Oct. 28, 1958 A. WERTH 2,857,755

METHOD AND MEANS OF PRESTRESSING

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Fig. 1.

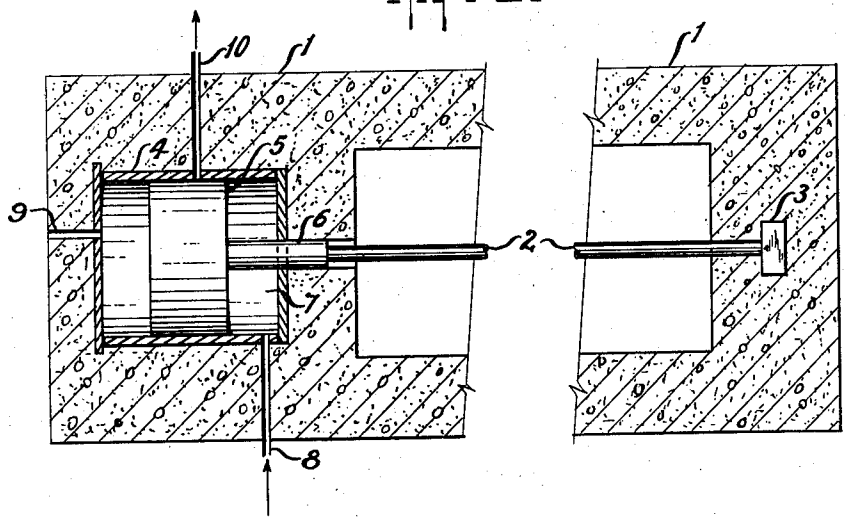
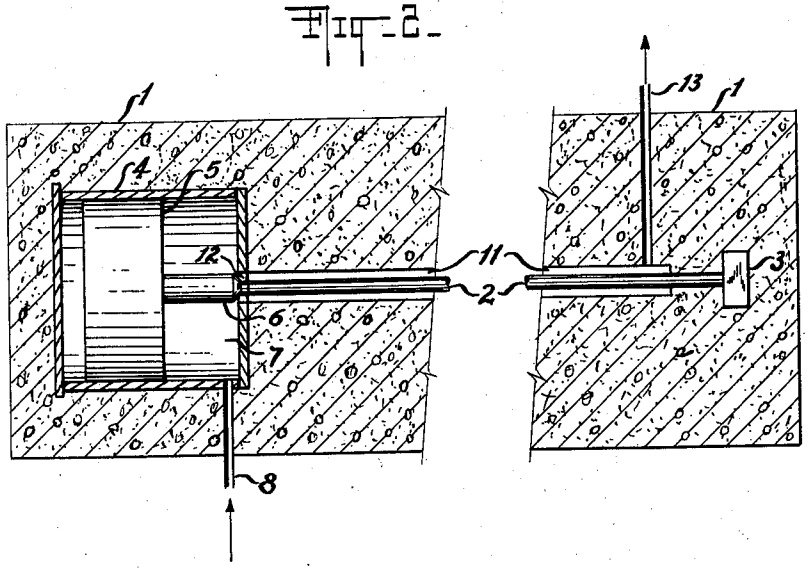


Fig. 2.



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FIG. 3.

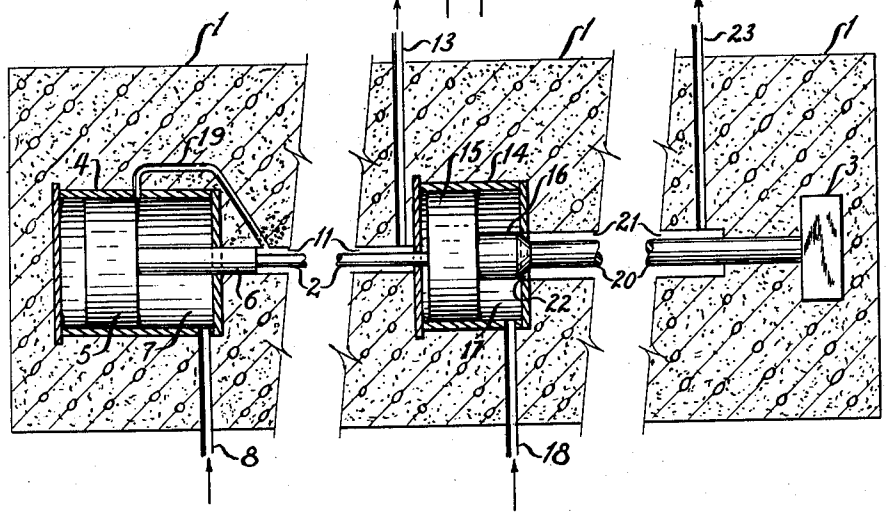
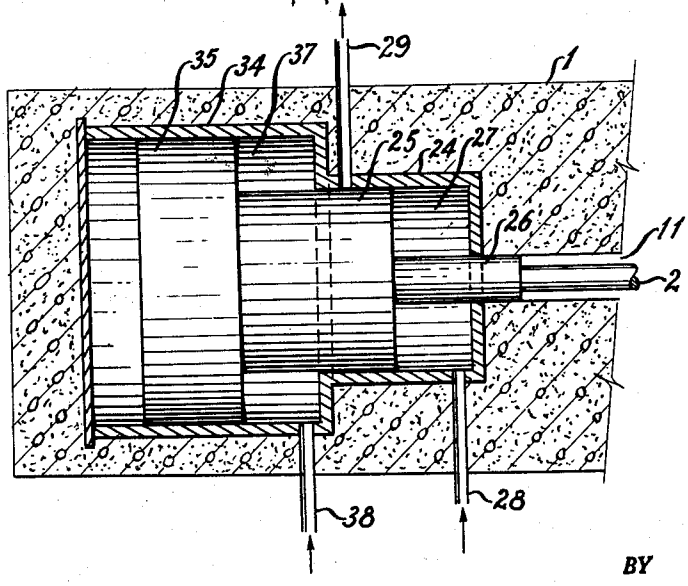


FIG. 4.



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Fig. 5.

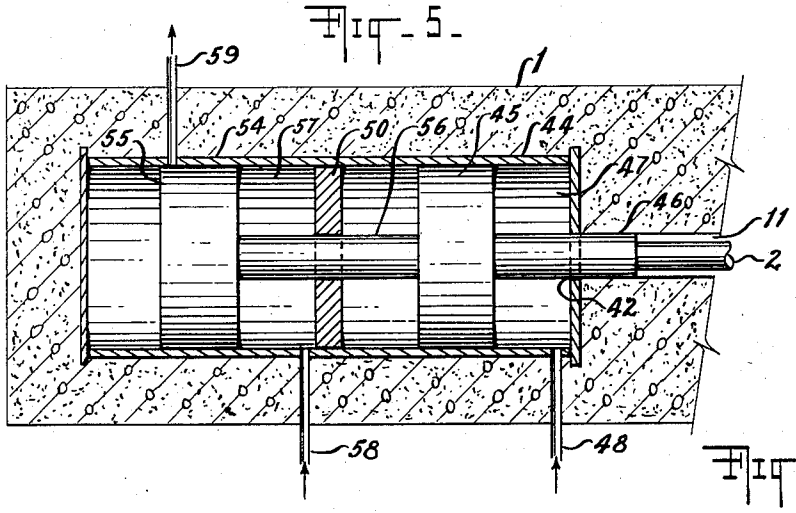


Fig. 6.

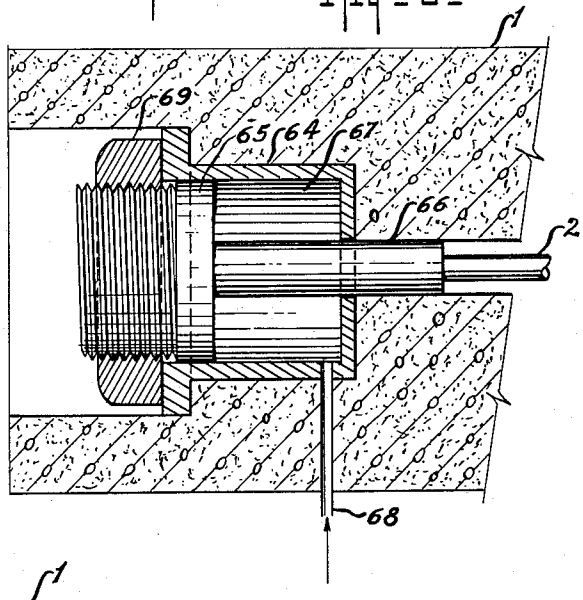
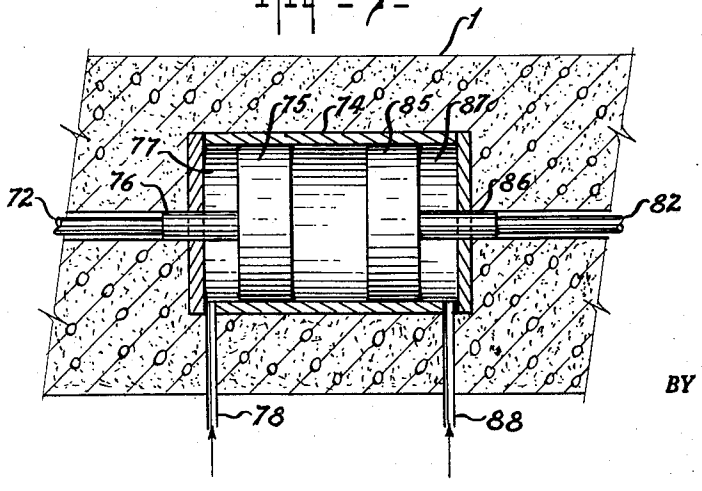


Fig. 7.



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United States Patent Office 2,857,755 Patented Oct. 28, 1958

2,857,755

METHOD AND MEANS OF PRESTRESSING

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Application July 22, 1953, Serial No. 369,665

11 Claims. (Cl. 72—61)

This invention relates to a novel system of prestressing concrete and like structures.

The use of prestressed concrete, to date, has not enjoyed the wide and varied application to which it is entitled largely because of the difficulties and shortcomings in the prior art prestressing methods. These prestressing methods, although differing in the manner in which the prestressing force is applied, possess one basic feature in common which hampers applicability in industry. This basic feature entails the external application of the prestressing force to the particular structure involved.

For the sake of clarity, the following terms shall have the indicated meanings in the present application.

Prestressing.—denotes the action upon a structure of applied forces calculated to impart stresses of sufficient magnitude to permanently neutralize undesirable stresses of opposite sign due to load.

Prestressing unit.—defines tensile unit to which pre stressing force is applied.

Anchor.—denotes the means by which the prestressing force is transferred from the tensile unit to the structure.

Structure.—defines structures and structural members, units, elements or portions thereof.

Concrete structure.—defines a structure made of concrete or any other material capable of withstanding compressive forces.

Grout.—defines any hydraulically compressible material used for the filling of cavities in structures.

In order to illustrate the shortcomings of the prior art prestressing methods as compared to the efficiency and efficaciousness of the present novel prestressing methods and means therefor, a résumé of the principal features of prior art prestressing methods is given as follows:

Type 1. Pre-tensioning.—The prestressing force is applied externally to the prestressing units, positioned inside of the forms prior to the pouring or casting of the concrete.

Type 2. Post-tensioning at anchor terminals.—The structure is poured monolithically, i. e., in one continuous operation, or is formed by assembling prefabricated members, and wherein cavities, if used, are left for the prestressing units only. The prestressing force is then applied externally to the prestressing units at terminals only, or at terminals and intermediate anchors, by means of removable mechanical tools or devices, such as jacks and wrenches. In order to apply prestressing force at the intermediate anchors, the latter have to be made accessible by means of temporary openings in the structure. Such openings subsequently have to be filled.

Type 3. Post-tensioning at joints.—The structure is divided by joints into two or more portions and is held together by prestressing units only, which units are placed in cavities and anchored in the concrete. The prestressing force is applied externally at the joints by means of jacks, pressure pilows, cells, etc., or by gravity action. The joints have to be filled in after the structure is prestressed. In some systems the prestressing devices remain in the structure permanently. This circumstance does not alter the fact that the structure is prestressed externally.

It is an object of the present invention to provide a simplified, more economical and more efficient method of prestressing concrete and similar structures capable of withstanding compressive forces.

It is another object of the present invention to provide a process and system for internally prestressing such structures.

A further object of the present invention is the provision of a method and mechanism therefor of internally prestressing such structures in which the application of the prestressing force and the anchorage of the prestressing units are combined in a single unit operation.

Another object of the present invention is a method for simultaneously tensioning and anchoring by the activation of internal prestressing means connected to an elongated prestressing unit at least partially within concrete and similar structures, and also to the provision of apparatus therefor.

A further object is a method and system for tensioning, anchoring and bonding a prestressing unit to concrete or the like involving internal prestressing thereof.

Another object is the obtention of novel pre-stressed structural members resulting from the application of said novel methods and arrangements.

A principal feature of the present invention relates to a process for tensioning or prestressing internally a reinforcing member disposed at least partially within a structure capable of withstanding compressive forces which comprises introducing a material under pressure internally within said structure to activate tensioning means disposed therein and connected to said reinforcing member, and applying tension internally thereby to said reinforcing member to stress the same within the structure. The invention relates also to a system or arrangement therefor.

Another practical aspect of the present invention relates to introducing under pressure a hardenable material into said internal tensioning means sufficient to stress said internal reinforcing member, and permitting said material to harden therein whereby said reinforcing member remains permanently under tension.

Other and additional objects, advantages and features of the present invention will be manifested in the following detailed description and claims taken in connection with the accompanying drawings, forming a part of this specification.

As indicated, the present novel system of prestressing possesses as a fundamental feature that the prestressing force is applied internally, i. e., within the structure itself, by means of either hydraulic power transmission or expansible agents acting in the interior of the structure. (Although this specification shall deal with hydraulically prestressed structures, the present invention shall not be so confined.) By reason thereof, the structure can be poured or cast monolithically, or may be formed by assembling prefabricated members; no external openings and no joints need be left for the application of prestressing force. Since the device or devices of the present invention for applying the prestressing force forms an integral part of the prestressed structure, all subsequent construction, such as the filling in of accesses, joints or temporary openings between component parts of the final structure, is obviated also. Furthermore, the prestressing devices may be positioned and operated at any point within the structure with equal ease. The nature of the internal prestressing device is such that any member thereof may be placed along the trace of a prestressing unit. This advantage permits of varying the prestressing along the structure in accordance with the magnitude of undesirable stresses of opposite sign due to load which it is desired to overcome. It is possible to achieve a saving in the amount of prestressing units therefore.

The essential means of applying internal prestressing to concrete structures and the like is afforded by an arrangement hereinafter designed as "stress anchor." The stress anchor is in function a combination of two devices that have been separately used in the external prestressing systems known and utilized previously which are the device for the application of prestressing force (jacks, pressure cells, etc.) and the device providing anchorage for the prestressing unit. The design of a stress anchor is in principle that of a hydraulic jack. Its one part, the "cylinder," is embedded in the concrete structure or otherwise affixed thereto; its other part, the "piston," is attached to the prestressing unit or units. It is to be understood that the terms "cylinder" and "piston" shall in no way restrict the possible sectional shapes or materials of the two parts; they are merely derived by analogy with hydraulic jacks in strictly a functional sense. For example, any chamber or cavity permitting piston travel is suitable as the "cylinder." Thus, a stress anchor tensions the prestressing unit by virtue of the mechanical principle underlying the hydraulic jack. The piston travel, which corresponds to the elongation produced in the prestressing unit, is effected through means of fluid under pressure, an expansible agent, or by grout or any other hydraulically compressible material. The prestressing unit is "anchored" when the piston is prevented from traveling back to its original position. Anchorage is secured in the stress anchor by maintaining the hydraulic pressure on the piston head, by using grout like, which upon hardening prevents piston return or effectively limits such, or by fastening the piston against the end of the cylinder by a nut and threads, or some similar arrangement, such as welds, rivets, bolts, keys, wedges, plugs, rings, springs, etc., or by a combination of any of these means known in the art.

These stress anchors can be attached in any number to and at any point along a given prestressing unit; hence prestressing force can be introduced at any point of a prestressing unit.

Another feature of the stress anchors are combined devices which are designed individually according to the magnitude of the prestressing force required to the elongation of the prestressing unit and to the special functions they can perform, as well as to the particular construction material used and to the space that is available. Hence a great variety of stress anchors may be anticipated. However, all the variations in function and design derive from their basic function of combining the tensioning and the anchoring of the prestressing unit.

The details of the operation and the design of stress anchors are best described by the accompanying drawings, wherein the prestressing units are shown as uncurved wire strands. This is merely an illustrative presentation. The prestressing units of the instant invention may be cables, strands, bars or groups of bars, any other tensile member, or any combination thereof. Furthermore, the prestressing unit or units may be so curved as to yield a desired stress pattern in the structure.

Referring more particularly to the drawings,

Fig. 1 is a schematic longitudinal part sectional view of the arrangement for internal prestressing according to the present invention;

Fig. 2 is similar and shows a modification or variation of the system in Fig. 1;

Fig. 3 is a similar view utilizing two stress anchors;

Figs. 4–7 are similar views and depict various modifications utilizing double stress anchors.

Figure 1 shows a simple arrangement of internal prestressing by means of a stress anchor. It presents a concrete or like structure **1** which may be formed by pouring the concrete, for example, upon a prestressing unit **2** which is attached or anchored at one end by means of any suitable type of anchor **3**, including all types of stress anchors, and at the opposite end by means of a

stress anchor. There is necessary at least one tensioning means. Although in some designs it may be advisable to tension from both extremities of the tensile unit, this is not necessary. With the use of one stress anchor, anchorage at the other extremity of the tensile unit may easily be obtained. Where the tensile unit consists of wires, for example, the concrete may be poured around a portion of the wires. This anchoring method effectuates bond, or holding resistance. The stress anchor at the other extremity comprises a cylinder **4**, which is embedded in the structure, a piston **5**, which is attached to the prestressing unit **2** and slidably mounted inside cylinder **4**, and a hollow piston rod **6**, through which the prestressing unit **2** passes. The pressure chamber **7**, i. e., the fluidtight space between the bottom of cylinder **4** and piston **5**, is connected by means of a conduit **8** with an external hydraulic power source. A hydraulically compressed fluid is conducted through conduit **8** into pressure chamber **7** so as to move piston **5**. The travel of the piston is checked either by means of a control gage **9** or by means of a pressure outlet **10**. The latter is located so as to communicate with pressure chamber **7** when the piston has moved through a predetermined distance; the emerging fluid from outlet **10** indicating that the prestressing operation is completed. The hydraulically compressed fluid used in this embodiment is grout or any other hardening substance which, after being kept under pressure a short time, prevents the piston **5** from moving back once the pressure is discontinued, thus anchoring the prestressing unit **2** permanently.

Figure 2 essentially differs from Figure 1 insofar as the prestressing unit **2** is shown passing through an elongated passage **11**. The length of piston rod **6** is such as to correspond with the required displacement of piston **5**. When this displacement has been attained, as shown in Figure 2, the opening **12** in cylinder **4** permits access of grout to passage **11**, whence the grout eventually passes through the outlet **13** to the exterior, thereby signalling that the prestressing and grouting of prestressing unit **2** and passage **11**, respectively, have been completed. Thus, the hardened grout not only furnishes anchorage, but also effects bond between the structure and the prestressing unit and provides protection of the latter against corrosion. Hence, in this embodiment of the instant invention resides yet another advantage over prior art, inasmuch as what are three separate operations in other systems, i. e., stressing, anchoring and bonding, have been combined into a single operation.

Figure 3 shows an internal prestressing arrangement utilizing two stress anchors: the end anchor comprising cylinder **4** and piston **5** and the intermediate anchor comprising cylinder **14** and piston **15**. The intermediate anchor divides the prestressing unit into two units: prestressing unit **2** between pistons **5** and **15**, and prestressing unit **20** between piston **15** and anchor **3**. This arrangement is generally used if the required sectional area and prestressing force of unit **20** is greater than that of unit **2**, or if friction losses along the prestressing unit are great enough to warrant offsetting by the application of prestressing force at intermediate points along the trace of the prestressing unit. For the tensioning of units **2** and **20**, grout under pressure is led simultaneously through conduits **8** and **18** into pressure chambers **7** and **17**, respectively. When piston **5** attains its final position, as shown in Figure 3, grout flows from pressure chamber **7** through outlet **19** into passage **11** and finally emerges from outlet **13**. Similarly, grout passes from pressure chamber **17** through opening **22** into passage **21** and then emerges through outlet **23**. The emergence of the grout indicates that the tensioning of the prestressing units **2** and **20** and the grouting operation are completed. Anchorage is achieved with the hardening of the grout.

The following figures illustrate some additional examples of the possible variations of stress anchor designs.

Figure 4 depicts a double stress anchor which might be

termed a concentric anchor. Two cylinders **24** and **34** and two pistons **25** and **35** are mounted concentrically one upon the other, forming two separate pressure chambers **27** and **37**. This arrangement permits of the use of different fluids and of different hydraulic pressures for tensioning. Conduits **28** and **38** lead the compressed fluids into pressure chambers **27** and **37**, respectively, while outlet **29** serves as a safety valve, indicating the completion of the prestressing operation. In order to anchor the prestressing unit, grout or the like is to be used in either one of the pressure chambers, at least in the final prestressing stage.

Another type of double stress anchor, which might be termed a line anchor, is presented in Figure 5. This embodiment of the instant invention serves in general the same purpose as the stress anchor shown in Figure 4. The principal criterion for the use of one or the other is that of dimension: line anchors usually require a greater length but a smaller diameter than concentric anchors. In Figure 5 the two cylinders **44** and **54** are separated by a partition **50** through which a piston rod **56** connects the two pistons **45** and **55**. By simultaneous introduction of compressed fluid into pressure chambers **47** and **57** prestressing is applied until piston **55** attains its final position, thus permitting the fluid to emerge from outlet **59**. The compressed fluid in at least one of the pressure chambers must be grout or the like if anchorage of prestressing unit **2** is to be secured. Should grouting of passage **11** also be desired, grout or the like shall be used in pressure chamber **47**, which communicates with passage **11** once piston rod **46** has wholly passed by opening **42**.

Figure 6 illustrates a stress anchor with direct access to the exterior. Anchorage of the prestressing unit **2** in this embodiment can be affected by screwing a nut on the threaded piston **65** after it has moved beyond the open end of the chamber under the influence of the material under pressure. This nut transmits the anchoring force to cylinder **64** which is embedded in structure **1**. After the nut **69** has been securely tightened, pressure chamber **67** may be emptied and refilled with grout or the like. It is readily apparent that instead of the use of a nut piston **65** may be secured to cylinder **64** by the use of a weld or by other simple mechanical means known in the art without incurring departure from the principles underlying the design of this type of stress anchor. It is also apparent that the access to nut **69** may be reduced to a shallow passage to admit a small tool by means of which the nut can be tightened. Further, without introducing substantial changes in the design the piston may be made to lock automatically by means of simple gadgets which are operated by the moving piston or by overflowing liquid. Finally, for the sake of clarity, it is to be pointed out that the provision of an access to the stress anchor in no way violates the principles of internal prestressing: the prestressing force is still applied internally, i. e., inside the stress anchor itself, which in turn is an integral part of the final structure.

Figure 7 presents a double stress anchor which possesses the additional attribute of being able to serve as a splicing means for two adjacent prestressing units **72** and **82**. This splicing stress anchor comprises a common cylinder **74**, two pistons **75** and **85**, two pressure chambers **77** and **87** and two conduit means **78** and **88**. By leading fluid under pressure into pressure chambers **77** and **87**, respectively, prestressing units **72** and **82**, respectively, are tensioned. The tensile force is transmitted through common cylinder **74** from one prestressing unit to the other; therefore, cylinder **74** performs also the function of splicing the prestressing units **72** and **82**. Anchorage in this simple embodiment may be effected by the use of grout or the like as the compressed fluid: after hardening, the grout prevents the pistons from moving back.

The foregoing detailed description of my novel system of internal prestressing using stress anchors lends itself readily to a variety of designs and applications in the construction field. The many advantages of this novel prestressing system can now be made fully evident by a detailed comparison with the prior art external prestressing systems:

External prestressing	Internal prestressing
Type 1. Pre-tensioned Structures: *a.* Restricted to relatively small structures.	Applicable to both small and large structures.
Type 2. Structures Post-tensioned at Anchor Terminals: *b.* Special equipment for prestressing required, such as jacks, adapters, etc.	No special equipment required; jacks are integral parts of the stress anchors.
c. In practice, prestressing units have to be adapted to standardized equipment; hence, they are restricted in size. Largest units that have been used have a capacity of about 50 tons. A great number of units are required even for a relatively small structure. A two lane, 100 ft. span highway bridge for H 20-S16-44 loading requires a total prestressing force of about 2300 tons, i. e., 54 units of 50 tons each.	Prestressing units are wholly built up individually. Their capacity is unrestricted; any quantity of wires, wire strands or bars may be assembled as a single unit. Therefore, for the bridge cited, eventually only 4 units of 700 tons capacity each are required.
d. Prestressing units are necessarily dispersed over the concrete section. Hence they require much space and therefore necessitate great concrete sections.	Concentrated prestressing units which require relatively little space, thus permitting the concrete section to be dimensioned relatively small.
e. Much space is required at the ends of the prestressing units for accommodation of jacks. This circumstance often causes design difficulties.	No space needed outisde the structure for application of prestressing. In many cases design is thereby simplified.
f. In longer units the elongation becomes greater than the rise of the jack; hence additional measures are required to effect temporary anchorage while the jacks are re-set.	Stress anchors are always so built and designed as to accommodate the total elongation. Hence prestressing is accomplished in a single operation; there is no delay incurred by a need to set and re-set jacks.
g. In general, the prestressing force is applied to the prestressing units at end terminals only. The application of prestressing force at intermediate points is often impossible and always complicated and expensive.	Stress anchors may be placed at any point along the prestressing unit and hence force can be introduced wherever desired without any complication and in an inexpensive manner. Simple differential prestressing is the result.
h. Units are prestressed successively. This circumstance requires special attention lest unallowable stresses be introduced into the structure. The process of prestressing a structure with many units requires much time and hence becomes relatively expensive.	All units or groups of units may be prestressed simultaneously by mutually coupling the stress anchors through hydraulic pressure intercommunication. Thus uniform prestressing is achieved and the operation is executed relatively quickly.
Type 3. Structures Post-Tensioned at Joints: *i.* The structure has to be divided into two or more portions by means of open joints, which must be connected or closed after completion of prestressing.	The whole structure is poured or cast monolithically, i. e. in a single operation or entirely formed at the outset by assembling prefabricated members. No subsequent work is necessitated.
j. The portions of the structure are moved apart a distance equal to the total elongation of the prestressing units. The heavy masses must be guided accurately, the jacks and other devices must be set precisely. Since the prestressing units are usually inclined to the longitudinal axis of the structure, this preparatory work, which is done on the site, becomes complicated and expensive. Such precision being alien to field practice, failures and jamming are likely to occur from time to time.	The whole structure is poured or cast in its final position. No displacement takes place, except for the relatively small elastic compression of the concrete. The many times greater elongation of the prestressing units is wholly taken up by the stress anchor. All precision work is done in the machine shop. Even for the machine shop, however, the order of work required for the stress anchor is ordinary, simple and inexpensive. Since the stress anchors are new and checked before they leave the shop, there is a large safety factor against failures.
k. Owing to the special requirements described under (*i*) and (*j*) above, additional material, labor and, especially, time are consumed.	Less material and less labor, skilled and unskilled, are required. The speed of construction is thereby increased.

While the invention has been described with reference to various examples and embodiments, it will be apparent to those skilled in the art that various modifications may be made and equivalents substituted therefor, without departing from the principles and true nature of the present invention.

Having thus described the invention what is claimed is:

1. A process for producing a predetermined state of stress in a structural member of high compressive strength reinforced with a reinforcing tensile member and for anchoring the latter which comprises embedding within said structural member a combined stressing and anchoring means forming an integral part of said structural member, said means comprising a cylinder and a piston slidably mounted therein so as to form a pressure chamber, said piston being connected to one end of said reinforcing member, the other end being affixed within said structural member, introducing a hydraulically compressed fluid into said pressure chamber sufficiently to move said piston and produce a predetermined tension in said reinforcing member, and maintaining pressure on said piston permanently so as to hold said reinforcing member permanently in tension and produce a permanent predetermined stress in said structural member.

2. A process in accordance with claim 1 wherein said cylinder has an open end and the piston extends beyond said open end after tensioning said reinforcing tensile member, and the piston is maintained under pressure by mechanically affixing said piston at the open end of the cylinder, thereby anchoring said reinforcing member permanently in tension and said structural member in compression.

3. A process for producing a predetermined state of stress in a concrete or similar structural member of high compressive strength reinforced with a reinforcing tensile member and for anchoring the latter therein which comprises affixing one extremity of said reinforcing member within said structural member, the other extremity being attached to a piston, said piston being slidably mounted in a cylinder within said structural member so as to form a pressure chamber, said chamber having inlet means extending to the exterior of said structural member, introducing through said inlet means a hardenable material under pressure into said pressure chamber so as to move said piston and apply a predetermined tension in said reinforcing member, and maintaining said hardenable material under pressure until it has hardened, thereby holding said reinforcing member permanently in tension and producing a permanent predetermined stress in said structural member.

4. A process in accordance with claim 3 wherein said hardenable material is grout.

5. A process for internal tensioning and anchoring of an elongated tensile unit constituting a reinforcement of a structural member which comprises arranging, within said structural member, said tensile unit and at least one stressing means attached thereto comprising a cavity and a piston slidably mounted therein, said cavity having outlet means to the exterior of said structural member and located so as to permit said piston to move under pressure through a predetermined distance along said cavity, introducing a fluid hardenable material under pressure to move said piston sufficiently to stress said tensile unit and until excess quantities of said hardenable material have passed into said outlet means, maintaining the pressure on said material until it has hardened, thereby anchoring said stressed tensile unit.

6. A process for tensioning, anchoring and bonding of an elongated tensile reinforcing member placed in a passage extending within a structural member which comprises arranging at least one fluid-operable stressing means within said structural member and which is connected to one extremity of said tensile reinforcing member in said passage, the other extremity of which is anchored within said structural member, introducing to said stressing means a hardenable fluid material under pressure to activate said stressing means and stress said reinforcing member, flowing said material under pressure from said stressing means to substantially fill the passage containing said reinforcing member, and permitting said material to harden whereby said reinforcing member remains permanently under tension and is bonded to said structural member.

7. A concrete structural member of high compressive strength, an elongated high strength metallic tensile unit constituting a reinforcement of said structure and passing at least partially therethrough, one end of said unit being embedded within said member adjacent one extremity thereof and being positively anchored therein, the opposite end of said tensile unit being integrally connected with a piston, the diameter of said piston being substantially greater than the diameter of said unit, said piston being disposed within a cylinder, said cylinder being embedded completely within said structural member and positioned toward the opposite extremity thereof, an elongated passage extending from said cylinder to a point adjacent the anchored end of said unit, the major portion of said elongated unit being disposed within said passage, a filling conduit extending from exteriorly of said structural member into said cylinder on the side of said piston to which said unit is connected, an exhaust conduit leading from said cylinder to the exterior of said member, said exhaust conduit communicating with said cylinder intermediate the length thereof, said elongated unit being in a highly tensioned condition and said piston occupying a position within said cylinder adjacent to the end of said cylinder and which is disposed toward said opposite extremity of said member, said exhaust conduit thereby communicating with the interior of said cylinder on the unit connected side of said piston, a hardened material filling said cylinder between the piston and the end of the cylinder away from said opposite extremity, said material maintaining said unit in its highly tensioned condition, the position of said exhaust conduit relative to the end of said cylinder away from said opposite extremity determining the degree of tension imparted to said unit and the degree of compression imparted to said member, said tension being imparted to said unit as the result of said filling material being forced into said cylinder through said filling conduit in a fluid state and forcing said piston toward said opposite extremity.

8. A concrete structural member in accordance with claim 7 wherein a second cylinder concentric with and larger than said first-mentioned cylinder is connected to the latter and forms an extension thereof towards said opposite extremity within said structural member, said second cylinder having a piston mounted therein concentric with and larger than said first-mentioned piston, and a filling conduit extending from exteriorly of said structural member into said second cylinder on the side of said second piston towards said first-mentioned cylinder.

9. A concrete structural member in accordance with claim 7 wherein a second cylinder is connected to said first-mentioned cylinder by an end wall which is common to both cylinders at least in part, said second cylinder forming an extension between said first-mentioned cylinder and said tensile unit, said second cylinder having a piston disposed therein, said second piston being connected with the opposite end of said tensile unit on the side adjacent thereto and being connected on the opposite side of said second piston to said first-mentioned piston by a piston rod extending through said end wall, and a filling conduit extending from exteriorly of said structural member into said second cylinder on the side of said second piston connected to said unit.

10. A concrete structural member of high compressive strength, an elongated high strength metallic tensile unit constituting a reinforcement of said structure and passing at least partially therethrough, one end of said unit being

embedded within said member adjacent one extremity thereof and being positively anchored therein, the opposite end of said tensile unit being integrally connected with a piston, said opposite end having an enlarged portion adjacent the piston, the diameter of said piston being substantially greater than the diameter of said unit, said piston being disposed within a cylinder, said cylinder being embedded completely within said structural member and positioned toward the opposite extremity thereof, an elongated passage communicating with said cylinder and extending to a point adjacent the anchored end of said unit, the major portion of said elongated unit being disposed within said passage, an exhaust conduit communicating with said passage and leading to the exterior of said member, a filling conduit extending from exteriorly of said structural member into said cylinder on the side of said piston to which said unit is connected, said elongated unit being in a highly tensioned condition and said piston occupying a position within said cylinder adjacent to the end of said cylinder and which is disposed toward said opposite extremity of said member, said exhaust conduit thereby communicating with the interior of said cylinder on the unit connected side of said piston through said passage, a hardened material filling said cylinder between the piston and the end of the cylinder away from said opposite extremity and filling said passage and said exhaust conduit, said material maintaining said unit in its highly tensioned condition and effecting bond in said passage between said unit and said member, the length of said enlarged portion determining the degree of tension

imparted to said unit and the degree of compression imparted to said member, said tension being imparted to said unit as the result of said filling material being forced into said cylinder through said filling conduit in a fluid state and forcing said piston toward said opposite extremity.

11. A concrete structural member in accordance with claim 10 wherein at least one additional cylinder and piston mounted therein are positioned along the length of said unit, said additional piston being integrally connected to said tensile unit.

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