-2-73 XR 3,762,937

106/93

United States Patent [19]

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[11] 3,762,937

[45] Oct. 2, 1973

[54] TENDON GROUTING MEANS

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[22] Filed: Sept. 7, 1971

[21] Appl. No.: 178,487

[52] U.S. Cl. 106/90, 106/93

[51] Int. Cl. C04b 7/02

[58] Field of Search 106/93, 90

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[57] **ABSTRACT**

A method is provided for preventing water bleed in grout for securing post-tensioned tendons, particularly strand tendons employed in the production of prestressed concrete, comprising the use of a gelling agent and a dispersing agent along with cement and water in proportions which provide a pourable, injectable grout composition, the relative proportions of ingredients being selected such that water bleed is controlled or substantially eliminated at pressures less than about 10 psig, at 80 psig, less than 10 percent water loss occurs. The composition preferably contains an expansion agent resulting in positive expansion as required by the specific circumstances of usage. The composition is capable of reducing water bleed to 0 percent at 80 psig differential pressure.

10 Claims, No Drawings

TENDON GROUTING MEANS

This invention is concerned with an improved technique of grouting post-tensioned tendons employed in the formation of prestressed concrete.

More particularly, this invention is concerned with an improved means for grouting post-tensioned tendons, particularly strand, whereby the problem of water bleed is substantially eliminated.

It is known that while concrete is very high in compressive strength, its tensile strength is comparatively low, being at best, only one-tenth as great as its compressive strength. Even this minimal degree of tensile strength is not available as a practical matter because it is dissipated wholly or partially by unavoidable internal stresses set up in the concrete. Consequently, simple concrete, or even concrete reinforced with unprestressed steel, is of little practical value in construction which will undergo even relatively moderate tensile stresses.

To overcome the lack of tensile strength in concrete and to take advantage of its high compressive strength, the concrete is prestressed by means of steel tendons. Typically, the concrete member which is to be subjected to a tensile load, is formed with hollow sheaths or ducts, positioned generally in the direction of the highest expected tensile load. Encased in the sheath, is a tendon. After the concrete has been allowed to set for a sufficient time to develop adequate strength, the tendon is post-tensioned by longitudinally extending it to the desired stress level. The thus post-tensioned tendon is then secured to the concrete member in a manner such that during use, the concrete member is subjected to compressive stresses equal to the tensile stresses upon the tendon member. When the concrete member is later put into use under tensile load conditions, any tensile load applied in the direction of the prestressing will, up to the degree of applied prestress, serve merely to relieve the compressive stresses upon the concrete member while not placing the concrete member under actual tension.

Because the tensile load carrying capabilities of the concrete member, as a practical matter, are due solely to the tensile stress carrying capabilities of the tendon members, it is essential that the tendon members be securely protected against corrosion. Moreover in certain cases, a secure bond between the tendon and the concrete contributes to the strength of the prestressed member. These benefits are conventionally achieved by injection of grout into the tendon ducts to completely embed the tendons and bond them to the duct. While this theory is simple, it is complex in actual practice.

The major problems encountered in grouting, are the segregation of water from the grout mixture, i.e., bleeding, and reduction of volume. The problem of reduction of volume by contraction due to hydration of the cement is satisfactorily controlled by the use of an expanding agent such as powdered aluminum which reacts with the alkali in the cement mixture to give off hydrogen gas which has an expanding effect by the creation of small voids in the cement. The problem of bleeding is more complex, and has not been so easily solved. In its simplest form, bleeding can amount to merely sedimentation of the cement particles. This type of bleed is especially prevalent in the grouting of vertical tendons or tendons which have a substantial vertical rise, where excess water in the grout collects at intervals along the ducts to form bubbles of water, and these bubbles may then float to the high point of the duct. Substantial damage to the tendon is potentially the result, since the tendon is not grouted at the high points. For solid wire or bar tendons, this problem may be minimized by decreasing the water content and adding a plasticizing component to the grout mixture. Under usual procedures, employing solid tendons, bleed can be held to about 0.4 percent. For strand tendons which have recently come into widespread usage, the problem of bleed encompasses more than mere simple sedimentation. Strand tendons are made up of a center wire with at least six outer wires spiraled tightly about it. For a seven strand wire the diameter of the central wire is about 5 to 7 percent larger than the diameter of the outer wires in order to achieve the closest possible packing of the wires. Sizes of the strand tendons range from about 0.25 inches to about 0.70 inches. When strand tendons are used, bleed occurs because of sedimentation and the filtering action of the spaces between the strands. Pressure forces the grout against the tendons where water passes through the interstices between the outer wires and the center wire whereas the cement particles do not. This filtering action is especially acute in wire tendons with a high vertical rise. Bleed can amount to up to 20 percent of the height of the vertical rise. This effect is compounded by the fact that strand tendons must be better protected from corrosion than simple single wire or bar tendons. This is suggested by the fact that if 0.1 mm. of a 26 mm. diameter bar is corroded, this amounts to a tendon loss of about 1.5 percent of the cross-sectional area of the tendon, but as much as 13 percent in the case of a 3 mm. diameter wire.

Bleed can also occur as a result of imperfections in the sheath surrounding the tendons. The walls of the sheath whether composed of the concrete member itself, or a rigid or flexible metal conduit, sometimes have small imperfections resulting from defective manufacture or the various stresses and strains placed upon the sheath during construction. If these imperfections are small, they allow water to leak out of the sheath, but not solid particles, thereby dehydrating the grout composition at the point of the leak. The dehydrated grout plugs the sheath and prevents completion of the grouting operation. It is difficult to remove the plugs when they occur and consequently great effort is taken to avoid them.

The control or elimination of bleed especially as caused by filtration of the solids from the water content of grout mixture is of great importance in successful construction with prestressed concrete.

In early efforts to control bleed in the grouting of tendons, a gelling compound such as methyl cellulose was tried in amounts up to 0.1 percent based on the weight of cement. Although this approach was successful for a 160 ft. vertical bar tendon, it was not successful in preventing bleed caused by pressure filtration and consequently, the problem of water bleed has not been solved for prestressed concrete employing strand tendons or involving other circumstances in which pressure filtration of the grout composition can occur. Uses of higher concentrations of gelling agent to impart greater bleed resistance is disadvantageous from the standpoint that with increased concentrations of gelling agents, the physical properties of the grout are reduced. Thus, the greater the amount of gelling agent, the less pourable it becomes, and the greater the difficulty of injecting the grout into the tendon sheath. Moreover, higher gelling agent concentrations lead to increased entrapment of air, lowered density, and consequently reduced strength in the resultant grout.

Accordingly, it is an object of this invention to provide improved means for grouting tendons in prestressed concrete.

It is a further object of this invention to effectively eliminate the problem of bleed in the grouting of post-tensioned strand tendons.

These and other objects are achieved by the present invention which provides an improved method for preventing or controlling water bleed in grouting compositions for securing post-tensioned tendons employed in the production of prestressed concrete. The improvement comprises adding sufficient gelling agent and dispersing agent to the grout composition to prevent substantial water loss due to filtration at pressures less than about 10 psig and at about 80 psig less than 10 percent water loss by filtration occurs, the amount of water being measured on the basis of water initially added to the grout composition.

The composition can also contain may other appropriate additives, e.g., expanding agents such as aluminum powder; defoaming and wetting agents; and accelerators.

The control of bleed according to the present invention has been found to be essentially independent of the particular cement composition used, and all conventional cement compositions normally used in grouting are contemplated for use in this invention. Typical cements are Type 1, Type 2, Type 3 and Type MX expansive cements. A water-to-cement ratio of from 0.45 to 0.5 is suitable for Type 1, Type 2 and expansive cements. It is essential that the grout be pourable and injectable: that is, that is be sufficiently fluid to permit its injection into the duct embracing the tendon, e.g., the wire strand tendon. There are many factors which affect injection of the grout into the duct such as the size and shape of the duct and tendons and the presence of any obstructions and the grout composition itself. These factors must all be balanced in each individual situation to achieve complete filling of the ducts with grouting cement having the ideal amount of water. However, slightly higher water contents can be used, under certain conditions, e.g., when the mix is too viscous.

The gelling agent may be selected from any of those commercially available. Typical gelling agents are Methocel methylated cellulose and Natrosol hydroxy ethyl cellulose, all of these being available in many viscosity types. Natrosol 250H has been found to be especially desirable. Natrosol 250H has a Brookfield viscosity of 1,500 to 2,500 cps., measured as a 1 percent aqueous solution at 25°C.

Commercially available dispersants which are compatible with aqueous systems can be employed in this invention. Typical of these are Nopcosant and Lomar D dispersants. Nopcosant is comprised of a sulfonated naphthalene; Lomar D is a highly polymerized naphthalene sulfonate which is supplied commercially as the sodium salt. Lomar D has been found to be most preferable for use in the present invention.

In preparing the grouting compositions of this invention, the ingredients are preferably dry-blended to assure thorough mixing before the addition of water. The water-to-cement ratio will usefully range from 0.40 to 0.55 and preferably be from 0.45 to 0.50. The most important factor in this regard is to achieve a pourable, injectable grouting composition with a minimum water/cement ratio. The gelling and dispersing agents are preferably used in amounts of above about 0.2 percent based on the weight of the cement, and more preferably in concentrations ranging from 0.3 to 0.6 percent, with 0.5 percent of each agent being most preferable. The expansion agent, if one is used, can be used in small amounts sufficient to produce 5–10 percent expansion of the cement. For example, if aluminum powder is used it may be present in amounts of up to about 0.01 percent based on the weight of the cement.

The exact relative amounts of the various ingredients will of course vary somewhat with ambient temperatures, the extent of vertical rise, and other conditions. The ranges indicated as preferred and most preferred, give the best results under the most extreme conditions; however, the degree of reduction in bleed because of economics balanced against other considerations, will vary from situation to situation. Effective bleed control is defined as total elimination of bleed when the composition is subjected to filtration against a filter which retains substantially all of the grout solids at pressures up to about 10 psig, and control of the amount of bleed occurring within 30 minutes, to less than about 10 percent of the total water added to the grout composition, at filtering pressures of about 80 psig. More preferably, bleed should be substantially prevented at bleed filtering pressures below about 50 psig, and controlled to less than about 1% at bleed filtering pressures of about 80 psig.

The solid ingredients of the grout composition are mixed thoroughly with the desired amount of water to achieve a uniform consistency, but are not mixed excessively as this may cause premature thickening of the mixture. Once mixed, the grouting composition is injected into the tendon duct by means known to the art. A complete discussion of grouting techniques is given in *Prestressed Concrete Design and Construction*, F. Leonhardt; Second edition; Wilhelm Ernst & Sohn, Germany (1964).

The following examples are presented to further illustrate this invention.

EXAMPLES

The filtering action causing bleed, results from pressures forcing the water of a grout mixture into the interstices of strand tendons. The size of the interstices are such that they prevent entry of solids, but permit entry of water. The effective driving force of the filtering action is the hydrostatic force created along the vertical rise of the strand tendon and the difference between the density of water (62.4 pounds per cubic foot) and the density of the solids of grout mixture (approximately 118 pounds per cubic foot). Thus, for a 100 foot high tendon the bleed filtration pressure would be about 40 psig, and for a 200 foot high tendon the bleed filtration pressure would be about 80 psig. Considering a seven strand tendon having a diameter of one-half inch, the spaces between each of the six outer wires is on the order of 0.001 to 0.002 inch. With the noted bleed filtration action, a laboratory-scale pressure filtration funnel in which the grout is forced against a properly sized filter, simulates actual conditions. Accordingly, a test procedure was designed to simulate the bleed filtration phenomenon employing a commercially available pressure filter. The particular device selected was a pressure filtration funnel manufactured by the Gelman Instrument Company utilizing a filter member having a Type A fiberglass filter which retains 97 percent of all particles over 0.3 microns at pressures up to 200 psig. Tests were run under conditions selected to approximate as nearly as possible the actual grouting conditions for a long strand tendon. The components of the grout were thoroughly blended in the dry state and then mixed with the desired amount of water by a mixer for from 3 to 5 minutes. After mixing, the grout composition was allowed to set for 10 minutes without agitation to approximate the most severe conditions which would be experienced in actual grouting. For a 200 foot vertical strand tendon which would have a total differential filtering pressure of 80 psig., total pumping time of the grout into the duct would be on the order of 24 minutes. Accordingly, as the grout composition fills the duct in an actual grouting procedure, the grout comes under increasingly greater pressures. This was simulated herein by starting with a pressure of zero psig and increasing the pressure by 10 psig every 3 minutes until a total of 24 minutes had elapsed. The pressure was applied to the pressure filter funnel in the tests by means of pressurized oxygen.

The results tabulated below summarize tests run according to the foregoing procedure utilizing a Marquette Type II cement. Two different gelling agents, namely, Natrosol 250M, and Natrosol 250H were tested and are identified in the table below as "NM" and "NH," respectively. The dispersing agent in all cases was Lomar D. The expansion agent was Alcoa 606 powdered aluminum. The percentages of the gelling, dispersing and expanding agents are based on the weight of cement added to the mixture. "Bleed" is reported as the percent separated water, based on the water added to the mixture. The "initial bleed pressure" indicated, is the pressure at which bleed was first noted.

TABLE I

TEST	H_2O/Cement wt/wt	Gelling Agent Name %	Lomar D Dispersing Agent wt. %	Expanding Agent wt. %	Initial Bleed Pressure (psig)	Bleed (% Orig. H_2O at 80 psig.
1	.45	NM .5	0	0	20	8.0
2	.45	NH .5	0	0	20	4.0
3	.45	0	.5	.01 Al. powd	0	70.0
4	.45	NH .5	.5	.015 "	80	0
5	.45	NH 0	0	0	5	45
6	.45	NH .3	.5	.01 "	50	5.4
7	.5	NH .4	.5	.01 "	70	1.3
8	.5	NH .3	.5	.01 "	30	7.5
9	.5	NH .3	.3	.01 "	30	10
10	.45	NH .3	.3	.01 "	40	4.7
11	.5	NH .4		.01 "	50	5.0
12	.5	NH .4	.4	.01 "	50	3.5
13	.5	NH .4	.4	.01 "	50	2.9
14	.5	NH .5	.4	.01 "	60	1.5
15	.45	NH .4	.6	.01 "	60	1.3
16	.45	NH .5	.5	.01 "	80	0
17	.45	NH .4	.5	.01 "	50	2.1
18	.45	NH .5	.5	.01 "	50	1.3
19	.5	NH .5	.5	.01 "	80	0.6
20	.45	NH .5	.5	.01 "	60	1.5

It will be apparent to those skilled in the art that many modifications and changes in gelling and dispersing agents may be made without departing from the spirit of this invention which has as a principal feature the use of a grouting composition which contains bal-

anced amounts of dispersing and gelling agents for grouting tendons in post-tensioned concrete members to avoid water bleed due to pressure filtration.

From the foregoing it is apparent that gelling agents by themselves do not prevent bleed at 80 psig., but they are capable of preventing bleed at lower pressures. Dispersing agents are ineffective by themselves and in fact increase the amount of bleed over that which is observed with neither dispersing agent nor gelling agent. The combination of sufficient gelling and dispersing agents gives desired bleed rates of less than 10 percent at 80 psig.; the combination of 0.5 percent gelling and 0.5 percent dispersing agents being capable of giving a grouting composition with zero percent bleed at 80 psig. under test conditions. By using grouting compositions containing the combination of dispersing and gelling agents required by the present invention, desired levels of water retention can be imparted without the disadvantages attendant the use of relatively high proportions of gelling agents exclusively. Thus, the grouting compositions with smaller amounts of gelling agents are less viscous and more easily injectable than bleed-resisting tendon grouting compositions which gain their resistance to bleed from gelling agents alone. Additionally, gelling agents increase the amount of air entrapped by a grouting composition. Grouting compositions of this invention, in requiring lower concentrations of gelling agents for a given level of bleed resistance, are less prone to entrap air, thus producing cured grouting compositions of greater density and consequently greater strength than known grouting compositions with similar bleed resistance levels. Still another advantage of the present invention is that it provides bleed resistant tendon grouting compositions which remain pourable at water-to-cement ratios which result in cured grout compositions having greater strength than grouting compositions with only gelling agents which require higher water-to-cement ratios for the same degree of pourability.

An important aspect of the present invention is the recognition that wire strand tendons filter solids from water during the filling of the tendon duct, and that this filtration causes bleed. Another aspect of this invention is the discovery that balance of concentrations of gelling and dispersing agents substantially prevents bleed. Without proper balance, neither by itself suffices. The balance which is proper depends on the specific agents used. The proper balance is defined as the amount of each agent which does not interfere with pourability, and prevents 10 percent bleed within 30 minutes under 80 psig against a filter which retains 97 percent of particles over 0.3 microns.

What is claimed is:

1. An improved method for grouting post-tensioned tendons for prestressed concrete which comprises:

injecting into a tendon duct a pourable grout composition comprising cement, water, a gelling agent and a dispersing agent, the relative proportions of each being such that no substantial water loss will occur by filtration at pressures less than 10 psig, and less than 10 percent water loss will occur by filtration at pressures of about 80 psig.

2. A method according to claim 1 wherein the tendons are wire strand tendons.

3. The method according to claim 1 wherein the gelling and dispersing agents are present in amounts

greater than about 0.2 percent by weight based on the weight of the cement.

4. The method according to claim **3** wherein at least one of the gelling and dispersing agents are present in amounts from about 0.3 to 0.5 weight percent.

5. The method according to claim **4** wherein an expansion agent is present in an amount which results in positive expansion between 5 and 10 percent of the volume of the original grout composition.

6. The method according to claim **4** wherein water is used in a weight ratio of water-to-cement of about 0.45 to 0.50.

7. The method according to claim **4** wherein the dispersing agent comprises a naphthalene sulfonate.

8. The method according to claim **4** wherein the gelling agent is a composition selected from the group consisting of methyl cellulose and hydroxyethyl cellulose.

9. The method according to claim **1** wherein the relative proportion of the ingredients of the grout composition is such that no substantial water loss by filtration will occur at bleed filtration pressures less than about 50 psig and water loss by filtration at bleed filtration pressures up to 80 psig is less than about 1 percent.

10. The method according to claim **9** wherein the gelling agent comprises an hydroxyethyl cellulose and the dispersing agent comprises a naphthalene sulfonate.

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