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J. B. KORNICK ET AL

3,397,626

PLASTIC COATED DOWEL BAR FOR CONCRETE

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Fig. 1.

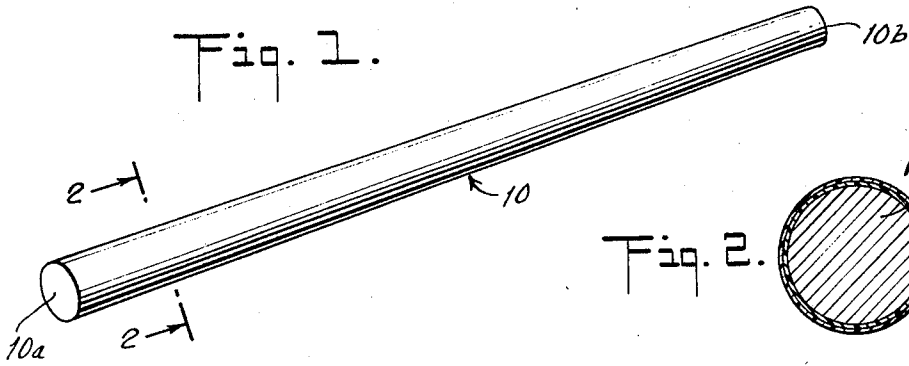


Fig. 2.

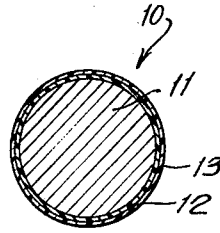


Fig. 3.

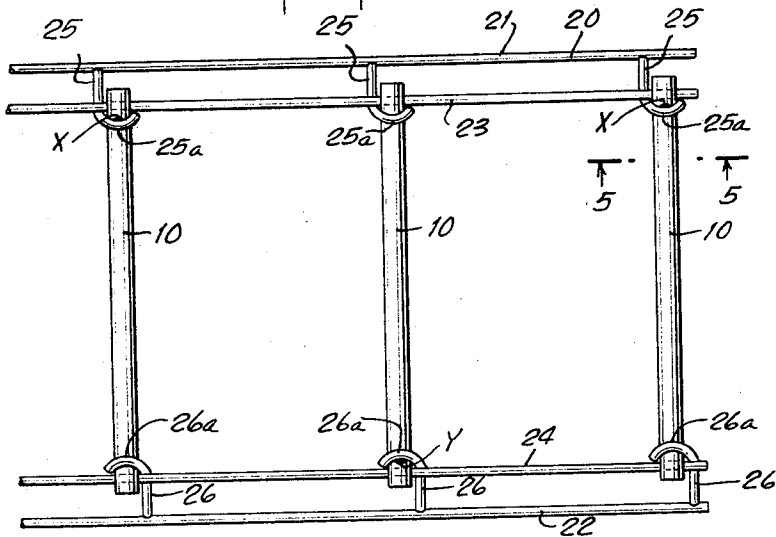


Fig. 4.

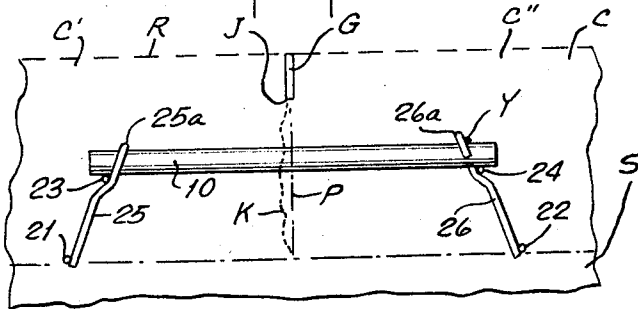
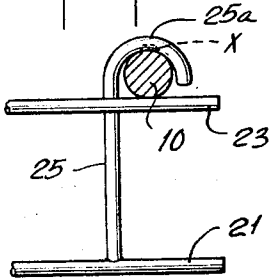


Fig. 5.



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PLASTIC COATED DOWEL BAR FOR CONCRETE

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ABSTRACT OF THE DISCLOSURE

A plastic coated steel dowel bar having a smooth and slippery outer coating layer and a flowable inner coating layer, adapted to be embedded in concrete hardened in situ about the dowel, for provision of low-friction sliding capability between the dowel surface and the contacting concrete, and protection of the steel core of the dowel against corrosion despite the presence of corrosive substances such as salt and despite the mechanical effects of such sliding contact on the outer coating layer. A polyolefin plastic outer coating layer, e.g., a polyethylene plastic layer, is provided with a flowable inner adhesive coating layer, a thermoplastic modified rubber type of adhesive, so as to protect a concrete highway joint dowel bar from the combined effects of friction due to expansion and/or contraction of the joint under shear and bending moment forces, and a corrosive attack by highway salt deposits and other substances carried both within and upon the highway concrete.

Background of the invention

It is customary in laying concrete highways to provide, at regular distances along the highway, for contraction joints so that cracking and buckling of the concrete can be forestalled. At fixed objects, such as bridges, it is also the practice to provide for expansion joints. There will be many contraction joints along the length of a highway, whereas usually there will be very few expansion joints. It has long been the practice to provide a plurality of dowel bars of considerable length and diameter, e.g., 18" long and 1 1/8" in diameter, each having its longitudinal axis lying along the direction of the roadway, the plurality of such dowel bars being spaced transversely across the roadway. The dowel bars are placed and supported at a height midway between the subgrade level and the prospective concrete roadway upper surface level, e.g. 4 1/2" above the subgrade when the concrete roadway is to be 9" thick.

After the dowel bars are laid out in this manner the concrete is poured, and hardens with the dowels bars embedded therein in situ. After hardening, a slot is sawed in the concrete along the transverse row of dowel bars to a shallow depth, e.g., 2 inches. A transverse crack in the concrete then develops downwardly from the slot, upon contraction of the concrete highway. The concrete portions on either side of the slot are then separate, but connected by the transverse row of dowel bars.

The function of the dowel bars is to keep these contiguous sections of concrete in alignment during contraction and re-expansion, to accept shear loads and to accept bending moment loads, so that the upper roadway surface of the concrete remains essentially coplanar at the joints under loading.

The dowel bars are closely held within the concrete, being embedded in situ, and accordingly their outer surface must have a relatively low coefficient of friction to facilitate the sliding between the dowel bar and the concrete encountered during contraction and re-expansion of the concrete sections. Further, highways are subjected to a number of substances during use, e.g. sodium

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and calcium chloride used for melting of snow and ice, and various agents in the concrete itself. Many of these substances are corrosive to steel, and because of the joint all such substances will find their way to the dowel bars. Accordingly the dowel bars must be protected against corrosion by these substances despite the abrasion incurred during the sliding motion and the loading of the dowel bars in shear and bending moment while sliding.

Previously, steel dowel bars have been painted with a varnish or a primer, followed by coating with a bituminous material or a light oil. Such dowel bars have proven unsatisfactory, in that they become corroded rapidly under the combination of sliding and the presence of corrosive agents, leading to a shearing of one or more of the bars at a joint, which in turn causes the adjacent concrete sections to buckle or incur shear loads causing random cracking. This is a serious economic problem, because such contact joints are typically spaced approximately 60 feet apart along the entire length of the highway meaning that there are nearly 100 such joints per mile of highway. The repair of an individual joint because of failed dowel bars is very expensive, and the repair of the great number of such joints in a highway can be almost prohibitive in cost. Provision of a dowel bar which will withstand the combination of sliding under shear and bending moment forces and the presence of corrosive substances, has therefore great direct economic benefit. Moreover, the buckling of the roadway and cracking of the cement and resultant "potholes," cause damage and inconvenience to vehicles using the roadway, and this is an additional and considerable economic consideration.

Brief summary of the invention

A steel dowel bar, e.g., 18" long by 1 1/8" in diameter, is coated with an inner layer one to eight mils, preferably four to eight mils, in thickness of a flowable adhesive suitable for bonding a polyolefin plastic to steel, preferably four to eight mils, in thickness of a flowable adhesive. An outer layer of polyolefin plastic, preferably polyethylene, is extruded upon the inner layer preferably under conditions such that the inner layer is subjected to compression, e.g. by moving the uncut dowel bar stock faster than the plastic is extruded during application of the outer layer. The outer layer is 10 to 20 mils in thickness, preferably 14 to 18 mils in thickness. This adhesive is such that it is, at room temperature, soft, rubbery and elastic. At such temperatures it does not flow freely of itself, but is soft enough so that when applied in films of 1 mil or more in thickness, it is susceptible to being pushed or caused to flow with the stress provided by the extruded plastic jacket. At elevated temperatures it is a free flowing liquid capable of being flooded onto the steel bars; additionally it must have very low moisture absorption and must not support the growth of fungi. The flowable adhesive inner layer seals punctures and abrasions in the outer layer by flowing thereinto, and also prevents underfilm migration of the outer layer by corrosive moisture from the end edges or chips in the outer layer too large to seal by flow action. Moreover, the flowability of the inner layer allows a certain degree of yield to the outer layer so as to minimize abrasions thereof due to sliding under shear and bending loads. This combination of attributes, together with a low coefficient of friction, provides a much improved dowel bar, as aforesaid.

Brief description of the figures

An illustrative embodiment of the invention is set forth hereinbelow in a detailed description of the invention with reference to the figures, in which:

FIG. 1 is a perspective view of a coated dowel bar according to the invention;

FIG. 2 is a cross-sectional view of the dowel bar shown in FIG. 1 taken along plane 2—2 therein and showing the inner and outer coating layers;

FIG. 3 is a plan view of a plurality of dowel bars according to the invention held in spaced parallel relationship by a wire frame in the positions occupied when employed to secure a highway joint;

FIG. 4 is a side view of the apparatus shown in FIG. 3 showing the outline of the concrete roadway, its subgrade, and its joint in phantom outline; and

FIG. 5 is a section view of a portion of the apparatus shown in FIG. 3 taken along plane 5—5 therein.

Referring now to the figures a dowel bar indicated generally at 10 according to the invention comprises a cylindrical inner steel core 11 surrounded by an inner layer 12 completely covering at least the cylindrical outer surface of the steel core 11. Inner layer 12 comprises a flowable adhesive suitable for bonding a polyolefin plastic to steel, preferably a thermoplastic modified rubber type of adhesive. Surrounding inner layer 12 is outer layer 13, which completely encloses inner layer 12, i.e., completely encloses the steel core 11 with the inner layer 12 therebetween. Outer layer 13 comprises a polyolefin plastic material, preferably polyethylene, and is under hoop stress so as to bear firmly upon inner layer 12. Outer layer 13 may attain this stressed condition by any of several application techniques, e.g., by extruding layer 13 upon layer 12 under conditions that the dowel bar 10 is moved faster than the extruding polyolefin plastic material. The adhesive of inner layer 12 is such that it is, at room temperature, soft, rubbery and elastic. At such temperatures it does not flow freely of itself, but is soft enough so that when applied in films of 1 mil or more in thickness, it is susceptible to being pushed or caused to flow with the stress provided by the extruded plastic jacket. At elevated temperatures it is a free flowing liquid capable of being flooded onto the steel bars; additionally it must have very low moisture absorption and must not support the growth of fungi.

The thickness of layer 12 may vary between about 1-8 mils, and preferably between about 4-8 mils. The lower operative limit is determined by the minimum thickness necessary to perform the function of bonding the outer layer 13 securely to the core 11 and at the same time confer the tear sealing and the cushioning advantages described hereinafter. The preferred lower limit is determined by the considerations of moisture barrier and scuffing resistance characteristics. The thicker layer 12 provides a more secure water penetration barrier, and its more substantial body protects against scuffing both by flowing into breaks in layer 13, and by providing a cushion for layer 13 so that localized surface pressures cause yielding thus avoiding tearing. The operative and preferred upper limits are determined by the desirable upper limit on deflection of the dowel bar under bending load, the bar tending to deflect more with a thicker layer 12.

The thickness of outer layer 13 may vary between about 10-20 mils, and preferably about 14-18 mils. As aforesaid, highway specifications will determine the maximum deflection permissible, under loading, of the dowel bar. An example of such a maximum permissible deflection would be a 10 mil deflection of an 18 inch long dowel bar, one and one-eighth inch in diameter, under a 4000 pound load while embedded in concrete across a joint with an absolutely firm subsurface. It has been found that the layer 13 tends to increase deflection above and below a certain thickness, and the stated upper and lower limits are therefore determined principally by this fact. In addition, the lower limits are partially determined by the desired minimum scuff resistance and moisture barrier characteristics.

The ends 10a, 10b of the dowel bar 10 may or may not be coated with layers 12, 13. In general, it is more economical to fabricate an elongated rod, which is coated with both layers on its cylindrical surface and then

cut into individual dowel bars 10. It is desirable from an operative standpoint to then coat the ends 10a, 10b with layers 12, 13 so that they are afforded corrosion protection. However, since the ends 10a, 10b do not encounter appreciable friction, it is possible to omit layer 13 and rely only upon layer 12. Furthermore, because layer 13 on the cylindrical surface of dowel bar 10 is so securely affixed to core 11 by layer 12, even if the ends 10a, 10b are left bare steel, there will be no migration of moisture under the coating toward the center of the length of dowel bar 10 from ends 10a, 10b, although there may be local corrosion at ends 10a, 10b. Since it is corrosion nearer the center, where the loads are principally borne, that is critical, it will be seen that the present dowel bar is less critical than heretofore as to the condition of the ends 10a, 10b as to moisture exposure thereof. In prior art dowel bars, e.g., in painted pins with a light oil coat over the paint, bare ends such as 10a, 10b or chips at the end edges, would allow moisture to enter under the paint coat, undermining it along its length and corroding the critical center of the dowel bar. The combination of layers 12, 13 renders the ends 10a, 10b less important insofar as the integrity or even the existence of coating thereat is concerned. This can be valuable economically in dispensing with end coating, or in rendering end-chipped bars acceptable.

Furthermore, corrosion at the center is also avoided in the first instance by the abrasion resistance of the bar due to both the slipperiness thereof and the cushioning effect of layer 12, as well as by sealing of abrasion or other apertures in layer 13 by the flowability of layer 12. Critical corrosion at the center is thus avoided directly by the overlying coating, and indirectly by the security of the coating at the bar end edges where moisture migration to the center of the bar has often originated in prior art bars.

In FIGS. 3-5, a plurality of dowel bars 10 such as are shown in FIGS. 1 and 2 are held in place for employment as highway joint dowel bars by a wire frame indicated generally at 20 comprising a pair of parallel, spaced lower wires 21, 22 and a pair of parallel, spaced upper wires 23, 24. The pair of wires 23, 24 are elevated with respect to the pair of wires 21, 22, but are parallel thereto, and are more closely spaced to one another than are wires 21, 22. A plurality of upwardly inclined wires 25 are spaced along wires 21, 23 and are welded to each, and have at their upper ends a free curved portion 25a of approximately the same radius of curvature as the outside radius of dowel bars 10. A similar plurality of upwardly inclined wires 26 is welded to each of wires 22, 24 at spaced positions therealong directly opposite to the positions occupied by wires 25. Wires 26 include curved portions 26a corresponding to curved portions 25a of wires 25. There is thereby provided a wire frame structure adapted to receive the plurality of dowel bars 10 across the upper wires 23, 24 within the opposed pairs of curved wire portions 25a, 26a, as illustrated.

The structure of wires 21, 23, 25 must be maintained in structural relationship to the structure of wires 22, 24, 26. If it is desired to have dowel bars 10 held within the curved wire portions 25a, 26a but without fixed connection thereto, the dowel bars 10 may be inserted as illustrated and the generally trapezoidal configuration of wires 25, 26 (FIG. 4) will cause a clockwise turning moment in wires 25 and a counterclockwise turning moment in wires 26, both as viewed in FIG. 4. It will readily be appreciated that both these moments will tend to grasp the dowels 10 between the upper wires 23, 24 and the curved portions 25a, 26a, respectively. The wire frame 20 can then support the plurality of dowel bars 10 in relative stability despite the lack of structural interconnections between the structure of wires 21, 23, 25 and the structure of wires 22, 24, 26. The greater the inclination from the vertical of wires 25, 26, the greater the stability will be. In general, since the wire frame 20 serves pri-

marily as a placement device for the correct location of the plurality of dowel bars 10 during pouring of the concrete, such an arrangement is fully acceptable.

However, if structural integrity of the wire frame 20 on the dowel bars 10 is desired, the dowel bars 10 may be welded to one or the other of curved wire portions 25a, 26a. That is to say, alternate ones of dowel bars 10 will be welded to their curved wire portions 25a while the others of dowel bars 10 will be welded to their curved wire portions 26a. In FIG. 3, two dowel bars 10 are shown welded to their curved wire portions 25a at x while the intermediate or alternate dowel bar 10 is shown welded to its curved wire portion 26a at y. This welded arrangement is superior over the previously described arrangement in that the plurality of wires 21-26 thereby form a structural unit with the various dowel bars 10, so that the total assembly can be handled as a unit. Furthermore, during pouring of concrete there is less likelihood of disruption of the orientation of the dowel bars 10. On the other hand, the welding of the coated dowel bars 10 penetrates the outer coating layers 12, 13 so that it becomes desirable to practice an added step of applying a protective coating over the welded spot. As a practical matter however, these weld spots x, y are easily protected by an application of the same adhesive employed to form inner layer 12, and in general the welds x, y do not present a sufficient problem to overcome the advantage in handling the assembly as a unit as aforesaid. Furthermore, it is a feature of the invention that, for the same reasons discussed above with regard to ends 10a, 10b, the bare metal exposed at weld spots x, y will not cause undercutting of layers 12, 13 by moisture, as in the prior art, and thus if local corrosion can be tolerated, the spots x, y need not even be re-coated. Thus the dowel bars 10 can be held in place by either of these approaches to the construction of a wire frame 20, or other supportive structures similar or dissimilar to wire frame 20 may instead be employed to support and position the dowel bars 10 during the pouring and setting of the concrete.

Before the concrete roadway is laid a subgrade indicated at S in FIG. 4 will be laid in the usual highway construction manner, and the wire frame 20 with the plurality of dowel bars 10 will be laid transversely of the direction of the roadway upon the subgrade S and at a position along the direction of the roadway at which a contraction joint is desired, the median plane P through the plurality of dowel bars 10 being the preferred location for the actual roadway joint. Then the wet concrete mixture itself will be filled in up to the level indicated at R in FIG. 4, which is generally approximately double the height of the dowel bars 10 above the subgrade S. When the concrete is set, a concrete body C is provided between subgrade S and surface R which embeds and completely surrounds the series of dowel bars 10. That is to say, the outer surface of dowel bars 10, i.e., the outer surface of outer layer 13 thereof, is in intimate contact with the hardened concrete C.

In typical practice, the groove G is then sawed transversely across the solid concrete C to a depth less than the depth of dowel bars 10, e.g., to about 2", preferably at the median plane P. When the concrete body C next begins to contract, e.g., by thermocontraction, a complete transverse crack will develop downward from groove G approximately along the median plane P. In FIG. 4 the crack is shown at K as being not quite along plane P, as will be typical. The slot G and the crack K may then divide the concrete body C into a portion C' located on one side thereof and another portion C'' located on the other side thereof.

Concrete portions C' and C'' may then contract and re-expand causing the opening and closing respectively of crack K. Each dowel bar 10 must, during this contraction and re-expansion process, develop a sliding relation with at least one or the other of concrete portions C' and C''. When weld spots x, y are employed, the dowel bars 10

will not slide with respect to that one of concrete portions C' and C'' including the weld spot, but will slide only with respect to the other of the concrete portions. When the dowel bars remain free, i.e., with no weld spots or other restraints imposed, the dowel bars may slide relative to one or both of the concrete portions C' and C''.

In any event, the dowel bars 10, being very closely and tightly held within the concrete body C, are subject to abrasion upon such sliding motion during contraction and re-expansion of the joint at J along G, K. This abrasion is intensified by virtue of the fact that dowel bars 10 are subjected both to shear and bending moment as a result of inevitable non-homogeneity of the subgrade S, either initially or after some period of time, causing one or the other of concrete portions C' and C'' to be less securely supported by the subgrade S in the vicinity of the joint J. In that event one or the other of concrete portions C' and C'' will tend to become depressed with respect to the other, thus applying shear forces to dowel bars 10, or applied loads, such as from vehicles, crossing joint J will tend to depress both portions C' and C'' in the vicinity of joint J thus setting up bending moment forces in the dowel bars 10. In either case, this is reflected in increased pressure and abrasion upon the outer surface of dowel bars 10 by the concrete body C.

It has now been found that provision of the flowable layer 12 according to the invention upon the steel core 11, together with the provision of the polyolefin plastic outer layer 13, particularly when the outer layer 13 is in compression so as to forcibly bear upon inner layer 12, results in an outer surface of the dowel bars 10, i.e. the surface of outer layer 13, which presents a low coefficient of friction to the concrete body C, is resistant of scuffing and tearing thereof, and yields somewhat due to the flowable inner layer 12 so as to preserve the integrity of outer layer 13 under the aforesaid shear and bending moment forces applied during sliding. In addition, when a tear or hole in outer layer 13 occurs despite this improved resistance thereto, the flowable inner layer 12 tends to flow into any crack or scratch or the like to continue to protect the steel core 11.

It has also been found that the dual layer construction according to the invention provides an improved barrier for the entire dowel bar 10, against moisture located outside both layers, as compared, for example, with prior art painted dowel bars. However a more serious problem has heretofore existed due to migration of moisture along the surface of core 11 once it had gained access thereto, thereby corroding a great area of the dowel bar. For example, as previously indicated, it is common in all but the most careful handling to chip or erode any coating, including the coating 12, 13 according to the present invention, at the edges presented at ends 10a, 10b. The tendency for moisture to work beneath the coating at that point is prevented by the present invention in that the outer layer 13 is securely bonded to the steel core 11 by the adhesive layer 12 and will not admit such migration even when exposed as aforesaid. Thus breaks in layer 12, 13 that are too large to be sealed by the flow of layer 12, will still allow less corrosion than heretofore.

The roadway surface R is subjected, in use, to corrosive substances, such as sodium and calcium chloride. These substances will migrate down through crack K to dowel bars 10, and will corrode the steel cores 11 thereof at any points in the outer coating thereof that are breached through to the steel core 11. But in the practice of the present invention breaches along the dowel bars 10 due to abrasions from slipping and due to other causes will be closed by the flowable nature of inner layer 12. Also, chipping as at the ends 10a, 10b of the dowel bars 10 will not lead to migration of moisture containing these corrosive substances undermining the coating, for the aforesaid reasons. The combination of these protections, together with the lowered susceptibility of the outer layer 13 to breach by abrasion, due both to a low coefficient of

friction and to a tendency to yield because of the flowable inner layer 12, provides dowel bars 10 which are greatly improved in resistance to corrosion under the service conditions of loading of the joints J as by vehicles, and the presence of corrosive substances.

Prevention or substantial reduction of corrosion of dowel bars 10 ensures that the respective concrete portions C' and C'' will remain substantially coplanar despite the shear and bending moment forces applied by their own weight and by the weight of vehicles and the like, and despite non-homogeneity of the supporting qualities of the subgrade S below joint J. On the other hand, and as has been common with prior art dowel bars, when dowel bars become heavily corroded, and when the subgrade S becomes undermined in the vicinity of joint J, there is a tendency for one or more of the dowel bars to shear thus allowing buckling of the roadway at joint J, or allowing the roadway to become non-planar at joint J, for example by one of concrete portions C' and C'' sinking somewhat at joint J. Since there may typically be 80 to 100 joints J per mile of roadway, the employment of dowel bars which are subject to corrosive attack ensures that there will frequently occur such failures somewhere along the roadway, although at any particular joint J the precise combination of factors necessary for failure may not occur.

With the present invention the likelihood of corrosion and failure of the dowel bars 10 is so greatly reduced that very few failures of joints J will occur. It may thus be seen that in a highway system covering hundreds and thousands of miles, provision of dowel bars 10 having very superior anticorrosion characteristics constitutes a very substantial economic advance in the art of highway construction and maintenance, and also a great improvement in road conditions in the reduction of "potholes" and other road defects, associated with dowel bar failure.

While the invention has been described with reference to a particular embodiment, the description is not limiting, but is merely illustrative of the inventive principles.

What is claimed is:

1. A highway dowel bar suitable for embedding in situ in a cast concrete highway across a joint therein, characterized by a generally cylindrical steel core, wherein the improvement comprises:

- (a) a first coating layer covering and bonded to the entire cylindrical surface of said steel core, having the characteristic of adhesion both to steel and to polyolefin plastic bodies, and the characteristic of flowability at normal ambient temperatures under pressure greater than that caused by its own weight, said first layer being between about 1 and about 8 mils in thickness; and

- (b) a second coating layer surrounding and bonded to said first layer, being an extruded polyolefin plastic body, and being between about 10 and about 20 mils in thickness.

2. A highway dowel bar according to claim 1 wherein said second coating layer is under hoop stress so as to exert compressive force upon said first coating layer.

3. A highway dowel bar according to claim 1 wherein said first coating layer comprises a thermoplastic modified rubber type of adhesive, and said second coating layer comprises polyethylene.

4. A highway dowel bar according to claim 1 wherein said first coating layer is between about 4 and about 8 mils in thickness, and said second coating layer is about 14 to about 18 mils in thickness.

5. A highway dowel bar according to claim 1 wherein said first coating layer is between about 4 and about 8 mils in thickness, and said second coating layer comprises polyethylene, under hoop stress so as to exert compressive force upon said first coating layer, and being between about 14 and about 18 mils in thickness.

6. A concrete highway joint construction, for the accommodation of contraction and/or expansion, characterized by a plurality of generally cylindrical steel core dowel bars arranged across a joint in the concrete body of the highway, the dowel bars being embedded in situ in the cast concrete thereby affording a tight fit therebetween, wherein the improvement comprises each said dowel bar including:

- (a) a first coating layer covering and bonded to the entire cylindrical surface of said steel core, having the characteristic of adhesion both to steel and to polyolefin plastic bodies, and the characteristic of flowability at normal ambient temperatures under pressure greater than that caused by its own weight, said first layer being between about 1 and about 8 mils in thickness; and

- (b) a second coating layer surrounding and bonded to said first layer, being an extruded polyolefin plastic body, and being between about 10 and about 20 mils in thickness.

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NILE C. BYERS, JR., *Primary Examiner.*

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,397,626

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John B. Kornick et al.

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 50, "thick:." should read ---thick. --; line 60, "kept" should read ---keep --. Column 2, line 39; "four to eight mils, in thickness of a flowable" should read --- a thermoplastic modified rubber type of --. Column 3, line 58, after "preferably" insert -- between --.

Signed and sealed this 10th day of March 1970.

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

WILLIAM E. SCHUYLER, JR.

Commissioner of Patents