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TESTING AND MODELLING OF FRESH CONCRETE RHEOLOGY

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ABSTRACT

This paper presents the results of an experimental program dealing with the rheology of fresh concrete. The two main goals were:obtain rheological data on concretes of various mixture compositions, and establish models to link mixture composition with rheological parameters.

1.Introduction

This paper presents the results of an experimental program dealing with the rheology of fresh concrete. The two main goals were:

- Obtain rheological data on concretes of various mixture compositions,and
- Establish models to link mixture composition with rheological parameters.

Approximately 20 mixtures (mortars and concretes) were formulated and tested A description of the rheological behavior of the material that is better than the usual linear Bingham model is provided by the Herschel-Bulkley model in the form, $\tau = \tau_0' + a\dot{\gamma}^b$ where τ is the shear stress, $\dot{\gamma}$ is the shear strain rate imposed on the sample, and τ'_0, a and b are characteristic parameters of the concrete being tested. Among other advantages, the non-linear model avoids the problem of a negative yield stress, which is sometimes encountered when the Bingham model is fitted to the test data. The "plastic viscosity" is defined from the characteristic parameters. However, for a certain number of applications, the Bingham approach may be retained as a first approximation.

2. Experiments

The principal aggregate used in this study is from silica-limestone alluvial deposits.It is rather rounded in shape. The two sizes (0-4 mm sand and 4-10 mm coarse aggregate) have a specific gravity (in the dry state) of 2.61 measured. The respective water absorptions are 0.6 and 0.7%, the dry packing density values are 0.715 and 0.612 .To assure continuity in the size distribution of the mixtures, a round fine sand (0.106 to 0.075 mm) was used. This sand corrected the deficiencies in gradation of the alluvial sand by adding fine particles with diameters between the fine sand fraction and the largest cement particle sizes. The grading curves of the aggregates, are given in Figure 1. For the mortars, the aggregates were screened to give a maximum 2.5 mm diameter (Figure 1).

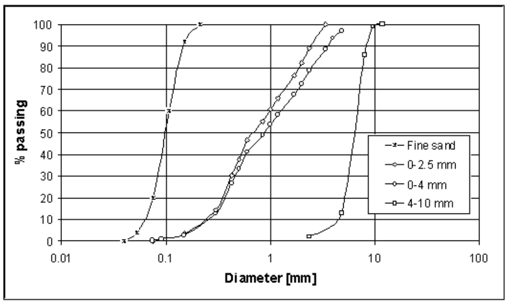

Figure 1: Size distribution of the aggregates used in the mortars and concretes

In order to model more precisely the contribution of the sand to the packing density of the mixtures, the packing densities of three granular fractions of the sand were also measured. The values were 0.625 for the coarse fraction (1.25 to 4 mm), 0.621 for the middle fraction (0.315 to 1.25 mm) and 0.581 for the finest fraction (0.125 to 0.315 mm).
The packing density mentioned in the paragraph above is defined as the maximum solid material in a unit volume. This factor is 1 for solid material (no air) and 0 for air only.
The aggregates were oven dried before use. All of the dry materials were introduced into the mixer and mixed dry for one minute, then the following mixing schedule was used:
Ordinary concretes:

- With the mixer running, the water was added at an approximately constant rate during a period of 30 seconds;
- Mixing was continued for another two minutes, and the mixture was discharged from the pan.

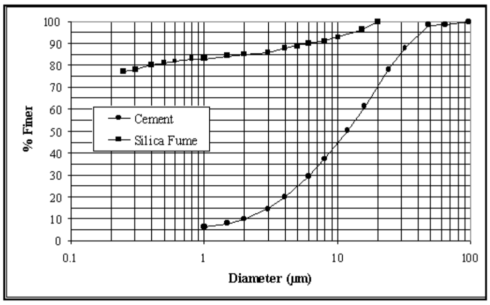

Figure 2. Size distribution of the binders used in the mortars and concretes

The experimental plan consisted of systematically characterizing a reasonable range of the mixtures that could be made from the three basic materials: coarse aggregates, combined sand (a mixture of alluvial sand and fine silica sand in fixed proportions) and cement. Based on a certain number of dry compositions (considering only the volumetric fractions of soild materials), three wet mixtures were made by varying the water content so as to cover the range of consistencies that could be characterized by the rheometer .The composition of the central mixture was designed to obtain the maximum dry packing density, but with a slight excess of cement in order to minimize the bleeding in all of the mixtures under-dosed with sand. It was the optimization of the packing density at a fixed cement content that led to adopting the proportion of fine sand to alluvial sand of 30% by mass, a value that was maintained throughout the series. The other dry mixtures were generated on the basis of the *central* mixture by changing one or both of the following two parameters: the volumetric proportion of cement and the volumetric ratio of sand to total aggregate. It should be noted that the latter ratio was 100% for three dry combinations that were mortars. For these mixtures, to avoid the bleeding that was produced with a cement dosage equivalent to those for the concretes, the proportion of cement by volume was increased. Finally, the combination corresponding to the lowest dosage of cement and the highest dosage of gravel was not made because of the segregation problems, i.e., sedimentation and bleeding, that would have unavoidably occurred.

In order to determine the dosages of water to produce the desired slumps, we began by adopting a dosage corresponding to the porosity of the dry system (provided by the Rene-LCPC software) plus a fixed additional amount of water. Based on the slump obtained, the water dosage was then reduced or increased, the objective being to obtain three concretes (or mortars) of different consistencies for each dry combination. This procedure has the advantage of conserving materials. On the other hand, we sometimes reached the operating limits of the rheometer. However, knowledge of the limits of the applicability of the methodology was also an objective of this study. In addition to the dry compositions (given in mass percentages), the proportions by mass per cubic meter, based on the assumption that the entrapped air content was 1%, are also presents. It should be noted that two additional concretes were produced for the *central* mixture, bringing to a total of five the number of concretes having the optimum dry composition but variable water content.

3. Conclusions

To establish a model to link the mixture composition with the rheological properties and to validate such a model, an ambitious experimental plan was developed and conducted. A total of 20 mixtures were made and tested. Analysis of the test results led to a modification of the widely-used assumption that concrete behaves as a Bingham fluid. A model for predicting the rheological properties of the mortars and concretes from the mixture composition, and fundamental characteristics of the components was proposed. To test the general validity of the model, it should be applied to other mixtures with different constituent characteristics.

References

[1] **Tattersall**, **G.H**. *Workability and Quality-Control of Concrete*, E & FN SPON, London. (1991)

[2] **Wallevik**, O. "*Den ferske betongens reologi og anvendelse pa betong med og uten tilsetning av silikaastov*," Ph.D. Thesis, University of Trondheim NTH. (1990)

[3] **Hu, C., DeLarrard, F**., and **Gjorv**, **O.E**. *Rheological Testing and Modelling of Fresh High-Performance Concrete, Materials and Structures*, Vol. 28, pp. 1-7. (1995)

[4] **Tanigawa**, **Y.,** and **Mori**, **H**. *Analytical Study of Deformation of Fresh Concrete*, *Journal of Engineering Mechanics*, Vol. 115, (3), March. (1989)

[5] **DeLarrard**, **F., Szitkar**, **J.C., Hu, C**., and **Joly**, **M.** "*Design of a Rheometer for fluid concretes*," Proceedings of the International RILEM Workshop Special Concretes: Workability and Mixing, Ed. P.J.M. Bartos, E & FN Spon, pp. 201-208. (1994)

[6] **Chang**, C., and **Powell**, **R.L**. *Effect of Particle Size Distributions on the Rheology of Concentrated Bimodal Suspensions*, *Journal of Rheology*, Vol. 38 No January-Feb.(1994).