

History and Application of Glass Fiber Reinforced Resin Wearing Surface

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This paper discusses the concept and application of a new type of wearing surface. The material and its method of application were developed by members of the Northern Fibre-Deck Association in conjunction with the New York State Department of Public Works. This wearing surface was first used in New York State under a contract in which the Bureau of Public Roads participated.

The paper relates information regarding the concept and development of the wearing surface and the actual installation of a glass fiber reinforced resin wearing surface, and gives data regarding weight and cost of this type of application.

• A GREAT VARIETY of materials has been tested and used to increase the durability of concrete in bridge decks and wearing courses. This paper deals with the development and use of a glass fiber reinforced polyester resin as a laminate to provide a durable protective coating for these portland cement concrete surfaces.

In the search for a more efficient solution to the problem of achieving this protective coating for portland cement concrete it was proposed to use a reinforced plastic. Reinforced plastics have been used successfully in applications ranging from household utensils to heat shields for missiles. Particularly impressive is the demonstrated ability of a reinforced thermosetting plastic to act as a shield or impervious skin.

In adopting a program to utilize a thermosetting plastic in this field of concrete protection it became necessary to select from the vast field of plastics the basic resin and reinforcing material most suited to meet the structural and physical characteristics of a concrete bridge.

The resin chosen for this application was an isothallic polyester (manufactured by Selectron Division, Pittsburgh Plate Glass); the reinforcing material chosen was chopped glass fibers (manufactured by Fiberglass Division of Pittsburgh Plate Glass). These two materials were mixed together, and the necessary catalytic agents added immediately before application to the structural deck. Following this application, these materials underwent a chemical change or transition from a viscous liquid to a rigid solid. This transition was brought about by the catalytic agent which caused a copolymerization of the reactive monomer (in this instance, styrene) with an unsaturated polyester.

Problems were encountered in the development of mechanical apparatus with which to spray this viscous pre-mix of resin and glass. The original method used to apply these materials was a two-pot system. One side or pot of this system contained the pre-mix with the addition of a promoter; the other side contained the pre-mix with a catalyst. These two mixtures were sprayed through separate units to blend by converging in the air before they came in contact with the deck.

The pre-mix was made by mixing together the ingredients for each side of the two-pot system separately. The mixture contained the resin; 3 percent by weight of $\frac{1}{2}$ -in. chopped strands of glass fibers; 1 lb per gal of 325 mesh silica flour as a thixotropic agent; and either the promoter, dimethylalanine, or the catalyst, benzoyl peroxide, depending on for which side of the system the particular mix was made. The polyester resin in this mixture had a specific gravity of 1.12 at 25 C and weighed 9.3 lb per gal.

The glass fibers specified for use in this protective coating were a continuous roving pre-chopped into $\frac{1}{2}$ -in. lengths. These were added to reinforce the resin, as steel is added to reinforce concrete.

The ratio of glass to resin to form the pre-mix was predicated on the ability of the equipment to handle a glass and resin mixture rather than the optimum mixture to give ultimate results.

The pre-mix of polyester resin and glass was specified because anything less than the actual blending together of resin and glass fibers does not result in a complete wetting of each glass fiber. Fibers that have not become completely wetted with the resin could act as capillaries and transmit moisture through the laminate, thereby defeating the purpose of the application.

There are no data available to indicate that this type of material had ever been sprayed before. Consequently, there was not any commercial equipment available to handle this pre-mix. This required the engineering and construction of a mechanical spray unit to deliver this material. The original equipment designed to accomplish this task was a dual unit built in the following manner.

The pots or reservoirs were 55-gal steel drums with a cone welded inside to direct the gravitational flow of the material. These were mounted directly above positive displacement pumps, and the material was forced into a hose line and through a nozzle with a restricted orifice. Air was injected into the stream of the material as it arrived at the nozzle causing a vortex, and the resulting spray of materials from these two nozzles converged.

The glass fiber reinforced protective coating was first applied to the Brewerton Bridge in the fall of 1960. This bridge, actually two parallel structures, forms a link in the chain of the Federal Interstate Highway System known as Interstate 81 which crosses New York State and connects Pennsylvania with Canada. The Brewerton Bridge, sometimes referred to as the Oneida Lake Bridge, was at the time of its completion the longest span prestressed concrete bridge in the western hemisphere, measuring 460 ft between abutments with a clear center span of 320 ft 6 in.

One of the problems considered in the construction of this bridge was the protection of the thirty-four 240-ton, prestressed concrete girders from the deterioration caused by the reaction of de-icing chemicals with melting snow and ice on concrete.

It was for this project and future applications, calling for the protection of portland cement concrete, that this reinforced polyester resin protective coating was developed.

This system described for the application of this glass fiber reinforced protective coating, while mechanically sound, did not work because the catalyst in the pre-mix was activated by contact with copper or brass, and the glass strands would impinge on some internal projection and form a screen through which nothing but strained resin would pass.

Several changes in pumps were made during this first application to the Brewerton Bridge until a pump was found that did not have any objectionable metals (such as brass or copper) and at the same time would not lose output due to cavitation.

Changes were also being made in the mechanical delivery system. It was decided to remove, if possible, the catalyst from the pre-mix and inject it into the vortex in the nozzle. This would greatly simplify the equipment and permit the use of a one-pot system and at the same time increase the stability of the materials.

Using the two-pot system, the drums of catalyzed pre-mix had to be protected from sunlight and kept cool at all times to insure its pot-life. Otherwise, the catalyst would react and effect cure in the drum, thereby wasting the material.

A new system of catalyst injection was designed. This system was predicated on the fact that catalytic materials with lower viscosity were available. Such a material was methylethylketone peroxide which has a specific gravity of 1.120 at 25 C and a Brookfield viscosity of 12.7 centipoises at 25 C using a No. 1 spindle at 60 rpm as opposed to the benzoyl peroxide originally used which had a specific gravity of 1.2125 at 25 C and a Brookfield viscosity of 87,000 centipoises at 25 C using a No. 4 spindle at 6 rpm.

The manufacturer of the polyester resin agreed to the new approach and furnished a new polyester resin with cobalt naphthanate as the promoter and a thixotropic agent built into it.

With the successful development of material and equipment, supported by the techniques learned during the transition from idea to product, a new concept of concrete protection specified as "glass fiber reinforced resin waterproofing" was initiated.

Due to the method of constructing the Brewerton Bridge, the placing of 240-ton post-tensioned concrete girders necessitated the use of concrete filler strips between the girders. These filler strips had some depressions which had to be patched; this was accomplished by placing a patching mortar over an unclean surface. The patches were then steel troweled, though a steel troweled finish does not offer optimum conditions with which to form a bond.

The entire deck was swept clean and the glass fiber reinforced resin protective coating applied. Immediately after the application of the laminate and before a cure was accomplished, sand was hand sprinkled over the laminate to provide a mechanical key for the sheet asphalt wearing course which was to follow.

The application of the polyester laminate was completed in October 1960. It was then too late to apply the sheet asphalt wearing course in accordance with the New York State Department of Public Works specification which has a deadline of October 15. This resulted in the exposure of the polyester laminate throughout a severe winter. During this period of exposure the polyester laminate was subjected to the climatic conditions given in Table 1.

TABLE 1
CLIMATIC CONDITIONS FOR POLYESTER LAMINATE^a

Date	Precipitation (days)	Snowfall (in.)	Number of Freeze-Thaw Cycles
Nov. 1960	19	2.7	12
Dec. 1960	26	27.8	9
Jan. 1961	24	37.8	14
Feb. 1961	17	25.8	13
March 1961	26	26.5	22
April 1961	<u>26</u>	<u>8.4</u>	<u>11</u>
Total	138	129.0	81

^a From "New York Climatological Data," published by U.S. Department of Commerce.

Investigation of the glass fiber polyester resin laminate early in May 1961 showed several areas of random cracking and delamination from the concrete deck, prevalent in the locations where the deck had been patched.

The possible reasons for these failures were as follows:

1. Failure to employ surface preparation of the concrete deck other than sweeping. In all future applications, all areas to receive the polyester laminate should be either sandblasted or acid washed.
2. Failure of concrete patches to adhere to bridge deck over which the polyester laminate was applied. All patching of bridge decks to receive laminate should be avoided, and the depressed area brought to grade.
3. Cause due to uneven thickness of laminate because of inequalities of deck. As these materials develop exothermic heat during cure, a better control of the thickness of the one-pass spray application must be observed to eliminate too much heat that would cause residual stress that could cause cracking.
4. The difference in coefficient of linear expansion between reinforced concrete and polyester laminate. The resin used in this first application was an excellent quality,

but rigid, polyester that offered little to accommodate the linear expansion and contraction in reinforced concrete. Therefore, the type of polyester resin should be changed from a rigid to a resilient and the glass content increased to eliminate these differences in linear coefficient.

Despite the difficulties encountered, the application of these materials to the Brewerton Bridge can be termed a success. The areas of adhesive failure totaled less than 5 percent of the application. This represents an area of 2,150 sq ft out of more than 43,000 sq ft of protective coating material placed.

Since the completion of the repairs of the protective coating in spring 1961, the glass fiber reinforced resin waterproofing has undergone three specification changes and has been used extensively in New York State. The following is the current New York State Department of Public Works specification covering the application of this protective coating:

ITEM 450C—Glass Fiber Reinforced Resin Coating

1. Work. Under this item the Contractor shall furnish and place by spraying, glass fiber reinforced resin coating at the location shown on the plans and in accordance with this specification.

2. Materials. The resin shall be polyester. The polyester shall be Selectron Resilient Resin No. 5196 as manufactured by Pittsburgh Plate Glass Company, Paint Division, No. 1 Gateway Center, Pittsburgh 22, Pa., or an approved equal. The catalyst shall be Lupersol DDM manufactured by the Lucidol Division of Wallace and Tiernan Corporation, 1740 Military Road, Buffalo 5, New York, or Cadox MDP manufactured by the Cadet Chemical Corporation, Burt, New York. The glass shall be HSI with 805 sizing manufactured by Owens-Corning Fiberglas Corporation, Toledo 1, Ohio, or an approved equal.

The glass fiber together with any inert filler, and the polyester resin shall be pre-mixed before spraying. The glass fiber filaments shall exhibit complete wetting in the pre-mix solution. The chemicals to activate the setting reaction of the polyester shall be added to this mixture at the time of spraying and shall be so mixed or metered to establish a uniform distribution through the mixture. The chemical composition of these materials shall be so controlled that the curing time after spraying shall be $\frac{1}{2}$ hr to $1\frac{1}{2}$ hr. The mixture shall contain not less than 10 percent of glass fibers by weight. The glass fiber strands shall be $\frac{1}{4}$ in. long.

3. Preparation of Surfaces. Concrete surfaces shall be uniform and free from depressions and projections. They shall be cleaned of any accumulation of dirt, foreign materials or water to the satisfaction of the Engineer. Steel surfaces shall be sand-blasted to clean metal and shall be free of all dust or foreign materials to the satisfaction of the Engineer.

4. Application of Coating. The coating material shall be sprayed by gun under pressure to provide a thickness of $\frac{1}{8}$ in. minimum and $\frac{1}{4}$ in. maximum. Hand rolling shall be required to smooth out the surface irregularities resulting from the method of application. All rolling shall be done immediately after application before the surface cure is accomplished. Sharp, clean, dry sand passing a No. 8 sieve with 90 percent retained on a No. 16 sieve shall be applied before surface cure is accomplished so as to provide proper embedment and bond. The sand shall be applied at the rate of 3 lb per sq yd of surface.

This coating after application must possess excellent adhesion to the surface, evidence of which shall be obtained by tapping lightly with a ball-peen hammer 24 hr after complete cure has been accomplished.

After placing, the coating shall be protected in a suitable manner to insure against loads of any nature or damage by the elements until final cure has been accomplished or 24 hours' time has elapsed whichever is greater.

5. Approved. The use of "approved" in this specification shall require the affirmative action of the Deputy Chief Engineer (Bridges) in writing for the specific material, method or conditions to which it is applied.

6. Method of Measurement. The quantity of glass fiber reinforced resin coating to be paid for under this item will be the number of square feet of surface covered in ac-

TABLE 2
PHYSICAL PROPERTIES OF LAMINATE^a

Property	Value
Brookfield viscosity, 25 C, poise	3.8
Specific gravity, 25 C, cured	1.24
24-hour water absorption (%)	0.12
Flexural strength ($\times 10^3$ psi)	12.6
Flexural modulus ($\times 10^6$ psi)	0.44
Tensile strength ($\times 10^3$ psi)	8.9
Elongation at break (%)	1.19
Compressive strength ($\times 10^3$ psi)	17.5
Barcol hardness	37

^a Compacted from data sheets of three of the approved resin manufacturers.

American Cyanamid; Durez Plastics; and Molded Fiber Glass) and 10 percent by weight of HSI fiberglass with an 805 sizing (manufactured by Owens-Corning) to produce a laminate with the physical characteristics given in Table 2.

In many applications this laminate has been subjected to traffic from heavy road-building equipment without apparent injury. In one observed instance, a bituminous spreading machine had crushed a No. 3 size aggregate between its tread and the laminate without leaving a trace of any area of stress. This demonstrated ability of the laminate to withstand sudden impact without damage led to the belief that it could be used as a wearing course.

A testing program was then initiated under laboratory conditions to determine the validity of this premise.

During this program, tests were carried out to determine what aggregate would be most suitable to use to make the surface of the application skid resistant. Materials ranging from fine granules of iron ore tailings to particles of carborundum and aluminum oxide large enough to pass a No. 4 sieve were tried in varying ratios of resin to aggregate. One of the facts pointed out during this laboratory research program was that, although it was possible to form a homogeneous mixture of resin, aggregate and fiber glass, this mixture could not be placed with the spray equipment in one application. This fact required that if a material of this nature was to be applied as a wearing surface, it would have to be done in two successive spray coats to form a dual laminate. The first coat would be the application of the polyester materials as presently used. The second coat or wearing surface would be an external mixture of aggregate and resin applied directly to the first coat.

The aggregate decided upon was a crystallized silica having a gradation of an 8 to 16 sieve with a hardness factor of No. 7 on the original Moh scale.

On May 10, 1961, following 27 successive days of rain, this trial application was applied to a section of slab on grade known as Transit Road, located northeast of Buffalo, N.Y., in the suburb of Williamsville.

This trial application was to ascertain if the laminate could be made to perform two functions: that of a wearing course as well as its intended use as a protective coating for portland cement concrete.

In this trial application to Transit Road an area approximately 24 by 20 ft was chosen. This area ran from curb to mall across two lanes of pavement. This area was sand-blasted to remove dirt or other impurities present on the surface of the concrete and swept clean.

It was proposed to use a resilient polyester resin reinforced with 10 percent glass fiber as the first coat and on cure to apply a second coat or a rigid polyester resin filled with 60 percent crystallized silica as the wearing course. In performing this test an error was made, and the rigid and resilient resins inadvertently transposed. There-

cordance with the specifications as indicated on the plans or as ordered by the Engineer.

7. Basis of Payment. The price bid per square foot shall include the cost of furnishing all labor, materials and equipment necessary to prepare the surface, place the coating, apply the sand and complete the work.

These materials as specified have formed a part of 21 separate contracts involving the application of the polyester laminate to more than 70 separate bridges exceeding a total usage of 600, -000 sq ft.

The product used under today's specification contains a resilient isothallic polyester resin (manufactured by Seleccion Division, Pittsburgh Plate Glass;

fore, in actual spraying the first coat was applied using the rigid resin; and the second coat, or wearing course, was applied using the resilient resin. Being aware of this error the test was completed, and this test section of roadway opened to traffic.

During the 6 months that this test area was subject to better than three million traffic vehicles, the laminate separated from the concrete highway in some sections along the trailing edge of the coating. It was concluded that this delamination was due to two reasons. First, because a polyester resin is water sensitive, it tends to cure without achieving its bond when the surface to which it is applied is damp. In this case, there was a very high water table present. Second, the rigid resin does not provide the same degree of adhesion as the resilient and therefore did not have the elastic properties necessary to accommodate the coefficient of expansion. Further, this test was performed on a slab on grade, which is not the location specified for the use of the end product. The test application, despite this delamination, was judged a success.

The coating was highly skid resistant and showed little wear from the passage of traffic. It also provided information that a coating of this type need not employ any but a resilient resin, as this resin held the crystallized silica intact.

In the July 1962 letting, a contract was awarded by the New York State Department of Public Works for the application of a glass fiber reinforced resin wearing surface for a test application on a structure.

The structures selected to receive this experimental wearing course were two three-span bridges with cantilever and suspended center span measuring 197 ft in length and 54 ft from curb to curb. These structures employ a 4-in. reinforced concrete paving slab. They are located west of Albany, N.Y., on Interstate 87, where it crosses over NY 5. They were completed and opened to traffic in October 1959.

In the preparation of the bridge decks to receive the application of the glass fiber reinforced resin wearing surface it was necessary to remove the existing joint material from the expansion joints and to chip out and clean the structural cracks.

The approach pavement and the existing bridge pavement being at the same grade necessitated the removal of a portion of the bridge pavement at the leading and trailing ends of the structure to prevent a bump. This was done by bush-hammering the slab down $\frac{1}{8}$ in. and back approximately 6 in. The decks were then cleaned by means of sandblasting with garnet and wollastonite to remove any dirt, laitance, or other impurities present on the concrete surface to which the laminate was to be applied. The rate of cleaning the concrete decks by this method was approximately 5,000 sq ft per day. On completion of the sandblasting, the contaminations along with the expended garnet and wollastonite were then removed by power sweeper, then by vacuum cleaning, and finally by blowing with air. After the decks had been thoroughly cleaned, the cracks in the concrete were sealed with a polysulfide crack sealer.

On cure of the crack sealant, the first spray application of the protective coat of polyester resin reinforced with glass fibers was begun. This spray application was made to the entire deck with the exception of the expansion joints which were protected by boards wrapped with polyethylene. The spray application was applied over all longitudinal or construction joints.

In the application of a polyester resin, cleanliness and dryness of the surface to which these resins are being applied is essential. Therefore, extreme care was taken in this application to protect the deck from contamination. When rain occurred, the application was delayed until the surface was dry and clean before resuming application of the polyester resin laminate. On completion of each spray pass and before a cure had been accomplished, crystallized silica was hand applied to the laminate to help provide a mechanical key with the second coat or wearing course to be applied.

When the application of the first coat was completed and cured, the second course or wearing coat of polyester resin and crystallized silica was applied. This coating was likewise sprayed over the longitudinal joints while protecting the expansion joints.

The two coats form the glass fiber reinforced resin wearing course as applied under the following specification:

ITEM 460—Glass Fiber Reinforced Resin Wearing Surface

1. Work. Under this item the contractor shall furnish and place by spraying a two-

course glass fiber reinforced resin wearing surface at the location shown on the plans and in accordance with this specification.

2. (a) Materials. The first course resin shall be polyester. The first course polyester shall be Selectron Resilient Resin No. 5196 as manufactured by Pittsburgh Plate Glass Co., Paint Division, No. 1 Gateway Center, Pittsburgh 22, Pa. The catalyst shall be Lupersol DDM manufactured by the Lucidol Division of the Wallace & Tiernan Corporation, 1740 Military Road, Buffalo 5, New York, or Cadox MDP manufactured by the Cadet Chemical Corp., Burt, New York. The glass shall be chopped spun strand Type T-043, with a Chrome-Silane Hard sizing manufactured by Owens-Corning Fiberglass Corporation, Toledo 1, Ohio.

The glass fiber and the polyester resin shall be premixed before spraying. The glass fiber filaments shall exhibit complete wetting in the premix solution. The chemicals to activate the setting reaction of the polyester shall be added at the time of spraying and shall be added by meter and mixed so as to establish a uniform distribution throughout the mixture. The chemical composition of these materials shall be so controlled that the curing time after spraying shall be from $\frac{1}{2}$ to $1\frac{1}{2}$ hr. The mixture shall contain not less than 10 percent of glass fiber by weight. The glass fiber strands shall be $\frac{1}{4}$ in. long.

(b) Materials. The second course resin shall be polyester. The second course polyester shall be Selectron Resilient Resin No. 5196 manufactured by Pittsburgh Plate Glass Company, Paint Division, No. 1 Gateway Center, Pittsburgh 22, Pa. The catalyst shall be Lupersol DDM manufactured by the Lucidol Division of Wallace and Tiernan Corp., 1740 Military Road, Buffalo 5, New York, or Cadox MDP manufactured by the Cadet Chemical Corp., Burt, New York.

The chemicals to activate the setting reaction of the polyester shall be added at the time of spraying and shall be added by meter and mixed so as to establish a uniform distribution through the mixture. The chemical composition of these materials shall be so controlled that the curing time after spraying shall be from $\frac{1}{2}$ hr to $1\frac{1}{2}$ hr.

Aggregate in the amount of 60 percent by weight of the total mix shall be added at the time of spraying the second course. The aggregate shall consist of crystallized silica in the form of quartz having a hardness of No. 7 on the original Moh scale and a minimum specific gravity of 2.65 as produced by Industrial Silica Co., Youngstown, Ohio. The aggregate shall be graded to pass a No. 8 sieve with 90 percent retained on a No. 16 sieve.

3. Preparation of Surfaces. All surfaces shall be thoroughly cleaned of any grease, oil, tar, dirt, dust, paint and rust to provide a satisfactory bond between the contact surfaces and the applied materials. Any loose, scaled or damaged concrete shall be removed and the surface repaired to the satisfaction of the Engineer prior to application of the first course. The entire area to be coated with the wearing surface shall be cleaned by sandblasting. A light scrubbing with a 10 to 15 percent solution of muriatic acid followed by a thorough flushing with clean water shall be performed where required at the direction of the Engineer. The surface shall be thoroughly prepared, clean and dry, to the satisfaction of the engineer before the first course is applied. The contractor shall adequately cover and protect painted metal surfaces adjacent to any sandblasted or acid-treated areas. Any damage to metal surfaces adjacent to areas cleaned shall be repaired and the surfaces restored to their original condition at the contractor's expense. The contractor shall also adequately shield the top of the existing premoulded bituminous joint material to prevent damage to this material during the sandblasting process.

The final stage of the cleaning shall consist of vacuum cleaning the entire surface. This cleaning shall be done at the time the wearing surface is applied. The vacuum cleaning equipment shall be the Tornado Series 400 Vacuum Cleaner Drum Conversion Unit.

4. Application of Wearing Surface. The surface shall be vacuum cleaned at the time the first course is applied. The vacuum cleaning equipment shall be operated ahead of the spray equipment by a distance not to exceed 20 ft. The first course resin shall be sprayed by gun under pressure to provide a minimum thickness of $\frac{1}{8}$ in. Hand rolling shall be required to smooth out the surface irregularities resulting from the method of application. Rolling shall be done immediately after application before the surface cure

is accomplished. This course must possess excellent adhesion to the surfaces. After placing, the first course shall be protected in a suitable manner against loads of any nature or damage by the elements until the second course is applied. The first course shall be allowed to cure for a minimum period of 24 hr before application of the second coat.

(b) The surface shall be vacuum cleaned at the time the second course is applied. The vacuum cleaning equipment shall be operated ahead of the spray equipment by a distance not to exceed 20 ft. The second course containing the aggregate shall be sprayed by gun under pressure. Mixing shall occur at the special multi-headed nozzle under pressure and the coating shall be sprayed on the surface of the first course to a thickness of $\frac{1}{4}$ in. \pm $\frac{1}{16}$ in. This application must possess excellent adhesion to the surface. After placement, the second course of the wearing surface shall be protected in a suitable manner to insure against loads of any nature or damage by the elements until final cure has been accomplished or a minimum period of 24 hr.

5. Approved. The use of "approved" in this specification shall require the affirmative action of the Deputy Chief Engineer (Bridges) in writing for the specific material, method or conditions to which it is applied.

6. Method of Measurement. The quantity of glass fiber reinforced resin wearing surface to be paid for under this item will be the number of square feet of surface covered and acceptable in accordance with these specifications and where indicated on the plans or as ordered by the Engineer.

7. Basis of Payment. The price bid per square foot shall include the cost of furnishing all labor, materials, and equipment necessary to prepare and clean the surfaces, place the two course wearing surface and complete the work.

On completion of the application of the glass fiber reinforced resin wearing course, the bridges were reopened to traffic. The southbound structure was reopened on August 20, 1962, and the northbound bridge on September 4, 1962.

The traffic on these two structures is 23,933 vehicles per day. The greatest volume of traffic occurs between the hours of 4:30 and 5:30 PM, at which time the traffic on the southbound bridge represents approximately 46 percent of the total flow during this period. This is counted at 1,100 vehicles per hour. The traffic over the northbound bridge is counted at 1,348 vehicles, during this same period of time.

This glass fiber reinforced resin wearing course, when applied in accordance with the specifications above, has a thickness of $\frac{3}{8}$ in. and weighs approximately 30 lb per sq yd. This is only $\frac{1}{10}$ as heavy as a 3-in. wearing course of bituminous macadam.

This glass fiber reinforced resin wearing course, though exposed to traffic for a limited time, is providing the concrete protection for which it was designed. This laminate is resistant to hydrocarbon solvents, it is impervious to the penetration of moisture, it is highly skid resistant, it is not affected by de-icing chemicals, and there has been no evidence of failure due to cracking or delamination.