ADMIXTURE FOR CONTROLLING BLEED IN CEMENT GROUT USED IN POST-TENSIONING

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The bleed characteristics of neat cement grout are well known. With usual mixing procedures and grout admixtures it can be expected that water separation will occur due to sedimentation of the suspension of cement and admixture in water. This is particularly exaggerated with strand-type tendons.

To control this characteristic and the general pumping problems of grout blockages with dewatering, a grout admixture has been developed which can control the bleed as desired. The basic research in developing this admixture used short strand tendons to determine the different water retentive characteristic of admixtures. However, based on these tests, it was found that the vertical scale factor of pressure is important. Thus, a pressure filter test was also used to determine the water retentive characteristic of various grouts.

Based on this research, a grout admixture was developed with the property of high water retentivity such that for instance no water loss will occur in the grout when the pressure is maintained at 10 atmospheres over 10 min. For shorter durations, water retentivity is fully maintained for even higher pressures.
The sedimentation or bleeding characteristics of a neat portland cement grout are well known. With usual mixing procedures and grout admixtures it can be expected that water separation will occur because of sedimentation of the suspension of cement and admixtures in water (see Fig. 1).

It so happens that the water separation is exaggerated with strand-type tendons which have a random degree of vertical orientation. A filtering phenomenon occurs with seven-wire strands or probably any type of strand which have outer wires tightly wrapped around one or more center wires. Apparently, the small spaces between the outer wires are large enough to permit passage of water but too small to permit most cement particles to pass.

With water in the inner space and grout surrounding it, a hydraulic driving force is developed since grout weighs about 120 pcf (1920 kg/m³) whereas water weighs 62.4 pcf (1000 kg/m³). This difference in head pushes water through the outer wires and up the interstices in the strand above the grout as can be seen in the simple test of placing 3 ft (1 m) of strand in a transparent tube containing say 2 ft (0.7 m) of freshly mixed grout.

![Morris Schupack](image)

Fig. 1. Comparison of expansion and sedimentation. Note—Admixture: Intraplast RD-4 (water-reducing and expansion). Cement: Type II. 1.6-in. (4 cm) diameter tubes, 14-ft (4 m) high.
Fig. 2 indicates that this bleed or water separation can accumulate to 15 percent of the vertical grout column. In vertically oriented tendons, used for instance in nuclear pressure vessels, rock anchors, and columns, voids such as shown in Fig. 2, are clearly unacceptable. Furthermore, horizontal tendons with vertical curvature would also accumulate water voids at the high points of the tendon duct.

Recognizing the need for a solution to the problem which is satisfactory for both performance and efficient construction, an investigation was initiated by the author. This was particularly prompted by the need to grout 200-ft (60 m) vertical tendons for a nuclear containment structure in the near future.

**REDUCED SCALE GROUT DEVELOPMENT TESTS**

The principal effort of the investigation was directed to ascertain if admixtures could be used to thwart the bleed phenomenon in a strand tendon. It was found that just a 2-ft (0.6 m) high tube (Fig. 3) containing one strand would exhibit the bleeding phenomenon and could be used to determine whether or not a particular mix would decrease water separation. Extensive testing, in which over 20 different ingredients and combinations were used, indicated that the use of relatively high quantities of gelling agents might be a solution.

After selecting the most promising thickener (gelling agent), tests were made with 10-ft (3 m) high tubes (Fig. 4) containing strands to see if the vertical scale factor had an important influence on water separation. It was found that the scale factor does have an effect, but that the basic direction of incorporating a gelling agent appeared sound.

Based on the encouraging results with vertical 2- and 10-ft (0.6 and 3 m)
tests, two 40-ft (12 m) vertical tests were undertaken. Grouts with thicken-
ers were used in the two 40-ft (12 m) high tests, one with an expansion agent and the other without.

The test results indicated that the use of an expansion agent as well as a thick-
ener was desirable. Although the gas evolved from the expansion seems to promote bleeding in the presence of strands, most of this effect was re-
strained by the presence of the thicken-
er. Furthermore, the minimal expansion compensated for any settlement, helped expel any bleed water that might have evolved and facilitated complete pene-
tration of the grout through all inter-
stices in the anchorage components.

Results of the 40-ft (12 m) tests were promising but the following problems remain to be resolved:

1. Generally, inadequate mixing equipment was used in all of the above tests. Since better mixing is likely to im-
prove results, a test of various mixers was conducted in a parallel effort.

2. Admixtures were specially pre-
blended into the cement by the cement suppliers. This dry blending had the advan-
tage of better dispersion of the admixture throughout the cement mass prior to incorporation of water; how-
ever, production blending of the expan-
sion agent is logistically difficult and may be undesirable if done too far in advance.

3. The influence of the vertical scale factor was not fully known. A promising performance in a 40-ft (12 m) tendon did not assure performance in a 200-ft (60 m) tendon due to the larger pres-
sure difference.

The latter two problems suggested that a means of model testing the bleed phenomenon of a tall tendon should be developed and that a packaged comp-
ound suitable for field admixing would be desirable.

PRESSURE TESTS OF STRAND TENDON MODEL

Pressure model

Since the strand essentially acts as a filter in separating the cement particles from the water under pressure, a con-
cept of modeling the strand with a pres-
sure vessel and a filter was developed and used to determine the effectiveness of various mixes.

The type of pressure vessel used was a commercially available Gelman Pressure Filter Vessel (Fig. 5) which can operate up to 200-psi (14 kg/cm²) pressure. Pilot tests with the apparatus were performed to select the type of filter.

It was found that water separation obtained with a Gelman Type A fiber-
glass filter could be reasonably correlat-
ed to those obtained with earlier strand tests. This filter, which retains 99.7 per-
cent of all particles greater than 0.3 microns, was selected.
Fig. 5 Pressure filter, used as a strand filter model, to evaluate water retention characteristics of different cement grouts. The concrete cylinder or plug shown on the right is actually a dehydrated grout sample (with a conventional admixture) removed from pressure filter after applying about one-half atmospheric pressure.

Testing procedure

In an effort to simulate the actual field conditions of 200-ft (60 m) vertical tendons as closely as possible, the grout was mixed for about 5 min with a shear mixer, placed in the pressure filter and left to stand without agitation for 10 min. Then pressure was applied in 10-psi (0.7 kg/cm²) increments at intervals of 3 min.

Thus, to obtain a pressure of 80 psi (5.6 kg/cm²), 24 min would elapse. This corresponds approximately to the pressure difference between 200-ft (60 m) columns of grout and water and to the time that would be required to fill a 200-ft (60 m) high tendon composed of fifty-four ½-in. diameter strands.

Having established a testing procedure, it was then possible to compare the relative performance when parameters such as brands of cement, different types of cement, mixing time, mixing method, and conventional admixtures were varied.

After extensive testing, results indicated that none of these variables had any significant effect on water retention. It was surprising to find that vigorous extended mixing did not seem to improve water retention significantly.

Development of grouting admixture using strand tendon model

Numerous grouting admixtures and combinations of admixtures were tested in various proportions in order to isolate the most effective of the admixtures and to optimize the proportions. In a typical test, as noted, the pressure was increased in 10-psi (0.7 kg/cm²) increments to 80 psi (5.6 kg/cm²).

As pressure was applied, the threshold pressure was noted at which water (if any) was forced through the filter. Any water forced out of the grout was collected and measured. The time and pressure at which first water separation occurred and the amount of water collected were used as an indication of water retentive properties.

Of all the combinations, one containing a gelling agent and water reducers was found to be the most effective.

The tests performed with the pressure filter indicated that there was a threshold at which the water retentivity of different admixtures would break down. It was noted that using the classical grout admixtures commercially available, a very rapid loss of water occurred and a solid cylinder of grout remained (see Fig. 5) before 10-psi (0.8 kg/cm²) pressure was reached.

Virtually complete separation of the grout and free water took place. Using water reducers or dispersants alone ac-
tually increased the rate of water separation.

Based on data from the pressure filter tests, Fig. 6 relates the proportion of the optimized grouting aid, as a percentage of cement weight, required to maintain water retention of the grout in the pressure filter for a given applied pressure. This is determined by observing the pressure at which the first water loss occurs for different percentages of grouting admixture.

As can be seen, for a given proportion of grouting aid there is a threshold pressure which causes water separation to occur. This stresses the importance of the scale factor.

Note that without any grouting admixture the water retention was lost on application of only a small pressure as would be expected. Fig. 7 relates the proportion of grouting admixture to the...
Fig. 8. Pressure vessel with strand used as filter to check “pressure filter model.”

Fig. 9. Pressure vessel with strand showing grout and water loss after building pressure up to 90 psi (six atmospheres) in about 30 min.

water loss at 80 psi (5.6 kg/cm²) measured as a percentage of the original amount of water in the sample.

To confirm that the pressure filter was a reasonable model, a test was designed by Burns and Roe, designers of a grouted nuclear containment structure for General Public Utilities.

The test consisted of a pressure vessel into which a strand was sealed in, with one end penetrating but sealed on the outside as shown in Fig. 8. Grout leakage occurred through the strand and probably some water as shown in Fig. 9.

The results of several tests using this device confirmed that the pressure filter was a practical method of determining the water retention characteristics of grout. These tests, carried out simultaneously with pressure filter tests, used a grout mixed in a full-sized shear mixer, rather than small laboratory mixers which were used for the developmental filter tests.

FULL-SCALE TESTS OF ADMIXTURE

Since the resulting grout is basically thixotropic, various full-scale tests were performed to determine the best procedure in mixing, pumpability, and general water retention under field conditions. Some of these tests were:

Mixing

For greatest ease in mixing, preblending of the grouting admixture is theoretically most desirable. This, however, creates a logistic problem in requiring the preblending or field blending of the materials.

It was found that for quantities of grouting admixture less than about 0.8 percent by weight of the cement, most propellor-type mixers would work well. For quantities over about 1 percent by weight of cement, shear mixers or high energy propellor mixers were preferable.
The nature of the grouting aid is such, that when added to the surface of the grout, surface gelling occurs. This has to be broken up by the mixer.

It was found that the best way of adding the grouting admixture was to place it through a perforated long tube into the vortex of previously mixed cement and water.

Furthermore, it was found that mixing time is increased somewhat for this grouting admixture. Since for most applications only about 0.6 percent of grouting admixture by weight of cement would be used, most usual mixing procedures would suffice, except that the grouting admixture cannot be placed directly into the water. It has to be placed in the already mixed grout.

The preferable mixing sequence based on experience to date is to use a shear-type mixer using the loading sequence of water, cement, mix until well dispersed, and then incorporate the grouting admixture gradually while mixing.

**Pumpability**

Grout was pumped through a 30-ft (9 m) length of 2½-in. flexible metal conduit with constricted end fittings in a qualitative test of pumpability. This conduit was not surrounded by concrete and was the usual flexible conduit used for enclosing post-tensioning tendons. Pumping was stopped and resumed with no difficulty.

The ease with which grout can be pumped depends on the water-cement ratio, how well it is mixed, the proportion of grouting aid, and to some extent, the fineness of the cement. Using cement with a Blaine fineness in the order of 3800, grout as thick as made with 0.41 water-cement ratio and 1.9 percent grouting admixture have been pumped.

In one particular test, grouts with 0.48 water-cement ratio and 1.6 percent grouting admixture, required the same power to be pumped as conventional water-cement grout incorporating a water reducer. This seems to indicate that even though the grout has thixotropic properties, in most cases it can be pumped as readily as conventional grout.

**Water retention**

The pumping test made above, and another test made with 70-ft (22 m) length of 2½-in. (6 cm) diameter flexible metal hose, indicated absolutely no leakage of water or grout through the joints in the flexible metal hose even pumping against a 30-ft (9 m) head. The dramatic difference could be seen when water alone was pumped through the same hose; water leaked profusely.

**Penetrability**

Several tests were made using nineteen ½-in. diameter strands strapped together in a 4-in. (10 cm) conduit. These were later cut and complete filling of the spaces between the strands was achieved (Fig. 10).

To further prove the suitability of the thixotropic grout on curvature, Burns and Roe had a test run by Stress-steel Corp. in which a 54-strand tensioned tendon on a 20-ft (6 m) radius and 30 ft (9 m) long was grouted. The excellent results of a section through the grouted tendon is shown in Fig. 11.

**Test of 54-strand 30-ft (9 m) high vertical tendon**

To determine that a large group of strands in a 30-ft (9 m) high tendon does not have undetermined performance which would negate the results of the filter tests, Burns and Roe tested a 54-strand tendon at a 30-ft (9 m) height. Using 1.5 percent grouting admixture by weight of cement, the test indicated freedom from water separation.

The above test is a prelude to a 180-ft (54 m) test which will be run for the same project for General Public Utilities Service Corporation.
PROPERTIES OF GROUT CONTAINING ADMIXTURE

In general, there are three important properties of grout containing a water retentive admixture, namely, setting time, strength, and porosity.

Setting time
The setting time of grout is a function of the characteristics of the cement, proportion of grouting admixture, temperature, and to a lesser extent, water-cement ratio. The values shown in Table 1 were obtained for grouts prepared with a 0.47 water-cement ratio and a normal setting cement kept at 70 F (20 C):

Strength
The cube compressive strengths at 28 days were in the 3700 to 5000-psi (260 to 350 kg/cm²) range for different cements, 1.3 percent admixture, and 0.45 water-cement ratio.

Porosity
The porosity could be described qualitatively as low and comparable to other grouts used.

The prime purpose of this development was to achieve the desired water retention of a cement paste. Besides accomplishing this, several other interesting characteristics of this type of grout admixture were found. These are:

1. Once the grout is mixed, it is difficult to intermix more water without supplying adequate energy. This makes cleaning equipment more deliberate but has the significant advantage of displacing water with a minimum of dilution. This property can be controlled by the quantity of grouting admixture used.

2. With quantities generally in excess of 0.6 percent by weight of cement, the material is apparently thixotropic. The thixotrophy can be controlled to the extent one desires by quantities of grouting admixture. In fact, the apparent viscosity can be such
that the grout can be handled in a caulking gun. It should be pointed out that high quantities of grouting aid reduce strength and increase retardation.

3. Based on the work done to date, the grouting aid does not appear to be sensitive to the type or brand of cement.

4. The grouting aid has been used up to a grout temperature of 95 F (35 C) without difficulties. This temperature, however, is not recommended.

### PRACTICAL APPLICATIONS

At the present time, the patented grouting admixture is available through Sika Chemical Corporation in the United States only. Later on, arrangements will be made for distribution of the grouting admixture in other countries.

The material has been selected by the Tennessee Valley Authority for grouting rock anchors.

It is being considered by Burns and Roe for General Public Utilities Sevice Corp. for the complete grouting of post-tensioned tendons for a nuclear containment vessel subject to the completion of the 180-ft (54 m) vertical tendon demonstration test.

One interesting application of the admixture has been the grouting of an interconnected system of ten 130-ft (40 m) thirteen ½-in. diameter strand tendons. These tendons are 70 ft (21 m) above the grout pump with about 2000 ft (600 m) of interconnected hose and conduit with valves at the end of each tendon.

The grouting procedure is shown diagrammatically in Fig. 12. The reason for this approach, as reported by Walt Driscoll of Stresstek Corp., supplier of the tendons was:

“The proximity of traffic, pedestrians and architectural concrete prohibited the usual dirty method of pumping grout through and splashing it out a vent on the ground until it reaches its proper

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### Table 1. Setting time (in hr) of grout for various percentages of admixture.

<table>
<thead>
<tr>
<th>Proportion of admixture by weight of cement, percent</th>
<th>Time of initial setting from initial water-cement ratio contact, hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>7½</td>
</tr>
<tr>
<td>0.8 (for usual tendon)</td>
<td>11</td>
</tr>
<tr>
<td>1.1 (up to 100 ft vertical rise)</td>
<td>12</td>
</tr>
<tr>
<td>1.3 (up to 150 ft vertical rise)</td>
<td>13½</td>
</tr>
<tr>
<td>1.6 (up to 200 ft plus vertical rise)</td>
<td>14½</td>
</tr>
</tbody>
</table>

consistency. It therefore became necessary, in order to run a clean grouting operation, to interconnect a series of tendons in a series of beams with grouting hose and then conduct the spillage out away from the structure to a safe location at ground level.”

“The grout mixing operations were set up at a central location on the ground level, once again to avoid making a mess. This resulted in pumping distance of approximately 2000 ft (610 m) when lengths of grout hose 3½ in. (2 cm) and tendon sheathing 2¾ in. (7 cm) with thirteen ½-in. diameter strands were added. With the 80 ft (21 m) static head on the top floor, grouting pressures at the pump ran continuously at 250 to 300 psi (17 to 20 atmospheres) with the ambient temperature 85 F (30 C).”

“After the tendons and beams were interconnected, clear water was flushed through the system as much to check for leakages as to determine whether there might be obstructions. With 2000 ft of lines full of grout you can’t afford to stop to replace a grout cap gasket or exchange a leaky hose connection. Upon completion of water pressurizing, the water was left in the system and the grout allowed to drive it out. A copious quantity of grout was expelled, once the system was filled, to insure there was no dilution. In fact, very little mixing took place. Good grout followed clean water out of the exit hose in a rather abrupt fashion. The grout remained homogeneous and fluid under high pressure, it didn’t bleed and left all the grout caps full.”

**PCI Journal/November-December 1974**
Fig. 12. Typical interconnecting grouting system for 10 two-span continuous tendons. The total grouting path length is approximately 2000 ft (600 m).
CONCLUSION

The use of the water retentive grouting admixture seems to resolve the problem of water separation from cement grout.

Particularly for tendons with any vertical rise, the proper use of the grouting admixture will greatly minimize or eliminate the bleed phenomenon.

For vertical strand type tendons, two-stage grouting can be avoided.

ACKNOWLEDGMENT

Most of the tests for the strand tendons were sponsored by General Public Utilities Service Corp. for its two subsidiaries, Jersey Central Power and Light Company and Metropolitan Edison Company.

Burns and Roe, architect-engineers, planned the large tendon tests and the verification test of the pressure filter which were performed at Stressteel Corp.

The author, as consultant to General Public Utilities observed and helped guide the above work and performed additional small scale and model tests from which the water retentive grouting admixture was developed.

REFERENCES


Discussion of this paper is invited.
Please forward your discussion to PCI Headquarters by April 1, 1975.