May 11, 1943. K. P. BILLNER 2,319,105

METHOD OF REINFORCING CONCRETE BODIES

Filed June 17, 1942

Fig. 1.

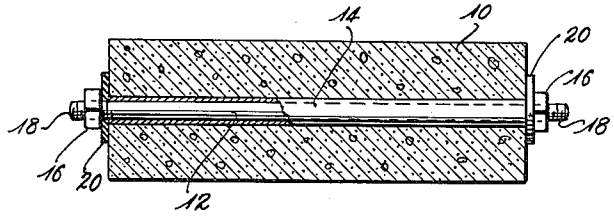


Fig. 2.

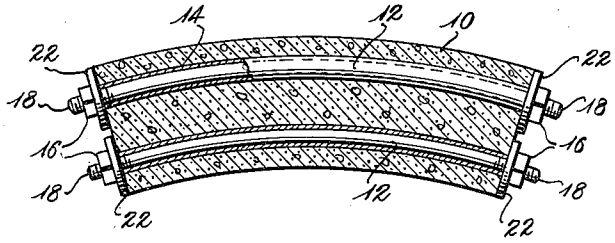


Fig. 3.

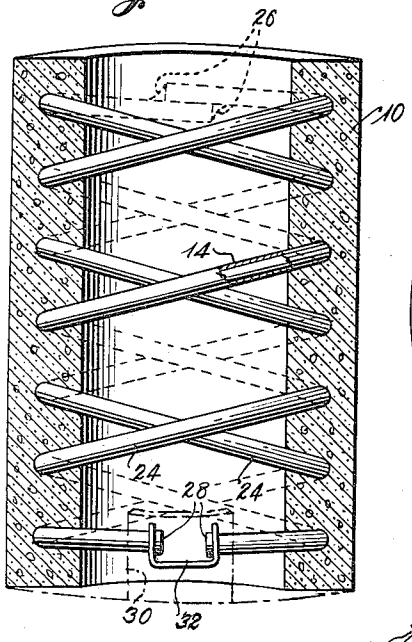


Fig. 4.

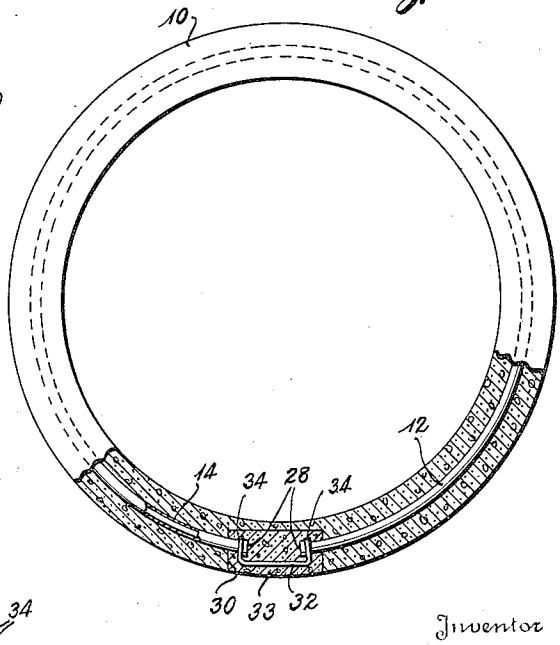
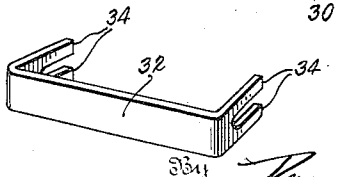


Fig. 5.



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METHOD OF REINFORCING CONCRETE BODIES

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Application June 17, 1942, Serial No. 447,407

18 Claims. (Cl. 25—154)

This invention relates to reinforced plastic bodies and methods of producing them.

The formation of cracks in concrete structures has always been a particularly troublesome problem. By its very nature, concrete is intended to assume compressive stresses only, while its reinforcing elements are relied upon to receive the tensile stresses. Yet an inevitable tendency accompanying the setting and hardening of concrete is the formation of internal stresses which are in turn responsible for the objectionable cracking. Among the various proposals for overcoming these effects is what is known as prestressing.

In concrete ships, for example, it has been considered advisable in the past to permit only very low working stresses in the steel reinforcement, since with higher stresses, small cracks have been observed in the concrete in portions of the ship which are subjected to tension. By way of contrast, much higher stresses have been permitted in ordinary concrete structures, such as buildings, whereby the properties of the steel reinforcement are utilized to much greater advantage. But, by prestressing the reinforcement, cracks and fissures can be avoided, air and water tightness achieved, and economy in reinforcement realized. Hence the use of prestressing adapts itself admirably to ship, tank and similar construction.

The advantages of prestressing reinforced plastic bodies, particularly concrete, have been known to the engineering profession for many years. Yet in spite of the appreciable thought and effort which have been expended in attempting to reduce this knowledge to a practicable basis, there has been no widespread adoption of any method thus far proposed. Most of the previously known methods have been directed along the lines of physically stretching the reinforcing elements, pouring the plastic material about them, allowing the material to harden and then releasing the reinforcing elements and permitting their contracting force to set up compressive stresses in the concrete. These methods have been fraught with difficulties in applying the tensile stresses and in regulating the magnitude of the forces which are ultimately imposed upon the hardened body.

It has been proposed also to prevent a bond between concrete and its reinforcing elements by coating the reinforcing bars with petroleum or asphaltic materials as described in the patents to Dill, No. 1,684,663, dated September 18, 1928, and Hewett, No. 1,818,254, dated August 11, 1931; and by surrounding the reinforcing bars with metal tubes as disclosed in the patent to Kennedy, No. 2,185,749, dated January 2, 1940. And in the patent to Steiner, No. 903,909, dated November 17, 1908, the progressive tensioning of reinforcing elements while the concrete is hardening has been described.

In accordance with the present invention, the effects of prestressing are obtained by thermally expanding the reinforcing elements after the plastic body has hardened. This is accomplished by forming the plastic body about the reinforcing element and releasing any bond between the body and the element so that the element may be expanded with respect to the body, whereupon the element is permitted to partially contract so as to bear upon the body and produce compressive stresses therein.

The reinforcing element is expanded preferably by the application of heat, which may be accomplished by passing therethrough an electric current having suitable characteristics. To assure desired movement of the reinforcing element with respect to the plastic body when expansion occurs, suitable covering or sheathing material may be interposed between the body and its reinforcement to prevent a direct bond therebetween. In some cases, a thermoplastic material is utilized so the heating effect will soften it to permit the reinforcing element to expand. Under some circumstances, thermosetting materials will be used. Where there is danger of short circuiting or leakage, the covering material may be electrically insulating, but in other cases, low melting metals or alloys may serve satisfactorily. The covering or coating materials should have melting or at least softening points which are sufficiently low as to permit the desired results without requiring the temperature of the reinforcing elements to be raised to a degree that would adversely affect their reinforcing characteristics.

When the reinforcing element has expanded an amount sufficient to impose the desired stresses upon subsequent contraction, it is suitably secured against excessive contraction so that the desired amount of its contracting force will be applied to produce compressive stresses within the body. The mode of securing the element may vary according to the type of structure involved, but such expedients as welding, clamping, threading and pinning suggest themselves. Where the securing arrangement employed requires a recess in the concrete body, for example, a dry packed concrete filling may be used to protect the joint and to impart to the structure a finished appearance.

A thermoplastic material such as sulfur, melting at approximately 120° C. is a good electrical insulator and at the same time furnishes a reasonably good bond between steel and concrete. In some cases, the thermoplastic or thermosetting covering or sheathing material may assume a preformed tubular shape.

For purposes of illustration, reference is made to the accompanying drawing wherein:

Fig. 1 is a sectional elevation of a reinforced member embodying the present invention;

Fig. 2 is a sectional elevation of an arcuate member;

Fig. 3 is a sectional elevation of a helically reinforced cylindrical body;

Fig. 4 is a sectional elevation of a cylindrical body containing an annular reinforcing element; and

Fig. 5 is a perspective of a clip for securing the ends of the reinforcing elements of Figs. 3 and 4.

The plastic body 10, depicted as concrete in the drawing, is provided with one or more reinforcing elements 12, and each element is covered by a material 14 which prevents a direct bond between the plastic body and its reinforcement. Where the plastic body is thermoplastic itself or where it possesses no tendency to adhere to the reinforcing element, the interposed material 14 may be omitted. But since concrete and steel have been indicated in the various figures of the drawing, the interposed material also has been indicated. Among the materials considered to be suited for interposition between the body and its reinforcement under proper conditions are sulfur, low melting resins, low melting alloys, various other thermoplastic and thermosetting substances, or other suitable materials which may be wrapped, coated, molded or otherwise formed about the reinforceing elements.

In Fig. 1, the body may represent a slab, beam, floor, deck, road, wall, or other member in which the effect of prestressing is desired. After the concrete has hardened sufficiently to resist substantial deformation upon application of the desired stresses, heat is applied to the reinforcing element 12 as by attaching electrical conductors to its ends and allowing a predetermined type and amount of current to flow so as to melt or soften the interposed material 14 and to elongate or axially expand the element 12 a desired amount. At this point the nuts 16 are advanced a predetermined amount upon the threaded ends 18 of the relatively smooth rod 12, so that when the thermal effect is reduced, as by decreasing the current flow, the rod will contract until the washers or bearing plates 20 engage the concrete body and the further contracting force of the reinforcing element will apply compressive stresses to the concrete body. Whereas but one reinforcing element has been shown in Fig. 1, it will be understood that any number may be employed depending upon the dimensions of the plastic body, the yield point of the reinforcing elements and the stresses to be imposed. Such additional reinforcing elements may be arranged parallel to or at any desired angle to the one shown.

Fig. 2 illustrates the invention as applied to an arcuate or curved member which may be an arch, floor, roof, wall, hull, or any reinforced body to which such a shape adapts itself. In this case, two reinforcing elements having threaded ends 18 and covered with sheathing material 14 have been shown, provided with nuts 16 and bearing plates or washers 22. In this instance, the reinforcing elements may be heated and clamped sequentially or simultaneously, the mode of operation being substantially the same as that described with reference to Fig. 1.

Fig. 3 illustrates a cylindrical concrete body reinforced with oppositely directed helices 24, the opposed upper ends of which are joined by welds 26 or other suitable means. In such an arrangement, the helices are preferably heated simultaneously so that they will both attain their desired degree of expansion at the same time, whereupon their free ends provided with enlarged heads 28 are engaged by the bifurcated ends of a clip 32 of predetermined length or otherwise suitably connected to restrict contraction. After the joints have been made, tendency of the helices to contract will cause the convolutions to embrace the adjacent concrete surfaces whereby the concrete body as a whole will be subjected to compressive stresses. As indicated by broken lines, the joint at the lower ends of the helices may be formed within a recess provided in the concrete body. Examples of structures to which this form of the invention may be applied include tanks, silos, linings, pipes, rings and other bodies.

Fig. 4 is directed to a cylindrical body of reinforced concrete wherein the enlarged ends 28 of the reinforcing element 12 are received in a recess 30 which is formed to permit the joint to be made internally of the structure. When current is applied to the ends 28, the thermoplastic or other suitable material 14 will soften and the discontinuous annulus or hoop will expand axially. After expansion has progressed sufficiently, the current is discontinued and a clip 32 having bifurcated ends 34 is slipped over the enlarged heads 28. Then the element 12 will partially contract and impose the desired compressive stresses upon the body of the plastic structure 12. If desired, the recess 30 may be filled with dry packed concrete 33 or the like to provide the body with an unbroken periphery and also protect the joint against the elements.

Where thermoplastic or thermosetting covering materials are used, upon reduction of the thermal effects below their melting or softening points, they will harden and effect a bond between the plastic body and its reinforcement. In connection with such covering materials, where it is desired to prevent undue abrasion during handling, a protective sheath such as mesh or other suitable fabric may be employed, or a suitable substance such as asbestos fibers may be incorporated in the covering material itself.

The heating current may be D. C. or A. C. of desired frequency, and of various voltages as will be determined by the resistance of the reinforcing elements, desired degree of expansion and the temperature limit to be observed to avoid injury to the properties of the steel or other materials.

Among the many uses to which the principles of the present invention may be applied, there will be mentioned but a few, namely: bridges, roads, piles, floors, roofs, arches, walls, ships, pipes, tanks, silos, tunnel linings, dome foundation rings, columns, beams and slabs.

The foregoing description is illustrative of the invention whose scope is set forth in the following claims.

I claim:

1. A method of stressing a reinforcing element in a hardened plastic body comprising thermally expanding said element with respect to said body,

causing said element to contract with respect to said body, applying at least a portion of the contracting force of said element to produce compressive stresses in said body and establishing a bond between said element and said body.

2. A method of stressing a reinforcing element bonded in a hardened plastic body comprising thermally reducing the bond and axially expanding said element with respect to said body, reducing the thermal effect, applying at least a portion of the contracting force of said element to produce compressive stresses in said body and restoring the bond.

3. A method of stressing a reinforcing element bonded in a hardened plastic body comprising thermally softening a bonding zone surrounding said element and axially expanding said element with respect to said body, causing said element to contract with respect to said body, applying at least a portion of the contracting force of said element to produce compressive stresses in said body and hardening said bonding zone.

4. A method of stressing an insulated reinforcing element in a hardened plastic body comprising thermally softening the insulation and expanding said element with respect to said body, causing said element to contract with respect to said body, applying at least a portion of the contracting force of said element to produce compressive stresses in said body and hardening said insulation to establish a bond between said element and said body.

5. A method of stressing a reinforcing element bonded in a hardened plastic body comprising passing an electric current through said element and thereby reducing the bond and axially expanding said element with respect to said body, reducing said current and applying at least a portion of the contracting force of said element to produce compressive stresses in said body.

6. A method of stressing a coated reinforcing element in a hardened plastic body comprising softening the coating on said element and axially expanding said element with respect to said body, causing said element to contract with respect to said body, applying at least a portion of the contracting force of said element to produce compressive stresses in said body and hardening said coating to establish a bond between said element and said body.

7. A method of stressing a coated reinforcing element in a hardened plastic body comprising thermally softening the coating on said element and axially expanding said element with respect to said body, causing said element to contract with respect to said body, applying at least a portion of the contracting force of said element to produce compressive stresses in said body and bonding said element to said body.

8. A method of stressing a reinforcing element bonded in a hardened plastic body comprising thermally reducing the bond and expanding said element with respect to said body, causing a limited contraction of said element with respect to said body, applying at least a portion of the contracting force of said element to produce compressive stresses in said body and restoring said bond.

9. A method of stressing a reinforcing element bonded in a hardened plastic body comprising thermally reducing the bond and expanding said element with respect to said body, positioning a bearing member on said element to engage said body upon subsequent contraction, causing said element to contract to an intermediate position whereupon said member engages said body to produce compressive stresses in said body and increasing said bond.

10. A method of stressing a thermoplastically covered reinforcing element in a hardened plastic body comprising thermally softening the coating on said element and axially expanding said element with respect to said body, positioning a bearing member on said element to engage said body upon subsequent contraction, reducing the thermal effect, causing said element to contract to a position in which said member engages said body to produce compressive stresses in said body and hardening said coating.

11. A method of stressing a reinforcing element in a hardened concrete body comprising thermally expanding said element with respect to said body, securing the ends of said element against complete contraction to its original length, causing said element to contract with respect to said body, applying at least a portion of the contracting force of said element to produce compressive stresses in said body and establishing a bond between said element and said body.

12. A method of stressing a reinforcing element bonded in a hardened concrete body comprising thermally reducing the bond and axially expanding said element with respect to said body, securing the ends of said element against complete contraction to its original length, reducing the thermal effect, increasing the bond and applying at least a portion of the contracting force of said element to produce compressive stresses in said body.

13. A method of reinforcing plastic materials comprising arranging a covering about a reinforcing element, forming a plastic body about said covering, allowing said plastic body to harden, softening said covering, elongating said reinforcing element, causing said element to contract with respect to said body, applying the contracting force of said element to produce compressive stresses in said plastic body and hardening said covering.

14. A method of reinforcing plastic materials comprising arranging a thermoplastic covering about a reinforcing element, forming a plastic body about said covering, allowing said plastic body to harden, thermally softening said covering and elongating said reinforcing element, reducing the thermal effect, applying the contracting force of said element to produce compressive stresses in said plastic body and hardening said covering.

15. A method of reinforcing plastic materials comprising arranging a thermosetting covering about a reinforcing element, forming a plastic body about said covering, allowing said plastic body to harden, thermally elongating said reinforcing element and setting said covering, reducing the thermal effect, and applying the contracting force of said element to produc compressive stresses in said plastic body.

16. A method of reinforcing plastic materials comprising arranging a thermoplastic electrical insulating covering about a reinforcing element, forming a plastic body about said covering, allowing said plastic body to harden, thermally softening said covering and elongating said reinforcing element, reducing the thermal effect, to harden said covering and applying the contracting force of said element to produce compressive stresses in said plastic body.

17. A method of reinforcing concrete bodies

comprising arranging a covering about a relatively smooth reinforcing element, forming a plastic concrete body about said covering, allowing the concrete to harden, thermally modifying said covering and elongating said reinforcing element, positioning a bearing member on said element to engage said body upon subsequent contraction, reducing the thermal effect, and permitting said element to contract until said member engages said body to produce compressive stresses in the concrete.

18. A method of reinforcing concrete bodies comprising coating a reinforcing element with sulfur, pouring concrete about said coated element, allowing the concrete to harden, passing an electric current through said element to soften the sulfur and elongate said element, securing the ends of said element against complete contraction to its original length, reducing said current, and permitting said sulfur to harden and said element to contract partially to impose compressive stresses in the concrete.

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