TEXAS TRANSPORTATION INSTITUTE

TEXAS HIGHWAY DEPARTMENT

COOPERATIVE RESEARCH

Bridge Decks
2-8-54-1

in cooperation with the
Department of Commerce
Bureau of Public Roads

BIBLIOGRAPHY 67-10

SURVEY OF LIBRARY FACILITIES PROJECT

Bridge Decks

1. M. D. Shelby and W. B. Ledbetter, Ice Prevention on Bridge Decks, Interim Report, Research Study. Texas Highway Department, Research Digest (Austin, Texas), No. 62-1, p. 4, January 1962.

   Results of a series of tests using heating cables in the deck of a bridge to prevent icing are reported. The twin bridges (grade separation for City View Drive) chosen for this research study are located northwest of Wichita Falls on US 287. A description of the project, including specifications, is presented along with a discussion of the results of the tests performed during a cold period beginning January 23, 1961, and lasting through January 29, 1961. Although a limited number of tests were performed during this period, some observations concerning effect of slab thickness, cable spacing and depth of heating cable embedment are made. (copies of the complete report may be obtained upon request from the Highway Design Division, File D-8, Austin, Texas).

2. T. H. Russell. Fiber Glass/Polyester Resin Laminate Surfacing of Timber Bridge Decks. Australian Road Research (60 Denmark St., Kew, E. 4, Victoria, Australia), Vol.1, No. 8, pp. 13-22, Dec. 1963.

   This paper outlines the results of investigations into the surfacing of timber bridge decks with fiber glass/polyester resin laminates.

   Timber decking which has been teeated at any time during its life with creosote must be first treated with caustic soda to neautralize the creosote and give good adhesion between the timber and polyester resin.

   The type and relative proportions of polyester resin, catalyst and accelerator must be determined by a competent person, and during the surfacing work the designated time of gelation must be maintained by varying the proportions of catalyst and accelerator according to the surface temperature at the time. This also means mixing the resin in relatively small batch quantities. To obtain good adhesion with the sand surfacing, the dry sand must be applied to a resin-rich surface before it has taken its initial cure.

   A static load test indicated that surfacing with fiber glass gives much better load distribution characteristics to a timber deck, and a fatigue load test indicated that the fatigue life for heavy traffic conditions would be more than adequate.

   Depending on the condition of the bridge and the gage of fiber glass treatment proposed, the cost may be expected to vary from 11/- to 15/-per sq ft. When a timber bridge has a sound substructure and beams, is of reasonable width, and the adjacent road alignment is adequate, fiber glass surfacing of the timber deck can be economical, in that it may avoid the cost of re-decking a bridge by prolonging the life of the existing decking and, in so doing, provide a much more satisfactory riding surface which is devoid of rattles and gaps between planks. Light fiber glass surfacing may also be economical shortly after re-decking a timber bridge for the same reasons listed above.

3. Durability Studies of Structural and Paving Concretes: Phase I-Durability of Bridge Deck Concrete. A Review of Literature Treating Various Aspects of Bridge Deck Concrete Durability. Intermediate Report. Pennsylvania State Univ. (University Park, Pa.), Dept. of Divil Engineering, Materials Research Rept., April 1964, 18 pp.

Severe exposure coupled with often inferior concrete has caused bridge deck concrete deterioration to be a matter of national concern. This report presents a review of recent literatur treating subjects closely related to concrete bridge deterioration and summarizes important findings to date on basic properties and design of concrete construction procedures, corrosion of steel reinforcement, and surveys of service enviroment, treatment and condition.

4. Durability of Concrete Bridge Decks, Report 1. A Cooperative Study with State Highway Commission of Kansas and U. S. Bureau of Public Roads. Portland Cement Association (33 W. Grand Ave., Chicago 10, Ill.) 1965, 130 pp.

In 1961, the Portland Cement Association, in cooperation with the U. S. Bureau of Public Roads and 12 state highway department, undertook a comprehensive study of concrete bridge deck deterioration. This first of a contemplated series of six reports presenting the results of the study delas witha detailed investigation of 18 bridge decks in Kansas. The bridges were chosen to provide a wide range of factors, including type and severity of deterioration, bridge type, span length, location, date of construction, and volume of traffic.

Observed occurrences of scaling, various types of cracking, and surface spalling are discussed based on data given. Recommendations for preventing deterioration in future deck construction are also presented. The detailed information consists of observations made in the field, information obtained from the construction records, and laboratory study of core samples, including linear traverse measurements of air content, high-pressure meter determinations of air content, high-pressure meter determinations of air content, chloride analyses, pulse velocity measurements, and detailed petrographic examinations.

The two most important findings are the non-uniform distribution of entrained air from top to bottom of bridge deck slabs and the effect of restraint to subsidence of the concrete by the top steel reinforcement.

5. Charles P. Carter, Nonskid Deck. California Highways and Public Works (P. O. Box 1499, Sacramento, Calif. 95807), Vol. 44, Nos. 5-6, pp. 48-49. May-June 1965.

A "roughing-up" job was recently done on the deck of the Maxwell Bridge over the Napa River Calif. 29. The deck of this 132-ft 2-lane lift span is an open steel gridtype consisting of longitudinal bars on edge 2½ in. apart with zigzag bars for spacers. In recent years as traffic volume increased and skidding became a problem in damp weather, the deck was treated with an epoxy adhesive covered with aluminum oxide grits. This process cost about $2,500 and had to be repeated 18 mos later at a cost of $2,000. With the continued increase in traffic, a yearly treatment would be necessary.

In the new process more than 18,000 study were welded at the bar intersections of the grid deck, resulting in a pattern 5 in. apart in longitudinal and transverse directions. The intermediate longitudinal bars were spotted with study at 15-in centers to break up any sway pattern. The state maintenance crew was unfamilar with the operation of the study guns, but after a short time study were being completed in 3½ days rather than the estimated time of 6 days. The previous treatments of epoxy and abrasives had taken more than a week each time.

6. John Ryell. An Unusual Case of Surface Deterioration on a Concrete Bridge Deck. Journal of American Concrete Institute (P. O. Box 4754, Redford St., Detroit, Mich. 48219), Proc. Vol. 62, No. 4, pp 421-442, April 1965.

Set-retarded concrete placed in a bridge deck and finished with conventional equipment exhibited severe surface deterioration in the form of flaking several days after paving. Similar concrete placed in the approach slab on a granular subgrade did not flake. Laboratory and field investigations showed that the flaking was due to formation of a weak plane immediately below the surface of the concrete and was closely connected with the bleeding characteristics of the mix. The solution was to reduce the bleeding rate of the concrete by a change in the type of set-retarding admixture.

7. Orthotropic Steel Bridge Decks, Batelle Technical Review (505 King Ave., Columbus, Ohio 43201), Vol. 14, No. 809, p. 18, Aug-Sept. 1965.

A new type of steel bridge deck, primarily developed in Germany, is just being introduced in the United States. The bridge decks are called orthotropic- a word combining orthogonal and anisotropic and meaning "having different stiffnesses in any two perpendicular directions." They feature integrally welded longitudinal stiffening ribs. The deck plate is an integral part of the overall structure, as well as the base for the wearing surface.

A new research program is being conducted to develop thin materials for orthotropic decks. Various paving materials will be applied to a steel plate simulating a bridge deck and subjected to variable strain and temperature conditions. Vibration and abrasion evaluations also will be conducted to simulate traffic and weather conditions.

One of the principal advantages of the orthotropic deck design is reduced steel requirement and a corresponding lower dead weight. The success and economy of such bridges depend to a considerable extent on the pavement coating system which provides both the wearing surface and a protective coating for the deck plates.

8. Jacob J. Creskoff. Crushed Stone vs Gravel in Bridge Decks. Penn. Triangle, University of Pennsylvania (Philadelphia, Pa.), Vo. 52, Jan. 1965. 4 pp. Journal of the American Concrete Institute, Proc. Vol. 62 no. 9, pp 1117, Sept. 1965.

A study was made to determine the relationship between losses and the Los Angeles Rattler Test of aggregates and wear and deterioration of bridge decks made from concretes containing the aggregates in questions. No evidence was found which tied the durability of bridge decks solely to aggregates which achieved low percentages on the LART. Strong and durable concretes were obtainable with any aggregate permitted by the state highway specifications. Sound aggregates of uniform composition used in low water-cement ratio mixes and anchored to a rigid substructure resulted in durable bridge decks.

9. Howard L. Payne and Lamar H. Caldwell. Ultimate Strength Design for Highway Bridges. Journal of the Structural Division, ASCE (345 E. 47th Street, New York, N. Y. 10017), Vol. 91, No. ST5, Proc. Paper 4499, pp. 43-56, Oct. 1965.

An ultimate strength design method for highway bridges is presented. Highway bridges have variable live-load capacity, and the smaller bridges control highway system capacity. It is demonstrated that the present minimum capacity is 2.0 live loads. A lower bound loading of 1.5 dead loads plus 2.0 live loads is advocated for all common bridges. This loading is applied to concrete decks, reinforced concrete girders, prestressed girders, composite steel girders, trusses, and substructures. These have intermediate grade reinforcing steel and A36 structural steel. Concrete girder bridges can be completely designed using existing specifications. Development work remains to be done on steel girder bridges and tresses. The proposed design method offers consistent service ratings and material economics in all common bridge types. The savings are estimated to be 4 percent of the national bridge budget.

10. J. J. Trott and D. S. Wilson. The Development of Asphalt Surfacings for Steel Bridge Decking. International Association for Bridge and Structural Engineering (Verlag Leeman, Zurich, Switzerland), Sixth Congress, Stockholm, June 27-July 1, 1960. V16 Reprint, pp. 889-906 (In English).

At the request of the Joint Consulting Engineers for the proposed new bridges over the rivers Forth and Severn, the British Ministry of Transport and Divil Aviation asked the Road Research Laboratory to make tests to help to decide on the choices of a surfacing that would be sufficiently impervious to protect the steel decking from rust and corrosion, and that would be durable, non-skid and of a thickness not exceeding 2 in. It was desirable to test the possible surfacings on the full-scale and steel panels 9 ft. long by 7 ft. wide of a construction similar to that of the then proposed decking were placed in the carriageway of the Colnbrook By-pass on Trunk Road A.4 This road carries more than 40,000 tons of traffic per day and some of the test panels were subjected to this traffic for periods of up to six years.

The tests began in 1949 and continued until the end of 1957, resulting in a surfacing considered satisfactory for the bridge decking described.

The tests were made on steel panels inserted into the carriageway of a trunk road carrying about 40,000 tons of traffic daily.

A surfacing of stone-filled mastic asphalt was tested in thickness of 1, 1½ and 2 inches. Precautions were taken to deep water out of the edge joints, and to prevent rusting of the plate, and these are described. The minimum thickness of surfacing necessary to withstand 5 years of heavy trafficing was found to be 1½ inches.

Strain measurements, made on the steel deck plates under standard wheel loads are described.

It was found that the contribution of the asphalt surfacing to the rigidity of the deck plates depended on the temperature at which the tests were carried out. Under winter conditions (0°C) the surfacing contributed about 80 percent to the rigidity of the steel plate for the 1½ in. thickness and 60 percent for the 1 in. thickness.

At temperatures of 0 to 8°C, dynamic strains under the 1½ in. asphalt were only about 70 percent of those measured under the 1 in. thickness. This may account for the differences of performance under traffic.

Under temperatures of summer conditions (30°C) the contribution of the surfacings to the stiffness of the deck was negligible.

11. A. Short and F.G. Thomas. Studies on Bridge-Deck Systems. III. Tests on Model Slab-and-Girder Bridge-Deck Systems. Gt. Britain Dept of Scientific and Industrial Research, Building Research Station, National Building Studies, Res. Paper 37. Her Majesty's Stationery Office, London 1963. 70 pp.

This is the third in a series of research papers on the subject of bridge-deck systems of various types. The first of these, Research Paper No. 21 dealt with "Tests on Model Jack Arch Systems," and the second, Research Paper No. 31, presented a theoretical analysis of the behavior of plate-and-girder system. The present paper is an account of experimental research on slab-and-girder model bridge decks under working loads and at incipient failure. Three large models were tested. Each consisted of a 3-in. thick reinforced concrete deck on 8- by 4-in. 14-lb girders spaced 3 ft and spanning 9 ft. In two of the models, the steel girders were left exposed, one with and one without shear connectors. In the third, stirrups were provided and the girders were encased in concrete. Both bending and punching shear failures were experienced. The authors found that for working-load conditions, the strain and deflection measurements indicate that the actual distribution of the bending-moments in a slab-and-girder system is defined, with sufficient accuracy for design, by the elastic theory of the plate supported on beams.

The bending-moment distribution that can safely be assumed for such conditions would not in general differ greatly from that obtained with the elastic theory.

The stiffness of the slab-and-girder systems was greatly increased by the combination of slab and girders to form a composite cross-section. It was also found that the collapse load in bending was almost doubled as a result of the introduction of composite action.

The maximum stresses under working loads however were not affected considerably, the effect of the increase in section modulus being counterbalanced by the increased proportion of the bending moment resisted by the beams.

Both deflections and maximum stresses were considerably increased as a result of cracking in the reinforced concrete slab, in both composite and non-composite systems.

The inclusion of cross-members between the girders, transversely to the direction in which they span, did not affect the behavior of the system considerably.

12. Bridge Design Data for Longitudinal Laminated Timber Deck. Rural Roads (Gillette Publishing Co., 22 West Maple St., Chicago 10, Ill.) Vol. 7, No. 2, pp. 68-69, March-April 1957.

The data given were presented at the County and Local Roads Div. meeting of the American Road Builders' Association at Macknac Island. The data were prepared by W.A. Stacey, District Engineer, American Wood Preservers' Association. This design eliminates the need for large structural grade stringers. It was evolved about 20 years ago to provide continuous wood slabs in spans up to 20 ft.

Basic design data are:

1. Douglas fir and southern yellow pine lumber of 1,450-lb grade is used.
2. Wheel loads are distributed laterally over a width of 3 ft.

The validity of this distribution has been proven by the performance of many bridges of this type over a period of nearly 20 years.

3. Dead loads are assumed at 100 lb per sq ft of deck to cover the weight of pressure-treated wood and 5 in. of earth, sand-clay, gravel, or bituminous mat wearing surface.

4. In continuous spans, 50 percent of dead load moment and 60 percent of live load moment are assigned to midspan and to support points.

5. In simple spans, all deck strips extend from cap to cap. In continuous spans, the strips are placed in a uniformly staggered pattern in which one-third joint over the caps and the other two-thirds at alternate quarter points.

6. The laminated strips are spiked at 12 in. to 15 in. centers horizontally with 60d nails, staggered along opposite edges to obtain maximum continuity in deck action.

7. The use of lamination of less than 3-in. nominal thickness is not recommended because lesser thicknesses tend to give a smaller width of distribution of the live load.

8. More complete data or plans may be obtained from the American Wood Preservers Institute, Ill West Washington Street, Chicago 2, Ill.

13. A Bridge Deck on Prestressed Planks, Concrete and Constructional Engineering (Concrete Publications Ltd., 14, Dartmouth St., London, S. W. 1), Vol 51, No. 9, p 482. September 1956.

The following notes on a road bridge with a span of 19 ft 8 in. and a width of 32 ft 6 in. built in Poland in 1953 are abstracted from "Inaynieria i Budownictwo" for January 1956.

The tensile forces in the deck slab are resisted by prestressed concrete "planks" spaning between the abutments and which also served as centering. Two layers of these planks are used, the upper layer being at right angles to the lower layer. To improve the bond with the concrete cast on top of the plans, steel stirrups of 4.5 mm (3/16-in) diameter were cast in the top of the lower planks. The planks in the bottom layer, measuring 6 3/8 in. wide by 1 5/8 in. thick, are placed close together; in the top layer the planks are 4 in wide by 1 5/8 in. thick and are placed at 15-in. centers. The two layers were not mortared together. About 1.1 lb of steel was used per square foot of the deck. Prestressed members measuring 2 3/4 in. by 1½ in. were used for handrail posts.

Owing to the novel form of construction, the bridge was tested three times to measure the deflection of the slab at different temperatures. The tests were all made with a load of about 22 tons due to the rear axles of two trucks.

In the first test, made in the autumn of 1953, the maximum deflection was 0.01457 inches. In the second test, made in the winter of 1954 at a temperature of 3 F, the maximum deflection was 0.00591 in. When tested in the summer of 1954 the deflection was 0.00748 in. The ratio of deflection to span varied from about 1 in 16,000 to 1 in 40,000.

During the last tests measurements were also made of the deflection due to a dynamic load. A board 2 3/8 in. thick was laid across the bridge and the impact was provided by a truck passing over it at 30 mph. The deflection due to the dynamic load was about 16 percent greater than that due to the static load. When the board was removed the deflection due to the load moving across the bridge was about 4 percent less than when the load was stationary.

14. S. D. Lash and B.B. Hope, The Structural Behavior of Highway Bridge Decks Abstract of paper to be presented at 74th annual meeting, Engineering Inst. of Canada, May 1960. Eng. Journal (Engineering Institute of Canada, 2050 Mansfield St., Montreal 2, Quebec, Canada), Vol 43, No. 2, p 100. March 1960.

Theoretical studies included the problems of composite action, lead distribution and research questions. From full-scale tests on 3 bridges, information is recorded on ultimate strength, loads transmitted longitudinally by floors, composite action on timber floor and concrete floor, load distribution, deflections, effects of concentrated loads applied between streingers, and a comparison of timber and concrete floors. Concluded concern safe capacity of bridge floors under static loads and methods of straghtening existing bridges.

15. Precast-Prestressed Concrete Bridges 6. Tests of Half-Scale Highway Bridge Continuous Over two Spans. Alan H. Mattock and Paul H. Kaar. Journal of the Research and Development Laboratories, Portland Cement Association (5420 Old Orchard Rd., Skokie, Ill.) Vol. 3, pp. 30-70. September 1961.

The series of papers entitled "Precast-Prestressed Concrete Bridges" presents the results of an extensive laboratory investigation of a type of bridge involving precast-prestressed I-shaped girders with a continuous situ-cast deck slab. This Part 6 reports an experimental investigation of the behavior of a half-scale highway bridge continuous over two spans when subject to loads at and above service load level. The behavior of the bridge under both service loads and considerable over-loads conformed closely to calculations based on the elastic theory. The lateral distribution predicted by the Guyon-Massonnet theory. Additional data also obtained on the punching shear strength of reinforced concrete deck slabs.

16. Paul Lieger and Richard S. Fountain. A Cooperative Bridge Deck Study. Portland Cement Association. Highway Research Bulletin No. 323. pp. 23-25.

In cooperation with the Bureau of Public Roads and a number of State highway departments, the Portland Cement Association is engaged in a study of the performance of concrete bridge decks. This study has four major objectives, as follows:

1. To determine the extent of concrete deck deterioration in selected areas of the country.
2. To determine the causes of the various types of deterioration.
3. To develop reliable methods, where needed, of preventing deterioration on future construction.
4. To develop methods of retarding deterioration on existing bridges now showing deterioration.

These objectives are being accomplished by a random field survey of 100 to 150 structures in each of ten States representing a range in climatic exposure and traffic conditions and by a detailed survey of approximately 15 structures in a minimum of four States. The detailed survey includes a field study of the condition of the structures, a laboratory petrographic study of core samples from affected and unaffected portions of the deck, measurements of concrete cover over steel, a study of the possible influence of primary and secondary stressed on performance, the influence of construction practices, and a number of other considerations.

17. Howard Newlon, Jr., Highway Research Engineer, and Harry E. Brown, Highway Engineer Trainee. A Survey of Bridge Deck Deterioration by the Surfax Method. Highway Research Record NO. 14, pp. 37-43.

As part of a study of the deterioration of concrete bridge decks, a condition survey of 18 structures was made with Surfax photographic equipment, developed as a tool for conducting condition surveys of pavements. The purpose of the study was to determine the ability of the decks. The structures surveyed, 15 of which were less than five years old, were selected to include transverse cracks (structural), surface seals, disintegration, spalling, and progressive scale.

The results of the photographic survey are compared with those of a detailed visual survey. Measurements of typical defects are presented to indicate the ability of the method to detect both major and minor defects.

18. E. O. Axon and R.W. Couch, Missouri State Highway Dept. Progress Rpt. of Effect of Insulating the Underside of a Bridge Deck. Highway Res. Record No. 14 p. 1-13.

The described investigation was designed to determine the merit of insulating the underside of a bridge deck in: (a) preventing formation of ice on a bridge deck prior to such formation on the abutting pavement, and (b) decreasing the number of freeze-thaw cycles and salt applications.

Information is presented regarding application and bonding performance of the urethane foam, instrumentation, and collection and analysis of data for the periods of December 1, 1961 to April 29, 1962; and October 1, 1962 to November 30, 1962.

Present data are considered insufficient to establish the merit of the insulation, but indicate that the effects tend to be beneficial.

19. J. W. McKnight, Regional Paving Engineer, Portland Cement Association, New York City. Specifications and Construction Controls to Obtain Smooth-Riding Bridge Decks. Highway Research Bulletin No. 295, p 6-18.

Construction procedures and specifications control that will produce smooth-riding bridge decks are presented.

It is pointed out that the basic principles that produce smooth-riding concrete surfaces are the same for pavements placed on grade and on bridge decks. The need for uniform subgrades is analogous to the need for determining cambers that reflect careful estimates of dead loads during placing and finishing of bridge decks.