Grout formulation and Specifications

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1.0 European Standard and Guidelines for Grouts for Pre-stressed Structures[1]

The currently applicable European Standard EN 447 "Grout for prestressing tendons – basic requirements" provides general guidance and define test procedures for quality control of grouts, but there is no guidance for grout formulation. Therefore within the research project "Improvement of properties of grouts for prestressing tendons and/or ground anchors" in the European COST Material Action 534 methods for testing rheology, bleeding, setting, expansion and mechanical strength of the grout were performed and evaluated. Research was carried out on the influence of different admixtures such as a superplasticizer (SP), an expanding agent (EXP), corrosion inhibitor (INH), etc., on physical and mechanical grout properties. The overall goal was to design an optimum grout that combines desirable fresh and hardened properties with good corrosion protection and to develop rules for grout formulation. Some of the most interesting results and conclusions are presented in this paper.

Portland cement grout is used in post-tensioned and retaining structures to provide bond between the tendon/anchor and the surrounding concrete and also to fill the voids between protective duct and prestressing strand which suppresses the flow of water and chloride ions. Grout is pumped into the space between the steel and the surrounding duct, where it hardens to transmit the stresses from the steel to the concrete. Therefore, the properties which are of interest and require specification and/or control are: rheology and flow; dimensional and material stability; setting and strength development; and durability.

1.2 Required Properties of Grout

1.2.1 Rheological Parameter

Rheological parameters of the grout should be tested and controlled to ensure that grout will fill the protective duct before it is sealed. The most common method for testing grout fluidity is the cone test. One point of criticism of the prescribed test method is that it is a single-point method. This method cannot be of the grout during 3 hours, within which grout needs to be injected into the duct. That is why during the project rheology tests were performed using a scientific instrument (coaxial rheometer), with which it is possible to monitor the change of shear stress of grout in time.

1.2.2 Bleeding and Volume Change

Bleeding and volume change of the grout should be tested to ensure that no voids are formed after the duct is filled with grout. The results obtained with methods for bleeding and volume change prescribed in EN 445:1996 do not represent the true conditions inside the duct because no strands are present, which have a strong influence. The fib-guideline prescribes the inclined-tube test (for bleeding) or the Wick-induced test (bleeding and volume change), which were taken over in the EN 447:2007. These methods are more representative, but are, on the other side, rather difficult to carry out in normal laboratories and even on site.

1.2.3 Mechanical Properties Testing

Mechanical properties of grout should be tested to ensure mechanical performance and stress transfer between prestressing strand and concrete. During research on the project it was concluded that compressive strength was usually satisfied regardless admixtures that were added into grout mixture.

1.2.4 Corrosion Testing of Grout

Corrosion behaviour of grout/prestressing strand system should be tested to verify that grout will resist aggressive substances and protect prestressing steel from corrosion. In order to evaluate corrosion protection capability of different grout mixtures samples with embedded prestressing steel were prepared and potentiostatic anodic polarization was performed. From corrosion testing it was concluded that grout with low chloride diffusion coefficient, good homogeneity and volume persistency could assure longer durability of prestressed structures.

2.0 Post-Tensioning Grout Bleed, Duct and Anchorage Protection Test[2]

Due to substantial problems with product quality of grout materials, the Department of Transportation, USA has revised all specifications concerning post-tensioning corrosion protection. New products for grouting post-tensioning ducts have recently become available. This article focuses upon three parts of the post-tensioning system: cementitious grout; internal duct; pour-back material.

2.1 Grout Testing

The current specification for post-tensioning grout does not differentiate between horizontal and vertical grout applications. In order to broaden the specification to address both applications, a relationship needs to be developed to associate laboratory test (Schupack) and field simulated test (wick induced bleed). The laboratory test can then be used with information collected from the testing to quantify the difference between horizontal and vertical applications. If a correlation is established between the vertical or inclined tests and the pressure tests, then the pressure tests can be used to test the bleed properties of new materials. In addition, the technique used for the simulated field test needs to be verified. The single wick, triple wick and inclined wick will be tested to determine the most severe condition for grout bleed.

2.2 Corrugated Duct Test

Corrugated duct is currently available with three distinct styles of ribs. The first type of duct has ribs that are parallel and oriented perpendicular to the axis of the duct. The second type has spiral ribs. The third type has parallel ribs similar to the first, but with four additional longitudinal ribs that are parallel to the axis of the duct and equally spaced radially around the circumference. This test can examine the effect of the corrugations on the bleed properties of the grout. Three 15 m long ducts should be grouted with the same prepackaged grout. After acquiring the required strength, the duct should be cut into segments and be examined to determine if the corrugations would have an adverse effect on the completeness of grouting.

2.3 Epoxy Pour-Back Test

A full scale mock-up of a combined multiple anchorage pour-back should be constructed and subjected to temperature variations. The test would determine if shrinkage and differential volume change between the materials would cause cracking of the pour-back.

3.0 Masonry Grout[3]

ASTM C476 has provisions for establishing grout proportions on the basis of specified compressive strength. The specified compressive strength must be at least 15 MPa. Grout mixers meeting the proportion table of ASTM C 476 have high cement contents and tend to produce much higher strength than specified compressive strength requirements of ASTM C 476, ACI 530 or model codes. Two types of masonry grouts are defined in ASTM C 476: fine grout with aggregates smaller than 10 mm and coarse aggregate sizes up to 12 mm. Choice of grout types depends primarily on the clear dimensions of the spacing being filled by the grout.

The consistency of grout affects its strength and other properties. It is critical that grout consistency permit the complete filling of void space without segregation of ingredients. Consistency of masonry grout may be measured with a slump cone ASTM C 143 and slumps of 200-275 mm are generally required for both fine and coarse grout. Self consolidating grout is a highly fluid and stable grout mix that does not require consolidation. These grouts are tested using the slump flow test, ASTM C 1611, which measures the spread of the grout using the slump cone.

For other types of grouts without aggregate, or only fine aggregate passing a No. 8 sieve, consistency, is best determined with a flow cone (ASTM C 939). For flow values exceeding 35 seconds, use the flow table in ASTM C 109, modified to use 5 drops in 3 seconds. Masonry grout(block fill) for strength test specimens should be cast in molds formed by masonry units having the same absorption characteristics and moisture content as the units used in construction (ASTM C 1019). Never use nonabsorbent cube or cylinder molds for this purpose.

Strength of other types of grout is determined using 50 mm cubes as per ASTM C 942. This standard allows for field preparation, recognizes fluid consistency, and also affords a means for determining compressive strength of grouts that contain expansive agents or grout fluidifiers. This is extremely important since expansive grouts can lose substantial compressive strengths if cubes are not confined. However, cylindrical specimens 150 mm x 300 mm or 100 mm x 200 mm may give more reliable results for grouts containing coarse aggregate. Special application grouts often require modification of standard test procedures.

4.0 Assessing the Stability of Grout[4]

The injection and filling of post-tensioning ducts have been carried out since last 5 to 6 decades. It was seen that post-tensioning tendons were often covered by a film of grout, indicating that grout had been present during construction but had fallen back. The bleeding was the major cause for failure of the grouts in such cases.

The specification of grout stability test is to measure the bleeding of the grout mix. This test also enables to measure the volume change of the grout. The grout need to be of high-performance having zero bleed and some limited expansion as per the provision of the standard which may be practically very difficult to achieve at site. Hence, it may be feasible to set a level closer to 1 % bleed as acceptable limit. With regard to expansion, it would be prudent to set a lower limit of 1% to compensate for early age shrinkage. In addition, it should be set an upper limit not higher than 5%, preferably lower, as excessive expansion can be accompanied by internal cracking and formations of cavities in a closed container.

5.0 Conclusion

Testing of physical and mechanical properties of grout is necessary to determine suitable grout, which will ensure durable prestressed structures and other applications. Laboratory and on-site testing should be performed as part of quality assurance and quality control of materials built into the structures. However, some of the tests methods that are prescribed in the standards and guidelines may not be suitable for laboratory and do not always fully deliver the necessary information. This need to be tested at site with some modifications that should be suitable for the site or some proto-type tests under the close supervision of experience engineers and executed by skilled operators who understand the correct procedures.