Old Bridges Give Clues to Steel Deck Performance

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WHENEVER STEEL DECK bridges are discussed, the question invariably arises: How well do the steel decks perform over the years? More specifically: How safe is a steel deck against corrosion? How good must the wearing surface be to protect it adequately? Is there a danger that the steel deck, with the top surface normally not accessible, will deteriorate under the surfacing?

The answers to these questions are provided by actual experiences with steel deck bridges.

The oldest of the new ("orthotropic plate") type steel bridge decks in Europe are, by now, 15 years old. Some steel deck structures of older types are more than twice that age, and considerable experience with them has been accumulated.

In this country, steel deck bridges of the new kind are still in the design or pre-construction stage. However, there are many "battledeck floor" type bridge structures in service, built in the 1930's.

Two notable examples are the Harlem River Bridge and the Bronx-Kill Bridge in New York City built in 1936 and recently resurfaced. The writer had an opportunity, on behalf of American Iron and Steel Institute, to investigate the conditions of these steel decks after 27 years of service.

The observations made[1] offer some clues to the questions raised.

Both structures are located on the approaches to the New York City Triborough Bridge; one of them (the Harlem River Bridge) provides connection to the Franklin D. Roosevelt Drive and the local streets in Manhattan, the other connects with the Major Deegan and Bruckner expressways. Traffic on both bridges is extremely heavy with the difference that the Harlem structure carries few trucks, while the Bronx span has a very large amount of truck traffic.

Figure 1 shows the cross section of the 6-lane Harlem River Bridge, a 310-ft lift span.

The cross section of the Bronx-Kill Bridge, a 350-ft fixed span structure, is very similar, except that the bridge is wider and has eight lanes.

ORIGINAL SURFACING

Both bridges were originally paved with 1-in. thick mineral-surfaced asphalt planks, 24 in. long and 12 in. wide. The steel deck was painted with red lead and the planks were bonded to the deck with asphalt cement. More complete details of the original plank surfacing are given in Section 8.3 of the AISC manual for steel plate deck bridges.[2]

Performance of the planking on the Harlem River Bridge was quite good, and at the time of repaving about 70 percent of the deck was still covered by the original plank. However, performance of the Bronx span planking was definitely less adequate, and almost all of the planking had been replaced during the 27 years.

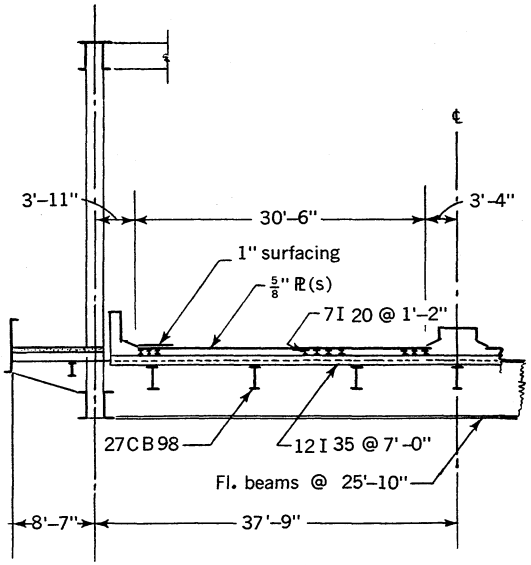

Fig. 1. Cross section of Harlem River Bridge

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1. Report on Repaving of the Harlem River Bridge and the Bronx-Kill Bridge (*unpublished*), *submitted to American Iron and Steel Institute by Roman Wolchuk, Consulting Engineer, New York, September, 1963.*

2. Design Manual for Orthotropic Steel Plate Deck Bridges, *American Institute of Steel Construction, New York, N. Y., 1963.*

There are indications that the difference in performance of the planking on the two bridges was due, primarily, to the difference in the quality of the original plank and the difference in method of placement of the planks on the deck.

The manner of placement of the plank is responsible for its bond to the deck and is very important because deterioration starts as the bond along the plank periphery is broken, and the plank begins to crumble at the edges, progressively exposing the deck (Fig. 2).

Regarding deck protection provided, it should be noted that asphalt planking even in its original condition cannot prevent access of moisture to the deck at the joints between the plank. Although the Triborough Bridge and Tunnel Authority, owner of the bridges, does not use snow melting salts on its structures, it can be assumed that the decks are not free from contamination by salts in wintertime, since salts are used freely by the city of New York on the approach expressways.

The decision by the Triborough Bridge and Tunnel Authority to repave both bridges with a 1-in. thick course of asphalt concrete rather than with asphalt plank was motivated primarily by the high cost of planking (about three times that of the asphalt concrete) and the fact that high-quality paving plank, to match the quality of the original paving, could not be supplied by the manufacturers.

PLANK REMOVAL AND DECK CLEANING

Repaving operations started with removal of the planking, using a 7 ton front end loader and manual labor.

Adhesion of the plank to the deck was very strong, and the bond was unbroken under the middle portions of the planks (Fig. 3), where the original asphalt cement was found to be still tacky. Around the periphery of the planks the bond was broken over a width of 2 to 4 in., and dust from the pulverized bituminous coating and the plank material had accumulated there. Whatever corrosion effects were found, were confined to these narrow strips along the edges of the plank.

CONDITION OF THE DECKS

After removal of the planks, lumps of asphalt sticking to the deck were scraped, and rust scale, generally present under the plank joints, was removed with air operated wire brushes. Most of the deck area, after cleaning, was still covered by the original red lead paint, occasionally overlaid with a coating of asphalt cement.

Typical conditions of the deck are shown in Figs. 4 and 5.

The effects of corrosion consisted of streaks of shallow pock marks, pits and scars following the outlines of the planks where the bond between the deck and the plank had failed. Outside of these strips, generally from 2 to 4 in. wide, the deck was not affected by corrosion.

Depths of corrosive pits and scars in the deck surface ranged in typical cases from 4 to 40 mils. Depths were measured directly by a dial indicator which could be moved horizontally along a steel base. Fig. 7a shows a characteristic profile across the affected strip corresponding to the conditions shown in Fig. 4; Fig. 7b shows a similar profile corresponding to the somewhat deeper scars in Fig. 5.

Deeper and more extensive pits were observed only infrequently. Figure 6 shows a cluster of pits and scars, surrounded by an area entirely unaffected by corrosion; the corresponding cross section is given in Fig. 7c. It shows that the depth of pit measured from the original steel deck surface was about 75 mils, or somewhat less than $\frac{1}{16}$ in. The deepest pit recorded anywhere on the decks was 115 mils. In general, however, conditions shown in Figs. 8a and 8b were typical.

In addition to dial indicator measurements of the top surface conditions, total thickness measurements of the deck plate were made in several locations with an Audigage ultrasonic instrument.

Fig. 2. Deteriorated original planking, Bronx-Kill Bridge

Fig. 3. Removal of planks by pick. Shiny surfaces are areas where the bond between the plank and the deck was intact

The readings consistently indicated a plate thickness in excess of the original nominal thickness of ⅝ in. or 625 mils and generally ranged from about 635 to 645 mils. This excess thickness indicates the usual mill overrun of a nominal ⅝ in. plate. The Audigage measurements confirmed that there was no overall loss of the specified plate thickness, and that no appreciable corrosion loss had occurred on the under side of the deck, which was not accessible for inspection.

Thus, the steel decks have been found to be in good structural condition after 27 years of service.

THE NEW SURFACING

The broom-clean deck received a hot asphalt tack coat (100 percent bitumen 60–70 penetration) of 0.05 to 0.10 gallons per square yard. Though this relatively small quantity did not form a continuous membrane, it was believed that a larger amount of bitumen may cause instability of the overlaying asphalt concrete.

Fig. 4. Dial indicator measurements of typical deck surface condition. Corresponding profile is shown in Fig. 7a

The composition of the asphalt concrete mix was as follows:

	Weight (%)
1. Stone (crushed trap rock, ¼ in. max. size)	24.3
2. Sand (coarse, natural)	58.0
3. Limestone dust	5.0
4. Asbestos fibers 7MO6 (7M Grade by Quebec Standard screen test, min 6.3 percent retained on 10 in. mesh, max., 25 percent passing 65 mesh)	3.1
5. Asphalt, 60–70 penetration (Specification M5 of N. Y. State Department of Public Works)	9.6
	100.0%

After an initial adjustment, the approximate aggregate gradation, including the limestone dust and the asbestos was as follows:

Sieve Size	*% Passing*
⅜ in.	100
#4	90
#10	68
#40	36
#80	14
#200	10

The characteristic feature of this mix is the relatively high bitumen content of 9.6 percent, which tends to improve the density and impermeability of the pavement. A recent report indicates that such an increase of

Fig. 5. View of typical deck surface condition, revealing only shallow corrosion marks and pits. Corresponding profile is shown in Fig. 7b

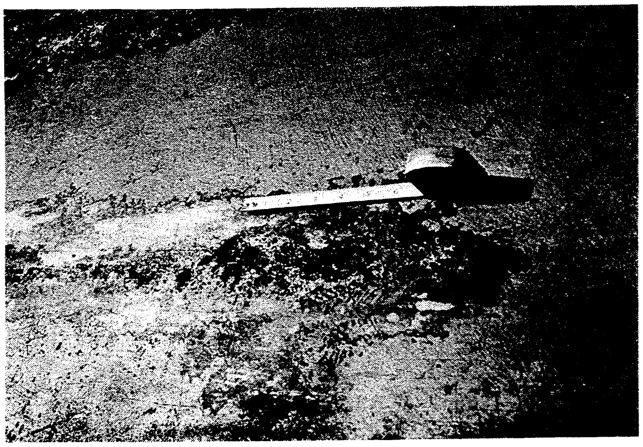

Fig. 6. Deeper corrosion pits, observed infrequently. Surrounding area unaffected by corrosion. Typical profile in Fig. 7c

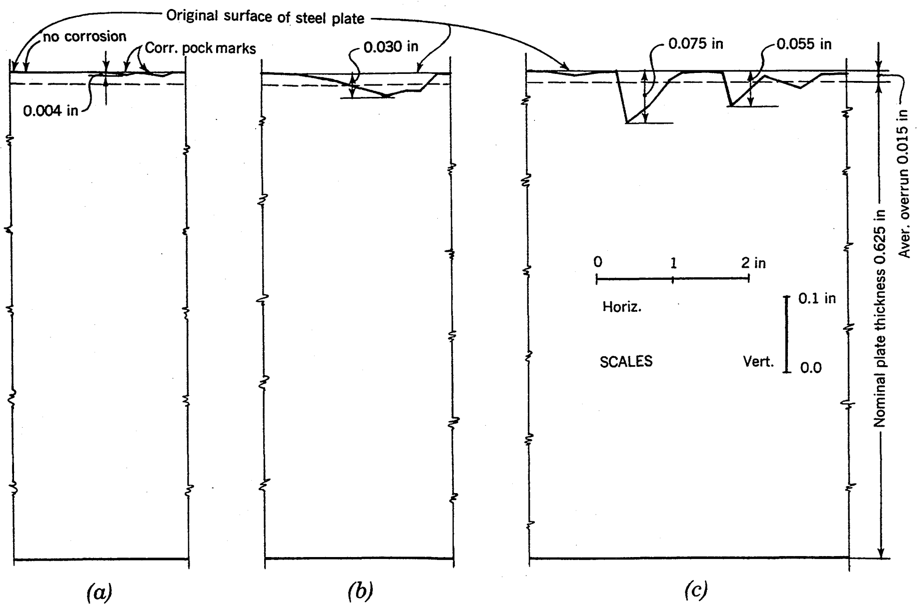

Fig. 7. Typical deck surface profiles
(*a*) *Profile corresponding to Fig. 4*
(*b*) *Profile corresponding to Fig. 5*
(*c*) *Profile corresponding to Fig. 6*

asphalt content without sacrifice of stability is possible if asbestos fibers are added to the mix.[3]

The new pavement has a smooth sandpaper-like surface texture. The friction value has been found satisfactory. The pavement has successfully withstood its first winter under traffic.

DISCUSSION

From the measurements and observations of the conditions of the steel decks discussed above it is seen that deck corrosion during 27 years of service was minor, and that the structural strength of the decks was not impaired.

It is well to note that the decks were covered with a plank surfacing that could not and did not prevent the penetration of water to the deck at the joints between the planks, and that the water may have been contaminated by salts during wintertime.

One of the reasons why little damage to the decks occurred under the surfacing may be that even though moisture could be absorbed and held by the dust in the joints, there was not enough fresh atmospheric oxygen necessary for corrosion.

Thus, if the experience with the Harlem River and Bronx-Kill bridges is any indication, it appears that the danger of deterioration of steel bridge decks by corrosion is not very acute, even if the wearing surface is not perfect. This view is supported by the experiences with European steel deck bridges, built both before and after World War II.

Such findings may also be of importance in establishing the criteria for the design of wearing surfaces on steel decks.

Basically, a wearing surface has to satisfy two requirements: (1) provide a durable, stable and skid-resistant riding surface, and (2) protect the deck against corrosion. In the light of these observations, it seems that primary attention ought to be directed to the first problem, while the second one appears to be much less critical.

Regarding the first objective, a good and lasting bond between the surfacing and the deck is one of the main factors determining the durability of the surfacing, as is evidenced by European experiences.

With regard to the second objective, bond is also a decisive factor. The observations on the Harlem River and the Bronx-Kill bridge decks clearly show that where the bond was intact, there was no corrosion. On the other hand, the fact that even under faulty surfacing corrosion damage was not significant suggests that costly multilayered wearing surface systems expressly devised for protecting decks against corrosion may be superfluous, and that simple and less expensive surfacings, well bonded and otherwise equal to the traffic demands, should suffice.

In conclusion, it may be said that the observations made on the two steel deck bridges offer a reassuring answer to the question of steel deck performance. This should give encouragement to the bridge engineers contemplating the new steel deck system for their structures.

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[3] The Performance of Asbestos-Asphalt Pavement Surface Course with High Asphalt Content *J. H. Kietzman, M. W. Blackhurst and J. A. Foxwell, presented at the Meeting of the Highway Research Board, January, 1963.*