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Timber Bridge Replacement to Resist Deicing Agents

Remplacement de ponts en bois en vue de résister aux agents dégivrants

Ersatz durch Holzbrücken zum Widerstand gegen Enteisungsmitteln

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SUMMARY
Deterioration of bridge structures in Western Pennsylvania, USA accelerated greatly after instituting a deicing-agents snow removal program approximately 17 years ago. The steel and concrete structures began to show gross weaknesses, and a need to examine and repair or replace the 1700 bridges in Allegheny County was exposed. Agents are still used, but timber is again being competively installed to resist the deicing attacks. Durability and other benefits are described in this paper.

RESUME
La détérioration de ponts en Pennsylvanie occidentale, USA, s'est grandement accélérée suite à l'introduction, il y à a peu près 17 ans, d'un programme de déneigement à l'aide d'agents dégivrants. Les structures en acier et en béton armé, commencèrent à manifester de grandes faiblesses, et il fut nécessaire d'examiner et de réparer ou de remplacer les 1 700 ponts au Allegheny County. Les agents sont toujours en usage, mais le bois de charpente peut de nouveau être installé d'une manière concurrentielle, afin de résister aux attaques des dégivrants. La durabilité et les autre avantages sont décrits.

ZUSAMMENFASSUNG
Die Einführung von Enteisungsmitteln in das Schneeräumprogramm vor ungefähr 17 Jahren hat den Verfall der Brückenstrukturen in West-Pennsylvanien, USA, stark beschleunigt. Stahl- und Betontragwerke begannen grosse Schwächen aufzuzeigen, was die Notwendigkeit zur Überprüfung, Reparatur oder Ersatz der 1700 Brücken im Bezirk Allegheny aufdeckte. Enteisungsmittel sind immer noch im Gebrauch, aber Holz ist wieder konkurrenzfähig wegen seines Widerstandes gegenüber Enteisungsmitteln. Dauerhaftigkeit und andere Vorteile der Holzbauweise sind in dieser Arbeit beschrieben.

BACKGROUND AND CAUSE OF PROBLEM

Three major rivers, a center of population and industry (Pittsburgh), and 1700 bridges characterize Allegheny County, Pennsylvania, U.S.A. Some of these bridges were originally of timber, but during the 1950s, most timber bridges were replaced. Current bridges, with the exception of those described herein, are generally of steel and concrete. In previous years, winter traffic passability was maintained by coal cinders. More recently, deicing salts have replaced cinders due to environmental constraints on coal burning.

After a few years of using deicing salts, first the deterioration of vehicles was noticed and, thereafter, rusting or spalling of bridges was observed. It was estimated that bridges of concrete and steel subjected to deicing salts would have to be replaced in a 15-year cycle. Because timber is relatively immune to attack by deicing salts and if properly treated with preservatives will not decay in the weather conditions prevailing in southwestern Pennsylvania, plans were made to install wood bridges in Allegheny County. Two case studies of wood bridges follow.

BRIDGE DESIGN CRITERIA

In decreasing order of importance, bridge parameters considered by the authors in designing the bridge were:

-1. Span length; which governs material properties.

-2. Loading; which determines member sizes.

-3. Initial cost of material and construction.

-4. Estimated life expectancy under action of deicing agents; which is used in economic comparisons.

-5. Estimated maintenance costs; these are to be used in economic comparisons.

-6. User costs due to delay and rerouting of traffic while bridge is out of service.

-7. Aesthetics.

-8. Construction time; this relates to the cost to the owner of providing inspectors and office personnel to audit the performance of the contractor.

In times past, only Items 1, 2, 3 and 7 were weighed heavily in the decision process. Item 4 had not been considered because the life expectancies of the various bridge materials subject to deicing salts were not significantly different. Item 5 is now of consequence because of the high cost of labor and materials required to maintain concrete and steel bridges subject to deicing salts. User costs as reflected in Item 6 have sharply increased recently as the cost of vehicle fuel has increased.

CASE STUDIES

Two case studies are presented. The first deals with a deck replacement and the second with the replacement of the entire bridge structure. In 1947, a steel beam bridge structure with a mechanically laminated wood deck was constructed in Allegheny County, Pennsylvania, U.S.A. Thirty years later the deck had become weakened from use without a protective wearing surface. Where the wood had been worn from traffic and damaged with snow plows, decay by natural organisms had done the damage that water, temperature, and deicing agents had not been able to do, as shown on Photograph 1.

The 61 ft (18.6 m) span with two nine-ft (2.7 m) lanes and a four ft (1.2 m) sidewalk was designed to carry coal trucks weighing 60,000 lb (27,215 kg) to a mining site. The rehabilitated structure was to be able to carry 73,280 lb (33,239 kg) trucks in an AASHTO (American Association of State Highway and Transportation Officials) HS-20-44 configuration in two 11-ft (3.3 m) lanes while continuing to support the cantilevered sidewalk, as shown on Photograph 2.

The owner wished to consider several alternative materials, including reinforced concrete, steel grid, concrete filled steel grid, and glue-laminated timber. Timber was chosen because it had the lowest initial cost, the most pleasant appearance in the wooded surroundings and a greater service life than concrete and steel where deicing agents are heavily used. The relative costs per square foot (square meter) for the deck alternatives, excluding approach and stream work, were $37 ($400) for timber, $70 ($750) for reinforced concrete, $77 ($830) for open steel grid, and $83 ($890) for concrete filled steel grid. The lower cost for timber resulted, in part, from the ease with which the bridge could be widened and the sidewalk cantilevered.

The glue-laminated timber deck was assigned an expected life of 50 years while the other decks, comprised of deicing agent susceptible materials, were assigned an expected life of 15 years. The advantage of timber in cost of maintenance and second replacement was even more convincing than the lower first cost.

These costs are tabulated as shown below:

Table 1

Type	First Cost	Life Expectancy Years	50 Year Replacement Reserve ($) *
Glue-laminated Timber	$50,000	50	-
Reinforced Concrete	$95,000	15	266,700
Open Steel Grid	$105,000	15	300,000
Concrete Filled Steel Grid	$113,000	15	326,700

*First cost differences compared to timber extended to 50 year value without interest.

The second structure is a 54-ft (16.5 m) through-girder-span bridge built during the 1920s. The bridge served well as the primary access to a small community until deicing agents began to be used. Drainage from the crowned roadway flowed under the curb rail and over the edge of the timber deck onto the nine inch (0.23 m) steel floor beams. These steel floor beams, bracing, connections and bottom girder flanges rapidly deteriorated, and a load limit of three tons

(2722 kg) was placed on the span. In the last 15 years, deicing agents caused near-collapse status to occur, although for approximately 45 years prior to their use, the steel performed well. After approximately 55 years, the timber deck with a bituminous concrete wearing surface was still functioning adequately, but was hiding the severely corroded steel beams. This replaced bridge is shown in Photograph 3.

The structure was widened from two 8-ft (2.4 m) lanes to two 12-ft (3.7 m) lanes and a four ft (1.2 m) sidewalk was added to the structure, as shown on Figure 1. The abutments, originally constructed from blocks of sandstone, which is also not affected by deicing agents, were in excellent condition and, therefore, reused.

The owner, in conjunction with the engineer, rejected reinforced concrete and steel grid decks because of proven higher initial cost and shortened life in the deicing agent environment. Only prestressed concrete box beams, and timber beams and deck were considered in this situation.

A cost comparison showed the two alternatives to cost, exclusive of demolition, abutment and approach work, $59 ($635) per sq ft (sq m) for concrete beams and $57 ($610) per sq ft (sq m) for glue-laminated timber. Timber was again chosen, based on its appearance in a wooded surrounding, expected ease of construction, and proven durability in the presence of deicing agents.

DESIGN CRITERIA

The design of these timber bridge structures was generally guided by using Section 1.10 of the AASHTO Standard Specifications for Highway Bridges. Extensive testing of material configurations prior to acceptance for a construction scheme is needed for inclusion in this specification. The glue-laminated timber manufacturers themselves, are the most progressive source of design information. They prepare independent test programs and test data on design configurations far more advanced than AASHTO. In some work, the engineer can design using that information, but for municipal work, as reported here, more in-service experience is expected before building the structure. The design process by any standard is no more complicated or time consuming than for a steel or concrete bridge.

MATERIAL QUALITY

Glue-laminated timber for this use is fabricated and then shipped to a treating plant for application of the preservatives; both are normally a distance of several hundred miles from the bridge site. Connections are made with bolts and clips. The connecting hardware is supplied by the fabricator whose plant drills all of the connection holes. Only the bearing pads and beam anchorages must be field fabricated. The timber bridge is shipped to the site and then field assembled on the prepared bridge seats.

The material quality and fabrication can be controlled, because this is done in the plant where representatives of AITC inspect and affix approval stamps to the acceptable members.

ADVANTAGES AND DISADVANTAGES

Timber has advantages and disadvantages as a material for bridge construction. The light weight of the timber allows for easier construction because the beams can be lifted into place with smaller cranes. Construction of the timber segments can be accomplished in cold and wet weather without detrimental effects to the material and the product can be used as part of the construction scheme as well.

The foremost advantage of timber in the Allegheny County vicinity is the imperviousness it exhibits in the presence of deicing chemicals which speed the deterioration of concrete and steel. With treatment for prevention of decay from natural organisms, it is a stable building material. It is lightweight, allowing rehabilitation of older bridges with the possibility of reusing the abutments while increasing the load carrying capacity of the crossing members. The initial and maintenance costs are lower than most other alternatives and certainly competetive with the traditionally more economical materials.

However, timber is restricted to relatively short spans, and has relatively deep sections required for carrying loads similar to steel structures. Thus, for crossing flat valley areas, the stream cross section at flooding is reduced. The time to fabricate the timber members is often in excess of that to obtain steel beams and concrete sections. Allegheny County is a steel producing region, but negative public opinion did not develop even though timber is not produced regionally.

CONCLUSION

In the climate of western Pennsylvania, U.S.A. and/or where deicing agents are used to control roadway conditions, timber is an economical and attractive solution to bridge deterioration. In some situations, timber has advantages over other bridge construction materials including its weight, imperviousness to deicing agents, all-weather construction, relatively low cost, and good life expectancy. It should be included in studies leading to the selection of bridge materials.

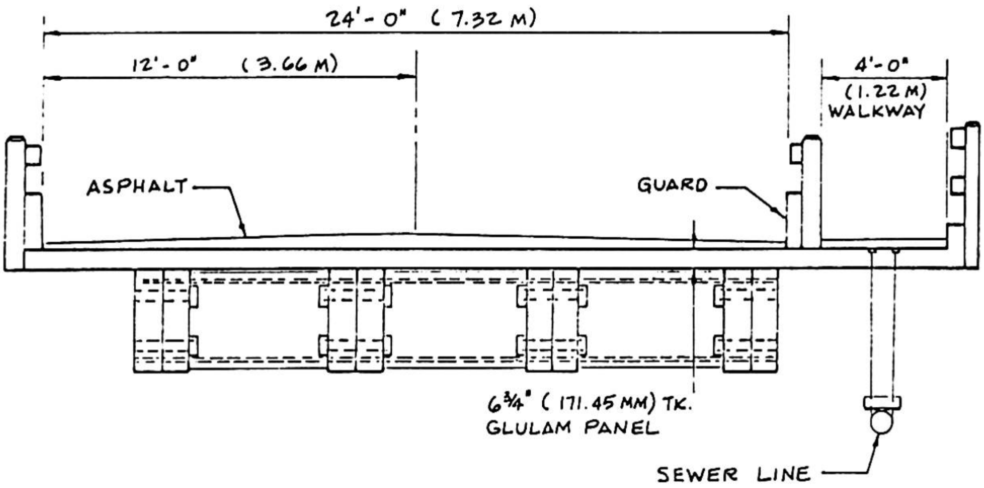
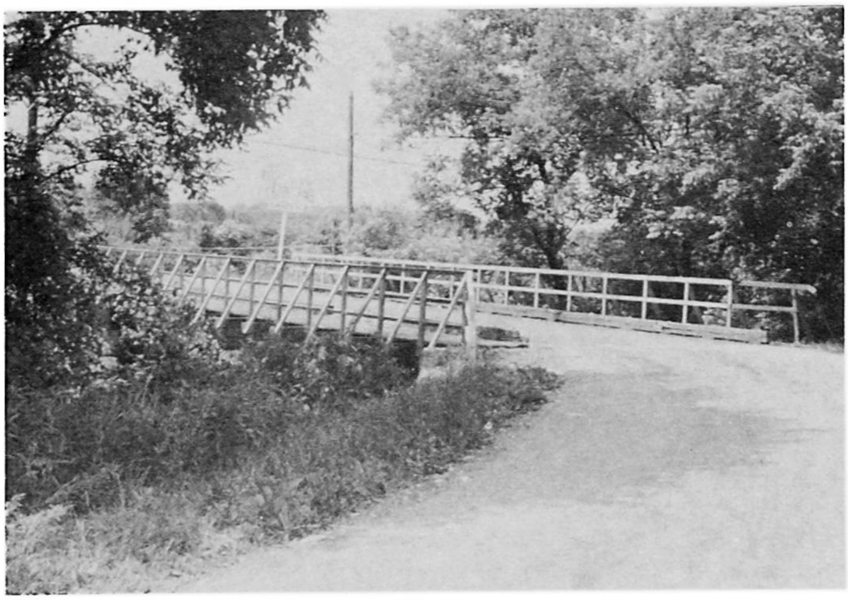
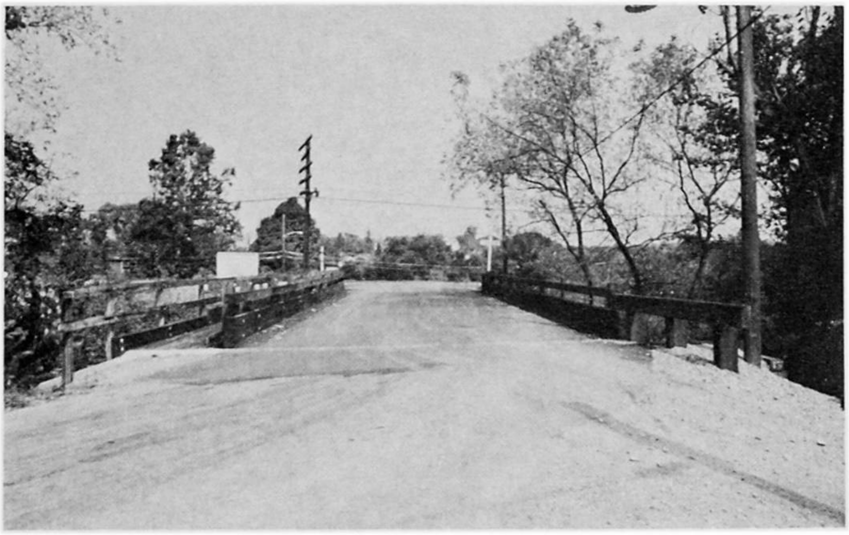


Figure 1: Case Study 2 - Cross section of glue-laminated timber replacement bridge.



Photograph 1: Case Study 1 - Bridge prior to renovation.



Photograph 2: Case Study 2 - Bridge with glue-laminated timber deck.

Photograph 3: Case Study 2 - Deteriorated steel through-girder bridge.