

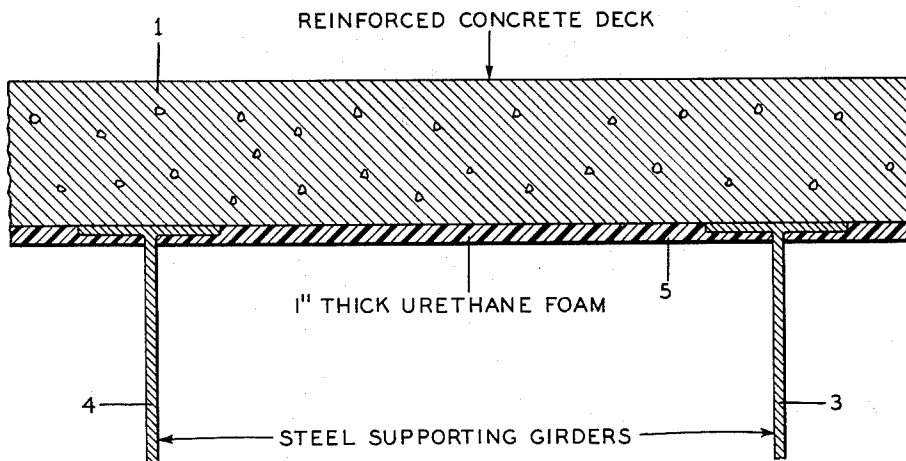
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HIGHWAY MAINTENANCE OF ELEVATED STRUCTURES

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HIGHWAY MAINTENANCE OF ELEVATED STRUCTURES

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This invention relates to bridges and other elevated structures and more particularly refers to elevated structures having concrete decks and the treatment of such concrete decks to improve their roadability and reduce maintenance.

In modern highway type of construction, grade crossings of railroads and other highways are eliminated by use of overpasses and underpasses. All of this is designed to promote safety and to insure steady flow of traffic. Along with this type of construction, however, other problems are encountered, primarily at the bridges and over- and underpasses where, particularly in the United States and Canada, these structures are exposed both top and bottom to early freezing due to sudden changes in temperatures, wind velocities, etc. This creates very hazardous conditions especially when the overland portions of the highways are free of ice and the traffic approaches the bridges at normal rates of speed which cannot be sustained with safety over the frost- and ice-covered structures. Highway officials, quick to recognize such hazards, have, in many instances, found it necessary to post warning signs at the approaches to these overhead structures warning the traffic of the dangerous conditions; such signs often read "Caution—Bridge Freezes Before Highway."

As previously stated, in modern highway construction greater use is made of overhead structures, such as bridges over streams, and overpasses and underpasses to eliminate grade crossings of railroads, highways and the like. There are estimated to be about 100,000 structures of these types in the United States alone. Based on this figure, it is believed that at least about 75,000 would be subject to frost conditions.

Another serious problem which has arisen as a result of the above type construction has to do with the "spalling" or cracking and fracturing of the concrete bridge decks. In the United States and other countries subject to frost, this condition has resulted in early failures of the bridge decks; such failures often occur during the first winter after installation and usually occur within a period of from six months to two years. The repair and maintenance of these structures is very costly and aggravates the safety problems described. Methods of repair include, but are not limited to, patching of the cavities and filling with new concrete, bituminous concrete and, more recently, with expensive epoxy resin compositions. If the repairs are not made at the early stages of deterioration, then complete renewal of the bridge decks with new concrete or bituminous concrete surfaces is required. It is, of course, impractical to continue adding new surface courses of concrete and bituminous concrete to the bridge decks because of the substantially increased weight which would become a significant danger factor.

In order to minimize the effect of added weight on these structures, the tendency on the part of highway engineers has been to decrease the thickness where bituminous concrete has been used to resurface the bridge decks. In many such instances, the spalling has continued at the interface between the bituminous concrete surface and the cement concrete deck and has caused the former to lose its bond and peel off from the deck. The types of maintenance described herein are, of course,

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very expensive and result in tying up the bridges during extended periods. Furthermore, this type of maintenance can only be done during the period from approximately May 1 to October 15 in the areas of the United States and Canada involved with this problem.

An object of the present invention is to provide a method for retardation of ice formation on the upper surface of a concrete deck of an elevated structure surfaced with either concrete or a bituminous layer.

Another object of the present invention is to provide a method for the obtainment of frost conditions on the upper surface of a concrete deck of a bridge surfaced with either concrete or a bituminous layer, similar to the road leading to the bridge.

A further object is to provide a method for materially reducing spalling of the concrete deck of an elevated structure.

A still further object is to provide a method of reducing spalling and improving roadability of the concrete deck of an elevated structure with a relatively small amount of weight added to the elevated structure.

Another object is to provide an efficient, economical method of reducing spalling and improving roadability of a concrete deck of an elevated structure. A further object is to provide an improved elevated structure with a concrete deck having reduced tendency to spalling of the concrete and better roadability. Other objects and advantages will be apparent from the following description and accompanying drawing.

I have discovered that spalling of the surface of a concrete deck of an elevated structure and retardation of ice formation on the upper surface may be materially reduced, ice formation on the upper surface of the deck retarded with frost conditions on the upper surface of the deck similar to the road approaches leading to the deck, by the application of a layer of about 1/2 inch to 3 inches thick, preferably about 3/4 to 1 1/2 inches thick, of cellular plastic material, preferably having closed cells and having a density of about 1 to 8 pounds, preferably about 1 1/2 to 5 pounds, per cubic foot bonded to the underside of the concrete surface of the elevated structure. The effect of reduced spalling and improved roadability by the bonding of a layer of cellular plastic material to the underside of the concrete surface is surprising and unexpected because the upper surface of the deck remains exposed to the elements as before and the lower surface, save for the interposition of the bonded cellular layer, remains exposed to the elements.

The accompanying drawing diagrammatically illustrates a section of an elevated structure having a concrete deck to which is bonded on its underside a layer of cellular plastic material. Referring to the drawing, the deck, designated by numeral 1, is a reinforced concrete deck about 9 inches thick. The substantially horizontal concrete deck 1 exposed to the atmosphere is supported by the usual supporting members as illustrated by steel support girders 3 and 4. On the underside of reinforced concrete deck 1 and bonded thereto is a layer 5 of cellular plastic, urethane foam, 1 inch thick and having a density of 4 pounds per cubic foot.

Typical bridge structures for which this development is considered particularly applicable are as follows: the span to be covered may be only 50 feet where the bridge crosses a small stream, a single- or double-lane highway or a railroad track. It may, on the other hand, be 1 to 1 1/2 miles in length where the bridge crosses a large body of water, where the roadway is elevated over marshy or low-lying areas of the country or where it passes over built-up areas of cities or villages. The structures may be supported by concrete piers or steel columns. The bridge decks are usually supported by fabricated longitudinal I-beams, channels or prestressed concrete beams.

Between the longitudinal members are cross-beams usually of the same type but of smaller dimensions. The bridge decks are of poured concrete type with typical reinforcing bars; the thicknesses may vary from 3 to 12 inches, depending upon span, weight to be carried and other factors, and are most generally from 6 to 9 inches. Of course, large over-water spans involve a somewhat different type of supporting structure and are usually of the suspension type; the bridge decks, however, are of the same type construction as described above.

The heights of the bridges are usually determined by the purpose for which they are installed. For overpass of a highway the height is generally 12 to 16 feet; for overpass of a railroad about 22 feet minimum; and over water it would depend on the type of navigation involved and often exceeds 75 feet. It can readily be seen that the decks of bridges, being generally elevated from about 12 to 75 feet or more, are exposed to the weather both top and bottom. They are therefore subjected to rapid changes in temperature which may be accentuated by high wind velocities. These conditions cause extreme weathering effects on the bridge decks and bring about, for example, rapid freezing and thawing which results in the serious safety problems and may be a major factor in the spalling of the decks.

The overhead structures to which the present invention applies have concrete decks exposed on their top and bottom sides to the elements. As previously pointed out, in some instances the bridge decks have been surfaced with a bituminous upper layer in an effort to reduce spalling and improve road conditions. The present invention is also applicable to decks which are constructed of concrete with an overlaying bituminous layer and the application of a cellular plastic material to the underside of such decks improves roadability and reduces spalling of the concrete.

Examples of cellular plastic suitable for application in the present invention are foam from polyurethanes, polystyrenes, polyvinylchloride, phenolics, polyethylene or the like, which materials are well known in the art. The layer of cellular plastic material may be applied in two manners. In one instance, preformed slabs of cellular plastic material of about $\frac{1}{2}$ to 3 inches thick (preferably about $\frac{3}{4}$ to $1\frac{1}{2}$ inches thick) and having densities of about 1 to 8 pounds (preferably $1\frac{1}{2}$ to 5 pounds) per cubic foot, are bonded to the under sides of the bridge decks by means of conventional adhesives of the elastomeric or polymeric type depending upon the specific foam to be used. It is important that the cellular plastic material be bonded to the underside of the concrete deck and securing the slabs by mechanical means such as clamps or the like are not satisfactory and should not be employed. Preferably, however, the cellular plastic is applied to the underside of the concrete deck by spraying liquid reactants which upon striking the concrete underside form a urethane foam which adheres to the concrete surface sprayed without the use of adhesives. This adhesive bond is generally stronger than the foam itself. Production of urethane foam by spraying is well known in the art involving spraying, by means of the spray gun, an isocyanate and an organic compound having a reactive hydrogen such as a polyester or a polyether which reacts with the isocyanate and in the presence of a blowing agent such as water or an aliphatic fluorine hydrocarbon designated in the art as "Genetron" form a cellular foam. The production of urethane foam is known in the art and needs no extended discussion herein. An important consideration in the use of the cellular plastic material in accordance with the present invention is its light weight. Bridges are designed to bear certain loads and the addition of a material amount of added weight on these structures would obviously be detrimental. Merely for illustrative purposes, the application of polyurethane having a density of 4 pounds per cubic foot and an inch thick would be equivalent when applied to a bridge having

a surface area of 2,000 feet of less than 700 pounds, which amount of weight is insignificant in a structure of that type particularly when distributed evenly over the underside. In contrast, a layer of bitumen of the same thickness would impose an added load on the bridge of approximately 50 times greater than the cellular plastic material. An additional advantage in the use of the cellular plastic material concerns aesthetics in that it is adapted to be painted, the same color as the rest of the bridge, if desired.

In practice, a dual highway-spanning bridge, each half of which is about 65 feet wide, 65 feet long and 15 feet high, and having a 9-inch thick concrete deck resting on prestressed concrete beams and crosspieces, was sprayed on $\frac{1}{2}$ of its underside with approximately 1 inch of polyurethane foam having a density of about 4 pounds per cubic foot. The formulation for preparing the foam urethane is as follows:

Parts by weight	
"Plaskon" polyester PFR-13	100
"Celluflex" CEF	25
"Emulphor" EL-719	4
Water	4
"Nacconate" 1080-HM	170

"Plaskon" polyester PFR-13 is a polyester made from adipic acid, trimethylol propane and the diamine reaction product of an amine with ethylene oxide and is obtainable from the Plastics and Coal Chemicals Division of Allied Chemical Corporation. "Celluflex" CEF (tris(2-chloroethyl)phosphate) is a fire retardant obtainable from Celanese Corporation of America. "Emulphor" EL-719 is a polyoxyethylated vegetable oil, a non-ionic emulsifier, product of Antara Division, General Aniline & Film Corporation. "Nacconate" 1080-HM is a modified toluene diisocyanate obtainable from National Aniline Division of Allied Chemical Corporation.

The foam was sprayed on the underside of the bridge deck utilizing an internal mixing spray gun. The spraying equipment was mounted on a 3-axle (GMC) truck chassis equipped with a flat body on which was mounted a conventional gasoline air-compressor (having a capacity in excess of 100 cubic feet of free air at 100 pounds pressure per minute), a gasoline-operated electric power generator, and a Gar-Wood telescopic platform from which the spraying was accomplished by the operator.

Another small portion of the bridge, roughly about 50 square feet was covered by bonding slabs of urethane foam sheets about 1 inch thick. The bonding material employed was "Bondmaster" DL-23A, a neoprene base adhesive, available from Rubber and Asbestos Corporation.

Examples of organic diisocyanate that can be used instead of the tolylene diisocyanate are 3,3'-bitolylene 4,4'-diisocyanate, diphenyl methane 4,4'-diisocyanate, m-phenylenediisocyanate, 1,4-cyclohexylenediisocyanate and 1,5-naphthylenediisocyanate. Examples of the polyesters that can be employed are the polyalkylene-ether glycols having molecular weights of at least 750 and which may be as high as about 10,000, e.g. polytetramethylene-ether glycol, polytrimethyleneether glycol and polyethylenemethyleneether glycol. Examples of other emulsifying agents that can be used are those marketed under the trademark name "Tween" 40 (polyoxyethylene sorbitan monopalmitate), "Triton" N-100 (Rohm & Haas Co.), and "Witco" 77-86 (Witco Chemical Co.).

A second dual bridge structure having three steel-supported spans from 52 to 78 feet wide crossing a 78-foot road right-of-way and, in part, a single-track railroad was sprayed on its underside with approximately 1 inch of polyurethane foam having a density of about 4 pounds per cubic foot in the same manner as described above. The bridge deck has a $2\frac{1}{2}$ inch bituminous concrete binder and top course over the concrete base of approximately 7 inches.

Although certain preferred embodiments of the inven-

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tion have been disclosed for purpose of illustration, it will be evident that various changes and modifications may be made therein without departing from the scope and the spirit of the invention.

What is claimed is:

1. An elevated structure carrying vehicular traffic having a concrete deck with the upper road surface of said elevated structure and the underside of said elevated structure exposed to the elements, the improvement which comprises a layer of about $\frac{1}{2}$ inch to 3 inches thick of cellular plastic material having a density of about 1 to 8 pounds per cubic foot bonded to the underside of the concrete surface of the elevated structure carrying vehicular traffic to reduce spalling and retard ice formation on the upper surface of the deck.

2. An elevated structure as claimed in claim 1 wherein the cellular plastic material is urethane foam.

3. An elevated structure as claimed in claim 1 wherein the upper surface of the concrete deck is paved with a bituminous layer.

4. An elevated structure carrying vehicular traffic having a concrete deck with the upper road surface of said elevated structure and the underside of said elevated structure exposed to the elements, the improvement which comprises a layer of about $\frac{3}{4}$ inch to $1\frac{1}{2}$ inch thick of cellular plastic material having a density of about $1\frac{1}{2}$ to 5 pounds per cubic foot bonded to the underside of the concrete surface of the elevated structure carrying vehicular traffic to reduce spalling and retard ice formation on the upper surface of the deck.

5. A method of reducing spalling and improving roadability of the concrete deck of an elevated structure carrying vehicular traffic and exposed on its upper and lower sides to the elements which comprises bonding a layer from about $\frac{3}{4}$ inch to $1\frac{1}{2}$ inches thick of cellular

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plastic material having a density of about $1\frac{1}{2}$ to 5 pounds per cubic foot to the underside of the concrete surface of the elevated structure carrying vehicular traffic.

6. A method of reducing spalling and improving roadability of the concrete deck of an elevated structure carrying vehicular traffic and exposed on its upper and lower sides to the elements which comprises applying urethane foam by spraying to the underside of the concrete surface of the elevated structure carrying vehicular traffic to bond to said underside a layer from about $\frac{1}{2}$ to 3 inches thick of urethane foam having a density of about 1 to 8 pounds per cubic foot.

7. A method of reducing spalling and improving roadability of a bituminous paved concrete deck of an elevated structure carrying vehicular traffic and exposed on its upper and lower sides to the elements which comprises bonding a layer from about $\frac{1}{2}$ inch to 3 inches thick of cellular plastic material having a density of about 1 to 8 pounds per cubic foot to the underside of the concrete surface of the elevated structure carrying vehicular traffic.

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