Stability of Cement Grout: Study of Sedimentation Phenomena

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Received: 1.6.2001, Final version: 23.11.2001

Abstract:
The grouts are suspensions containing cement used in the technique of prestressing by post-tension. Cement, from its chemical nature, protects the wire ropes (strands) from corrosion. To be able to play correctly this protective role, the grout must remain homogeneous and must entirely cover the strands. The lack of stability of the grouts, which results in packing or sedimentation, is a major problem. In this article, we try to correlate the rheological properties of the grout with its capacity to remain homogeneous. We show that an increase in the concentration of superplasticizer, a polymer solution, decreases the thixotropic behavior of the grout, but on the other hand, increases the effects of sedimentation. We explain this phenomenon by the modification of the structure of a three-dimensional network in relation to the interparticle interactions.

Zusammenfassung:
Mörtel, welcher in der Technik des "prestressing by post-tension" verwendet wird, ist eine Zement-enthaltende Suspension. Zement schützt Drahtseile (Stränge) aufgrund seiner chemischen Natur vor Korrosion. Um diese schützende Rolle auch vollumfänglich wahrzunehmen, muss der Mörtel homogen bleiben und die Stränge vollständig bedecken. Die mangelnde Stabilität des Mörtels, welche in Verdichtung und Sedimentation resultiert, ist ein beträchtliches Problem. In diesem Artikel versuchen wir die rheologischen Eigenschaften des Mörtels mit seiner Fähigkeit, homogen zu bleiben, zu korrelieren. Wir können zeigen, dass ein Anstieg in der Konzentration eines Superplastifizierers, einer Polymerlösung, das thixotrope Verhalten des Mörtel vermindert, aber auf der anderen Seite den Effekt der Sedimentation verstärkt. Dieses Phänomen erklären wir mit der Modifikation der Struktur eines dreidimensionalen Netzwerks unter Berücksichtigung von Partikel-Partikel-Wechselwirkungen.

Résumé:
Les coulis sont des suspensions à base de ciment utilisées pour la précontrainte par post-tension. Le ciment, de par sa nature chimique, protège les câbles d'aciers (torons) de la corrosion. Pour jouer correctement son rôle, le coulis doit rester homogène et couvrir entièrement les torons. Le manque de stabilité des coulis, conséquence de la sédimentation ou de la consolidation des particules de ciment, est un problème important. Dans cet article, nous tentons de corréler les propriétés rhéologiques des coulis avec leur capacité à rester homogène. Nous montrons qu'une augmentation de la concentration en superplastifiant, une solution de polymères, entraîne une diminution du comportement thixotrope, ainsi qu'une augmentation des effets de sédimentation. Nous expliquons ce phénomène par la modification de la structure tridimensionnelle, formée par les particules de ciment, en relation avec les interactions interparticulaires.

Key words: prestressing, cement grout, rheology, sedimentation, interactions, thixotropy

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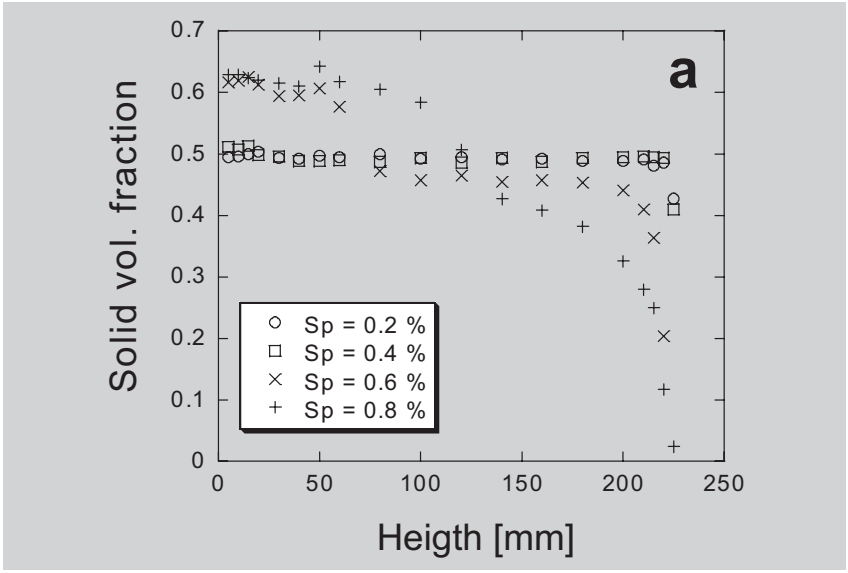

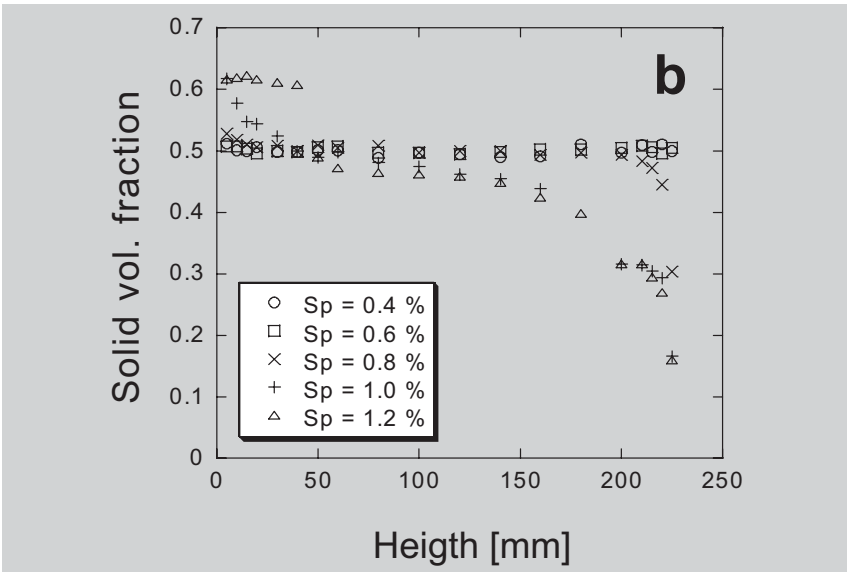

Figure 4: Volume fraction profile of cement grout versus superplasticizer concentration without silica fume (a) (above) and with silica fume (b) (below).

amplitude seems to depend on the superplasticizer concentration. This consolidation phenomenon is accompanied by a weak increasing of the volume fraction. The higher the concentration in superplasticizer is, the more the tube presents a strong gradient of volume fraction. The maximum volume fraction measured is 62-63 %. The measurement of gamma-densimetry becomes more delicate when more than two bodies are involved (the grout can contain, in addition to cement, a mineral addition). If the grout presents a double segregation (for example involving a modification of the proportion of cement compared to water, but also of the mineral addition compared to cement), it is not possible anymore to access to the volume fraction. The volume fraction can however be evaluated (Fig. 4b) if:

- quantity of cement compared to mineral addition remains constant.
  or
- absorption of the mineral addition is negligible.

For the studied grouts with silica fume, the absorption of silica fume is not negligible (silica fume = 11 % of the mass of cement). For the homogeneous grouts, quantity of cement compared to silica fume remains constant. For the heterogeneous grouts, the silica fume proportion is higher at the top, so solid volume fraction of the suspension can not be determined exactly.

4 DISCUSSIONS AND SUMMARY

The increase of the superplasticizer concentration leads to the reduction of the structuration of the material (Fig. 2a), and in parallel we observe the appearance of a deposit (Fig. 4a). The same experiments were made on a grout of slightly different formulation (with 10 % of silica fume) and show an identical behavior (cf. fig. 2b and 4b). Superplasticizer acts on the interactions between cement grains: the polymers adsorb on the surface of the cement grains and modify the interactions [2,11,12]. These repulsive interactions cause an increasing on deflocculation when the superplasticizer concentration increases. This phenomenon is reflected as well on the rheological properties (reduction of the yield stress) as on sedimentation.

The results of local granularity and profile of density enable us to differentiate two types of phenomena which are responsible of the lack of cement in the top of the suspension: for the low superplasticizer concentrations (0.2 % and 0.4 %), there is consolidation of the network of grains without interparticle movement. For higher concentrations, the particles form a deposit. A greater proportion of large particles is found in the bottom of the tube characterizing a sedimentation phenomenon.

This phenomenon can be described as follow: without superplasticizer, because of high attractive interactions, cement particles build up a tri-dimensional structure. When interparticle interactions are not strong enough (for the strong superplasticizer concentration), the structure collapse: the cement suspension start to sediment and segregation can be observed.

These results show that it is possible to correlate rheological measurements with the sedimentation of the grout: indeed, one can think that a grout with a high yield stress leads to a grout which does not form a deposit. It now remains to see whether the measurement of the structuration is possible with simpler systems of measurement, adapted to sites, like the tilted plan [14] or slump flow test for example.

ACKNOWLEDGMENTS

We thanks French technical association of hydraulic binders industry (ATILH) for the financing it brings to this study, Laurent Nachbaur and Jean Joseph Serrano for theirs enriching remarks.

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ANNEX: DETERMINATION OF GAMMA ABSORPTION COEFFICIENT OF CEMENT AND WATER

The mass proportion of the different components of the cement (CaO, SiO_2 ...) are known and the absorption coefficients for each element can be found in handbook [15]. The average coefficient absorption of cement is the sum of the absorption coefficients of each element of cement weighted by its mass proportion. A commonly used absorption coefficient for Portland Cement is μ_c = 0.077 m²/kg. The absorption coefficient of water is μ_c = 0.086 m²/kg.

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