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E. FREYSSINET ET AL

2,080,074

PIECE OF REINFORCED CONCRETE

Filed March 8, 1934

Fig. 1.

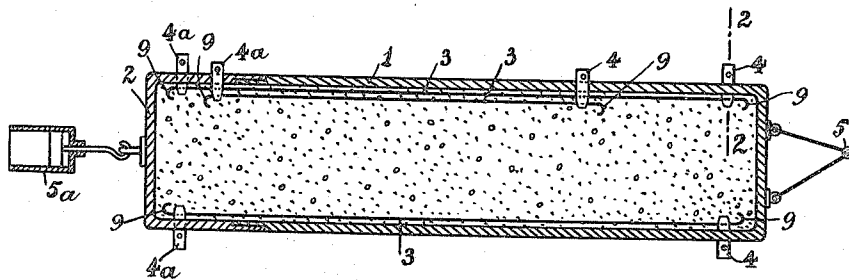


Fig. 2.

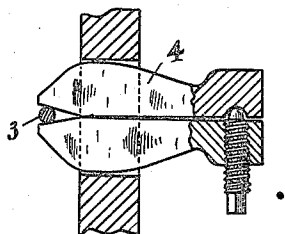


Fig. 3.

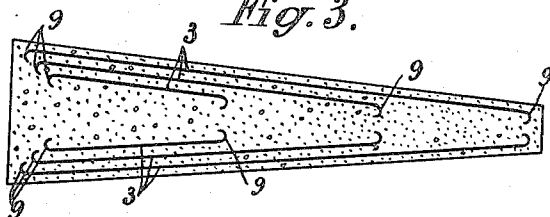
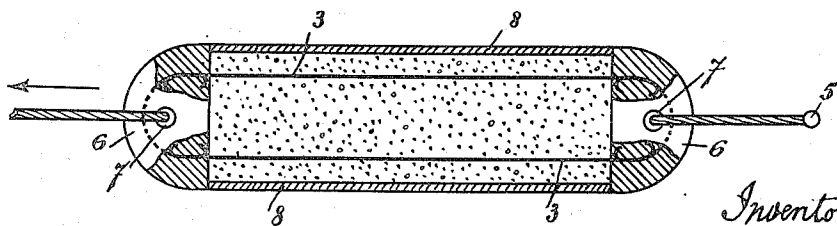


Fig. 4.



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PIECE OF REINFORCED CONCRETE

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Séailles, Paris, FranceApplication March 8, 1934, Serial No. 714,724
In France October 2, 1928

7 Claims. (Cl. 72—61)

The present application is a continuation in part of the U. S. patent application Ser. No. 395,297, filed Sept. 26, 1929 in which we described a process of improving the manufacture of reinforced concrete articles by subjecting to a preliminary tension the metallic reinforcements so as to obtain compressive stresses in the concrete of these articles. The present invention concerns the permanently improved articles obtained by means of this process.

It has been proposed to subject the reinforcements of reinforced concrete articles to preliminary tensions before pouring the concrete into the moulds and then to transfer this tension of the reinforcements to the concrete after setting and hardening of the latter, by releasing the devices by means of which the reinforcements were subjected to tension. However, if special precautions are not taken, no permanent improvement of reinforced concrete articles can be obtained in this way. This is due to the fact that, when the tensions of the reinforcements are transferred to the concrete, numerous causes intervene for reducing this tension:

First of all, in the course of the setting and hardening of the concrete, the dimensions of the latter decrease, due to a certain phenomenon, which is called "shrinkage".

Secondly, concrete compressed by reinforcements that have been subjected to tension is elastically deformed.

Furthermore, a certain sliding displacement of the reinforcements with respect to concrete may occur in spite of anchoring members disposed on the reinforcements, until, due to the pressing together of the particles of concrete by the anchoring members, in the vicinity of these members, this sliding displacement ceases.

Finally, we discovered that, in concretes subjected to constant stresses, the concrete mass undergoes a progressive reduction of length analogous to a kind of shrinkage proportional to the stresses and which may be numerically more important than ordinary shrinkage, in the case of high tensions (see report of the session of September 22, 1926 of the "Commission Technique de la Chambre Syndicale des Constructeurs en Ciment Armé de France; Report of the Reinforced Concrete Convention, Liéges 1930; Report of the Convention of the Association Internationale des Ponts et Charpentes, Paris, 1932).

The sum of these drops of tension can amount to 30 kilogrammes per square millimetre, in the case of very resistant concretes, and even much more, in the case of ordinary concretes. Con-

sequently, if the tensions to which the reinforcements are subjected are lower than 30 or 40 kilogrammes per square millimetre, a time will come when these tensions will be reduced to zero by the total shrinkage of the concrete, so that the increase of resistance which was intended to be obtained by subjecting the reinforcements to tension is destroyed and constructions including such concrete pieces may be ruined.

Now, the reinforcements that are employed at the present time are made of metals the elastic limit of which is, as a rule, much lower than 40 kilogrammes per square millimetre. In ordinary reinforced concrete, it is not known how to utilize the resistance of steels having higher elastic limits and the use of such steels is therefore unnecessary. The present regulations concerning concrete advise not to exceed stresses of 16,000 lbs. per sq. in. (which corresponds to 11.20 kilogrammes per square millimetre) for all kinds of steels (see Hool and Johnson "Concrete Engineer's Handbook", page 37, section 56). Therefore, the use of steels of high elastic limit has not developed in the ordinary technic of reinforced concrete, the fact being that the reinforcements utilized in the ordinary technic are of relatively low elastic limit. Now, with such reinforcements, it is impossible to bring into play tensile stresses sufficiently high for obtaining permanent improvements.

The object of the present invention is to provide reinforced concrete objects that are improved in a permanent manner, owing to the utilization of reinforcements having a sufficiently high elastic limit in order that these reinforcements may be subjected to preliminary tensions which considerably exceed the sum of the possible drops of tension and that, account being taken of these drops of tension, there may remain in these reinforcements high permanent tensions which are an important portion of the initial tension imparted to the reinforcements.

Therefore, in a reinforced concrete article according to the present invention, the concrete of which has set and hardened and has undergone all the shrinkages and reductions of length above referred to, there remain permanent tensions of the reinforcements, which exert on the concrete of the article permanent compressions. Owing to a suitable distribution of the tensioned reinforcements in the concrete, these compressive stresses are opposed to the stresses created in the concrete article by the external forces acting thereon, so as to compensate them.

The reinforcements utilized according to the present invention are made of metals having elastic limits which are considerably greater than 40 kilogs. per square millimetre, so that they
 5 may be subjected to tensions at least equal to this value and generally much higher, say 60 kilogs., 80 kilogs. and even more. Of course the elastic limit can be increased by suitably treating the metal, for instance by previously drawing or tempering it. The increase of the elastic limit may
 10 also result from the preliminary tensioning treatment itself, provided, of course, that the preliminary tension is lower than the ultimate strength of the metal. The reinforcements that
 15 are in contact with the concrete may be provided with anchoring members for preventing them from sliding with respect to the concrete. However, in most cases, the adhesion of reinforcement bars to concrete constitutes a sufficient
 20 anchoring.

Figs. 1 to 4 of the accompanying drawing show, by way of example, two embodiments of devices serving to subject the reinforcements to tension.

In Fig. 1, the mould 1, in which concrete is to be poured, comprises, at one end, a movable part 2. The ends of the reinforcements 3, which may be of unequal lengths and which are distributed in the concrete mass according to the diagram of the stresses to be created, are fixed,
 25 on the one hand to the mould through any suitable means such as gripping members 4 holding tightly the ends of the reinforcements (see the detail view of Fig. 2 which is a section on the line 2—2 of Fig. 1) or any other equivalent organ, and, on the other hand to the movable part 2 by means of similar gripping members 4a. This movable part 2 is connected to the piston of a powerful hydraulic jack 5a the cylinder of which is stationary while the mould is fixed, at
 30 the opposite end, to a stationary point 5. The reinforcements, made of a metal of high elastic limit, are first subjected to the required preliminary tensions by admitting into the jack a liquid under suitable pressure, which displaces
 35 the movable part 2 and stretches the reinforcements. Concrete is then poured into the mould, the reinforcements being kept tensioned. When concrete has set and hardened, the pressure in jack 5a is brought back to zero and consequently
 40 the tension of reinforcements 3 is transferred to the concrete. The movable part 2 is then removed, after the means 4 for fixing the reinforcements have been removed and the concrete piece can be taken off from the mould. Reinforcements of unequal lengths must be used when
 45 the cross section of the piece is not uniform in order that concrete may nevertheless be subjected to a uniform compression. There is for instance the case of a post of the shape of a frustum of a cone or of a frustum of a pyramid.
 50 This post will be provided with tensioned reinforcements 3 (Fig. 3) of unequal lengths. The number of these reinforcements in a cross section of the post is larger at the big end of said
 55 post than at the small end thereof. With tensioned reinforcements all of the same length, it would be impossible to subject the concrete to high compressive stresses without risk of crushing the concrete at the small end of the post.
 60 In the example of Fig. 4, the ends of the reinforcements 3 are imbedded in blocks of concrete 6 by providing in said blocks suitable gripping means or means through which the blocks can be pulled away from each other, for instance
 65 holes such as 7. Once the concrete of the blocks

has set and hardened and is sufficiently strong, the reinforcements 3 are subjected to the required tensions by moving blocks 6 away from each other, for instance by means of powerful
 5 hydraulic jacks. The reinforcements being thus kept in the tensioned state, we dispose between blocks 6 walls 8 forming the mould and concrete is poured thereinto. When concrete has set and hardened, walls 8 are removed and the pressure exerted by the hydraulic jacks is released. The
 10 reinforcements tend to shrink, and thus to bring blocks 6 toward each other, thus exerting a compression on the concrete in the mould.

In the example of Figs. 1, 2, and 3, anchoring members prevent the tensioned reinforcements
 15 from sliding with respect to the concrete. These members will consist of hooks 9 provided at the ends of the reinforcements or of any other organ, either integral with or fixed to said reinforcements, for instance local thickened portions
 20 thereof.

In the example of Fig. 4, the anchoring members consist of the two concrete blocks 6, in which the reinforcements will be, in turn anchored, by means of hooks or the equivalent.
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For practical purposes, we generally use carbon steels in the form of wires of diameters ranging between 6 and 15 millimetres, cooled rather suddenly in the course of rolling, so that the ultimate strength of these steels ranges between
 30 90 and 100 kilogs. per square millimetre and their elastic limit ranges between 45 and 50 kilogrammes per square millimetre. This elastic limit is increased up to 80–90 kilogrammes per square millimetre. We may also use steels that
 35 have been subjected to thermic treatments so that their ultimate strengths may be as high as 160 kgs. per square millimetre, particularly in the case of special steels, such as silicon steels. The tensions that give the best results range between
 40 two-thirds and three-fourths of the elastic limit of the metal, so that after all the drops of tension above referred to, there remain permanent tensile stresses of at least 30 or 40 kilogrammes per square millimeter. In such products, the
 45 normal working fatigue should range between $\frac{1}{3}$ and $\frac{2}{5}$ of the ultimate strength of the steels, which permits of subjecting the steels to stresses of 50 and 60 kilogrammes per square millimetre and even more without any risk of cracking of
 50 the concrete.

The products obtained according to the present invention differ from ordinary reinforced concrete products in that their strength is considerably higher than that of an ordinary reinforced
 55 concrete product of the same weight and price or their weight and cost are much lower than those of an ordinary reinforced concrete product of the same strength. More especially, the products according to the present invention have an extraordinary resistance to shearing and twisting stresses, often five times greater than those of ordinary reinforced concrete elements of the same section. Their resistance to alternating stresses is practically unlimited, while ordinary
 60 reinforced concrete has but a rather bad resistance to this kind of stresses.

What we claim is:

1. A piece of reinforced concrete which comprises set and hardened concrete having undergone shrinkage, and reinforcements of a steel having a high elastic limit in permanent tension anchored in said concrete and adhering thereto along their whole length, whereby said concrete is permanently subjected to compressive stresses.
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 75

2. A piece of reinforced concrete which comprises set and hardened concrete having undergone shrinkage, and reinforcements of a steel having a high elastic limit in permanent tension anchored in said concrete and adhering thereto along their whole length, said reinforcements being tensioned and distributed in accordance with the diagram of the tensile stresses that are to be developed in the piece by determined external forces acting thereon, so as to produce in the concrete permanent compressive stresses that balance these tensile stresses.

3. A piece of reinforced concrete which comprises permanently compressed set and hardened concrete having undergone shrinkage, and reinforcements of a metal the elastic limit of which is higher than 40 kilogrammes per square millimeter, anchored in said concrete and adhering thereto along their whole length, said reinforcements being in permanent tension.

4. A piece of reinforced concrete which comprises permanently compressed set and hardened concrete having undergone shrinkage, and reinforcements of a metal the elastic limit of which is higher than 40 kilogrammes per square millimeter, anchored in said concrete and adhering thereto along their whole length, said reinforcements being in permanent tension at a rate of at least 10 kilogrammes per square millimeter.

5. A piece of reinforced concrete which comprises permanently compressed set and hardened concrete having undergone shrinkage, and reinforcements of a metal the elastic limit of which is higher than 40 kilogrammes per square millimeter, anchored in said concrete and adhering thereto along their whole length, said reinforcements being permanently tensioned, at a rate of at least 10 kilogrammes per square millimeter, and distributed in accordance with the diagram of the tensile stresses that are to be developed in

the piece by determined external forces acting thereon, so as to produce in the concrete permanent compressive stresses that balance these tensile stresses.

6. A piece of reinforced concrete which comprises permanently compressed set and hardened concrete having undergone shrinkage, and a plurality of rectilinear reinforcements made of a metal the elastic limit of which is higher than 40 kilogrammes per square millimeter, anchored in said concrete and adhering therewith along their whole length, said reinforcements being in permanent tension at a rate of at least 10 kilogrammes per square millimeter, the length, distribution and tension of these reinforcements being so chosen, in accordance with the system of tensile stresses to be developed in the piece by determined external forces acting thereon, as to produce in the concrete permanent compressive stresses that balance these tensile stresses.

7. A piece of reinforced concrete which comprises permanently compressed set and hardened concrete having undergone shrinkage, and a plurality of parallel rectilinear reinforcements made of a metal the elastic limit of which is higher than 40 kilogrammes per square millimeter, anchored in said concrete and adhering therewith along their whole length, said reinforcements being in permanent tension at a rate of at least 10 kilogrammes per square millimeter, the respective lengths and tensions of these reinforcements being so chosen, in accordance with the system of tensile stresses that are to be developed in the piece by determined external forces acting thereon, as to produce in the concrete permanent compressive stresses that balance these tensile stresses.

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