Wearing Surfaces for Orthotropic Decks

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CHAPTER 8, "Wearing Surfaces", of the AISC *Design Manual for Orthotropic Steel Plate Deck Bridges*[1] contains the most complete descriptions of current steel deck surfacing systems and specific information on surfacing materials to be found in English language references. This paper presents new information on steel deck surfacing systems in use in the United States, systems proposed for three large orthotropic steel plate deck bridges being constructed or to be constructed in North America, and suggestions on novel components for surfacing systems that possibly justify consideration and further research.

Despite the number of unprotected steel plate deck bridges giving satisfactory service in this country, there is agreement that a steel plate bridge deck requires some type of surfacing. Most existing steel plate bridge decks employ "pattern" or "checkered" steel plates. Such plates have different regular patterns of metal projections on the plate surface. The principal objection to unprotected pattern plate for highway bridge decks has not been corrosion of the steel plate, but the low friction developed between the steel plate and rubber tires in most conditions of service. It is generally agreed that steel plate decks require surfacing to improve resistance to skidding. It then follows that the surfacing system must be impervious to moisture. Trapped moisture on a steel plate under a surfacing system, admitted through cracks or holes in the surfacing system, will create a corrosion condition considerably worse than if the surfacing system were not present. The importance of the steel plate deck in orthotropic plate construction, as a member to distribute loads to stringers and as the top flange of stringers and floor beams, requires that the steel deck not be subject to corrosion. Thus, the two foremost requirements for a steel deck surfacing system are that the system must not admit moisture to the steel plate and the surface of the system must provide good resistance to skidding.

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The following are the principal requirements for a steel plate deck surfacing system:

1. The surfacing system must be lightweight to achieve a minimum dead load on the bridge structure.
2. The surface of the system should provide good skid resistance in the wet and dry conditions over a long period of service.
3. The system should be stable and durable over the expected service temperature range; it should have a high resistance to shoving, rippling and other deformations resulting from acceleration and braking of vehicles.
4. The system should be of sufficient thickness to compensate for normal fabrication tolerances and discontinuities in the steel deck and adequate to provide an even and plane wearing surface. Some engineers feel the surfacing systems should also be of sufficient thickness to reduce noise and dampen vibrations caused by vehicles passing over the steel deck.
5. The system should provide positive and lasting protection to the steel deck plate. It should be impervious to moisture and chemicals, and resist the shear resulting from composite action of the steel plate and the surfacing system.
6. The system should be easy to maintain and repair. While a minimum of maintenance over a long period of time is desired, it must be recognized that some repair will be required with any system. When required, the system must be able to be repaired quickly, easily and inexpensively.

WEARING SURFACES ON EXISTING BRIDGES

It is truly said that there is nothing new under the sun. Orthotropic steel plate decks are not new. Editions of the *Carnegie Pocket Companion* dating back to 1923 contain information on "buckle-plate", "trough-plate" and "corrugated-plate" flooring systems—all stiffened plate decks. These flooring systems were generally covered with portland cement or asphalt concrete. In the early 1930's the "battledeck floor" gained attention as a solution to providing lightweight decks for highway bridges. The battledeck floor, an orthotropic steel plate deck, is composed of a smooth flat steel plate supported and stiffened by steel I-beam stringers uniformly spaced laterally and attached to the underside of the plate. Plate thickness and size and spacing of the I-beams depend on the loading and span or floor beam spacing. The results of a research project on the strength of battledeck floors are contained in a paper by Inge Lyse and I. E. Madsen.[2] Model and full-size panels of battledeck floors were tested at Lehigh University to develop the design provisions given in Reference 3 published in 1938.

It is interesting to review the history of one of the full-size panels used in the above-mentioned project. This panel, 9 ft-5 in. wide by 17 ft-6 in. long, composed of an 11⁄16-in. thick steel plate and 12-in. deep American Standard I-beams weighing 31.8 lbs per ft spaced on 26-in. centers, was installed in a roadway in the Saucon Plant of Bethlehem Steel Co., Bethlehem, Pa., in the fall of 1937 to develop information on a lightweight surfacing system for steel battledeck floors for bridges. The panel is located on a sharp curve in the inbound lane of the roadway leading from the main gate of the plant. The panel spans a trench dug in the roadway for the project. The I-beams of the panel are supported by continuous concrete piers at the ends of the trench. Prior to installation, the plate surface had been coated with one coat of a mixture of red lead paint and linseed oil. After installation, the plate surface was coated with one coat of a proprietary emulsified asphalt applied with a brush. A covering coat composed of a mixture of the asphalt emulsion, portland cement, foundry sand, crushed stone having a maximum size of 3⁄8-in. and enough water to make the mixture the consistency of soft clay was applied to the plate. The mixture was spread with a trowel to a thickness of 3⁄8-in. and compacted and smoothed with a 280-lb float. During the two years following installation some fine shallow-depth cracks appeared on the surface. These were filled with a mixture of neat asphalt and water and the surface was dusted with portland cement. This panel has now been in service for 26 years, withstanding heavy usage under normal and heavier than normal highway loadings with only minor repairs. Progress reports on the project were issued by AISC in 1939[4] and 1941.[5] The panel has recently been resurfaced and will continue to provide a lightweight, low-cost, low-maintenance deck for many years. This very simple surfacing system and its remarkable performance is worthy of consideration for our modern steel plate decks. It is understood that another progress report on the project is in preparation.

Battledeck floor systems were used on the Harlem River Lift Bridge and on the Bronxkill Bridges which form a part of the Triborough Bridge in New York City under the jurisdiction of the Triborough Bridge and Tunnel Authority. The Harlem River Bridge is a through-truss lift bridge having a span of 310 ft. The bridge has three lanes in each direction and no trucks are permitted on the bridge. The Bronxkill Bridge is a fixed through-truss bridge, 350 ft in length, and has four lanes in each direction. Trucks are permitted on this bridge. The bridges were opened to traffic in 1936. Although deicing salt is not used on either bridge, it is reasonable to assume that over the past 27 years many gallons of salt brine have been deposited on the bridge decks as drippings from cars.

The battledeck floors on both bridges are composed of 5⁄8-in. thick steel plates on 7-in. deep I-beams weighing 20 lbs per ft on 26-in. centers. The plates and beams are made of structural silicon steel, the old ASTM A94 steel. The deck surfaces were divided into 10-ft wide lanes and 22-ft long lengths in each lane by 13⁄16-in. high by 3⁄8-in. wide rectangular steel bars tack-welded to the plate to provide lateral and longitudinal support for the surfacing. The plate surface was brush cleaned and coated with one coat of red lead paint followed by a coat of asphaltic cement. Asphalt planking measuring 12-in. wide by 24-in. long by 1-in. thick was then placed on the 10-ft by 22-ft panels with transverse joints in adjacent rows of planking staggered. The planks had the following specified composition by weight; asphalt up to 50%, mineral filler from 35 to 45% and organic fiber not less than 12%. After manufacture, 3⁄4-in. trap rock was pressed partially into the plank wearing surface at the manufacturer's plant. The protruding stones were to provide improved traction for vehicles. It should be noted that planks for the two bridges were made by different manufacturers and were placed by different contractors.

Over the past 27 years, individual planks on the Bronxkill Bridge have often required replacement. In contrast, the surface on the Harlem River Bridge has required very little maintenance. In recent years, traffic on the Triborough bridges averages 140,000 vehicles per day as determined from toll records. Because the protruding stones in the planks became worn and polished, making the surface slippery, the Authority decided to resurface the 47,000 sq ft of the two bridge decks with new planking at a cost of $97,000. Unfortunately because the original suppliers were unable to furnish planking to the original specifications, the Authority has resorted to another system for resurfacing.

In September, 1963, the original wearing surfaces of both bridges were removed. Examinations of the condition of the steel plate decks indicate that the performance of the planking on the Harlem Bridge was excellent and on the Bronxkill Bridge was good. Some minor pitting of the steel plate due to corrosion was observed along lines under joints between adjacent planks. Again, a relatively simple surfacing system has given remarkable performance and is worthy of consideration for our modern steel plate decks.

The California Division of Highways has had experience with wearing surfaces on two steel deck plate bridges. The Smoky Gulch Bridge, built in 1950, is located in a hot, dry desert area on a 6% grade. The original 3 in. thickness of an asphaltic-base material did not adhere in many locations and began to deteriorate after a few days in service. The remaining sound surface was given a coat of asphaltic emulsion and a patch coat about 1-in. thick, followed by an asphaltic emulsion seal coat. With only minor repairs this surfacing has performed satisfactorily for the past 13 years. The Ulatis Creek Bridge, built in 1952, is located between Sacramento and San Francisco where temperatures range between 20° and 110° F. Two types of 7⁄16-in. thick deck plates, checkered and smooth plates, and two types of surfacing systems were used on the bridge. Where a ¼-in. thick rubber-latex asphalt emulsion with screenings was used, results were initially good, but where rubber-latex with lumnite cement and screenings was used, results were poor. The checkered plate showed some advantage over the smooth plate by providing a better bonding surface. In 1956 the entire surface of the Ulatis Bridge was smoothed to remove high spots and excess screenings, and a new asphalt-latex surface with screenings was applied. Except for some roughness in the truck lanes, the new surfacing has been satisfactory. In mid-1963, the California Division of Highways applied a thin surfacing coat on a 20-ft widened section of the Ulatis Bridge. This surfacing coat consists of a coal tar modified thermo-setting epoxy resin with aluminum oxide aggregate. Because the widened section of the bridge carries a heavily traveled truck lane, any deficiencies in this epoxy surfacing system should occur in a short period of time.

Use of epoxy resin in surfacing two steel deck plate bridges in Philadelphia are discussed in Reference 1. These bridges are surfaced with an abrasive aggregate imbedded in an epoxy and coal tar epoxy compound. Recent reports indicate that the surfacing systems on the two bridges are performing satisfactorily

Reference 1 also describes the Belgrade-Save River Bridge which has a surfacing system composed of quilted aluminum foil cemented to the steel deck plate with a mopped-on coat of hot asphalt followed by two courses of asphalt concrete providing a total thickness of 2½-in. The bridge was opened in 1956 and is subject to temperature extremes from −13° to 113° F. During winter months deicing salt is used freely on the bridge surface. In August, 1963, Dr. T. R. Higgins, Director of Engineering and Research, AISC inspected the wearing surface of the bridge.[6] He found the surface in excellent condition. The Yugoslav Bridge Director's office estimates that some spot renewal may be required in four or five years. Deterioration of the surface is caused by oil and gasoline dripping from passing vehicles.

PROPOSED SURFACING SYSTEMS FOR NEW BRIDGES

Mr. E. J. Shields, Sverdrup & Parcel and Assoc., Inc., has, elsewhere in this Journal, described the first modern orthotropic steel plate deck bridge to be built in the United States, the Poplar Street Bridge at St. Louis, Mo. Realizing the importance of the selection of a satisfactory roadway wearing surface and provisions for positive protection of an orthotropic deck plate from corrosion, prior to recommending the orthotropic plate design the States of Illinois and Missouri and the firm of Sverdrup & Parcel conducted sufficient research to provide assurance that a satisfactory surfacing system could be developed. A four-component surfacing system was adopted: 1) a protective coat for the steels, 2) an air and moisture-proof sealant, 3) a 1½-in. maximum asphalt leveling course and 4) a 1-in. asphalt wearing surface. A limited laboratory research program[7] was conducted on different products and mixes for the different components at the Kentucky Research Foundation of the University of Kentucky, Lexington, Ky. The most promising of the products and mixes investigated are currently under test on a 24-ft wide by 40-ft long orthotropic plate deck bridge located on U. S. Route 40 near Troy, Ill. The deck plate, stiffeners and floor beams of the test bridge are similar to those to be used in the Poplar Street Bridge. The test bridge on this heavy truck traffic highway was opened to traffic in November, 1962.

The steel deck plate of the test bridge was blast-cleaned to "white metal" and given a 5-mil thick metalizing coat of zinc. Two different coal tar epoxies were used for the seal coat, each on half the bridge. Two spray coats were applied, and, in the second coat, a sand grit was sprinkled in the wet epoxy to provide anchorage for the subsequent asphalt courses. A tack coat followed. The deck surface area was divided into four 6-ft wide strips extending parallel to traffic, and four types of asphalt pavement were placed in approximately half-length strips in each traffic lane. Two areas were chosen for each type pavement so that each pavement was subjected to different plate deflection contours. The asphalt pavement mixes were put down in two courses as mentioned previously. The types were: Type I, asphalt concrete with liquid latex additives in both courses; Type II, asphalt concrete with asphalt rubberizer in both courses; Type III, leveling course same as Type II and wearing course of sand asphalt with asbestos fiber and liquid latex additives; and Type IV, asphalt concrete with asbestos fiber additive in both courses.

After having been subjected to a severe cold winter (1962–1963) and a very hot summer (1963), each type pavement appears to be in good condition. In an inspection made by the author in February, 1963, no evidence of cracking of the surface was found. Moisture appeared to be present in the surface at the interfaces of the different strips and at the end dams. The different types of pavement have different surface roughnesses which may influence skidding resistance. Determination of the materials to be used on the Poplar Street Bridge will be deferred until just prior to the scheduled application of the wearing surface on the bridge probably during the summer of 1966.

Another orthotropic steel plate deck bridge currently under construction is the Port Mann Bridge in British Columbia, Canada.[8, 9] The bridge spans the Fraser River and forms a link in the Trans Canada Highway. The bridge is a stiffened tied-arch having a main span of 1200-ft and end spans of 360-ft each. The 1920-ft total length has a steel plate deck composed of $\frac{7}{16}$-in. and $\frac{1}{2}$-in. plates stiffened with $\frac{5}{16}$-in. cold formed U-shapes, both made of a killed and normalized high-strength low-alloy steel. The following information concerning the surfacing system to be used on the bridge was furnished by Mr. G. Hardenberg[10] of C.B.A. Engineering, Ltd., Vancouver, B. C., consultants to the British Columbia Highway Department on the bridge. The steel deck will be blast cleaned and coated with an epoxy red lead primer, and subsequently sealed with a coal tar epoxy seal coat at a rate of 40 lbs per 100 sq ft. Before the seal coat has cured, small stone chips will be broadcast over the surface with the intent to form an anchor for the asphalt paving because epoxy coatings do not have sufficient adhesion to asphalt concrete. The chips will be covered with an emulsion tack coat prior to placing a 2-in.-thick layer of asphalt concrete. A number of proprietary coal tar epoxy coatings are currently being tested. It should be noted that the surfacing systems to be used on the Port Mann and Poplar Street Bridges are similar.

Another bridge to utilize an orthotropic steel plate deck, currently being designed, is the San Mateo-Hayward Bridge in California. This bridge is to be built by the California Toll Bridge Authority. Approximately 5000 lineal feet of the bridge will be orthotropic plate deck construction. Faced with the problem of designing a surfacing system, the Authority has undertaken a program of tests on samples of different combinations of surfacing system components. The following materials are being considered:

Corrosion protection:
: Sprayed metallic zinc or a zinc-filled self-curing inorganic coating.

Tack coat:
: Liquid asphalt or epon asphalt applied hot.

Surface course:
: $1\frac{1}{2}$-in. asphalt concrete or $1\frac{1}{2}$-in. epon asphalt applied hot.

It is apparent from this discussion that much uncertainty exists in regard to components for surfacing systems for orthotropic steel plate decks. Specifications are urgently needed to eliminate the costly and time consuming evaluations of different products that must be made prior to designing a surfacing system. Currently, the German Committee for Steel Construction has a program to investigate a number of surfacing systems and surfacing system components. The results of this program will be used in preparing specifications for surfacing systems. At present, wearing surfaces for orthotropic steel deck plates for bridges in Germany are prepared and tested in accordance with a *Tentative Leaflet on Bituminous Wearing Surfaces for Light Surfaces on Steel Deck Bridges*, issued by the Federal Ministry for Transport. In the United States, the American Iron and Steel Institute is engaged in a program to develop information on which to base specifications for surfacing systems for orthotropic decks.

SUGGESTED COMPONENTS FOR SURFACING SYSTEMS

It has been reported that coal tar coating compositions have less permeability to moisture than asphalt-based products. It is suggested that coal tar products be considered as the prime or seal coats on orthotropic decks.

It is known that the thickness of a paint film on an irregular surface is not uniform. As paint films dry they tend to shrink from projections and sharp edges. Thixotropic paint compositions do not exhibit this tendency. It is suggested that thixotropic-type compositions be considered for use on plate decks.

A number of chemical companies have introduced a number of new surfacing materials. Some of these materials exhibit good toughness, resilience and surface characteristics which provide a high degree of traction, even when subjected to atmospheric temperature extremes. It is suggested that such materials when bonded to a steel deck may provide a satisfactory surfacing for orthotropic decks.

Finally, it is suggested that the possibilities of using surfacing systems composed of polyester-bound aggregate and coal tar concrete paving mixtures be investigated for possible use as wearing surfaces on orthotropic decks.

CLOSURE

Although steel plate decks have been used for highway bridges for the past 25 years, the problem of designing a satisfactory surfacing system has not been resolved. Surfacing systems in use and proposed for modern orthotropic plate decks are considerably more complex than the simpler systems used in the past on battledeck floors. Information obtained from inspection of satisfactory systems on battledeck floors in the United States, from experience with systems on modern orthotropic decks in Europe and the United States, and from current research on systems and system components in the United States and Germany should provide a basis for preparing public specifications for satisfactory, lightweight and low-cost surfacing systems for orthotropic steel plate decks. It is expected that having such specifications, highway bridge engineers will adopt orthotropic plate deck bridge construction for bridges other than the monumental long span bridges currently employing orthotropic construction.

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