6-m intervals, the longitudinal girders, and the three cover panels. Single-story SKB bridges are provided with a lower wind bracing; for two-story SKB bridges the wind braces may be arranged in both the lower and upper chords.

So far the SKB bridge is the sole sectional bridge system in which deflection from permanent load, bolt tolerance, and a quarter of the live load can be compensated. SKB bridges, therefore, do not sag; they comply with all conditions for full-speed traffic.

The SKB bridge can be erected both by the cantilever method and by launching. To launch the bridge requires that stationary sets of roller boxes be used. The carrying capacity of the roller sets is 200 to 800 tons. The weight of the cantilever structure is minimized during launching by use of a special launching nose on the launching tip, which also consists of standardized SKB elements.

CONCLUSION

The three bridge systems described, the fast-assembly bridge of the Rheinhausen type, the D bridge, and the SKB bridge, fulfill all conditions for a system bridge stipulated in the beginning of the paper: They consist of standardized single elements; these elements are interchangeable; and they can be combined in a structure of high variability and versatile use. They can be delivered early, quickly erected, simply dismantled, and easily reused. Because the number of single elements is limited to as few as possible, stockage and storage, too, can be carried out at a small expenditure. The bridge parts can be stored either with the manufacturer or at any of the road-building authorities' storeyards. In addition to the typical buying and selling transactions, leasing transactions are also possible for short-term use of a system bridge.