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Marsh cone coupled to a plexiglas horizontal channel: Rheological characterization of cement grout

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A B S T R A C T

The apparition of a wide generation of mineral powders industrially mastered (like silica fume and limestone filler) and organic products (particularly the superplasticizers) increases significantly the range of rheological performance of concrete.

Varying the dosage of superplasticizer, the type and the amount of mineral powders, this experimental study consists of measuring the cement grout flow time and the visualization of its flow profile using a new experimental tool: Marsh cone coupled to a Plexiglas horizontal channel. Then, the rheological properties of this grout are studied by means of a rheometer with vane spindle. The comparison between experimental results and rheometer measurements allows us to confirm the ability of the used approach. To characterize the fluidity of cement grout, the results show that this approach can replace the rheometer.

1. Introduction

During the concrete manufacturing, we have to adjust its fluidity in order to obtain an optimal implementation. However, it seems reasonable to affirm that the rheology of concrete is influenced by the behavior of its cement paste [1–3].

Measurements on a grout, that contains water, cement and additions, show that these materials are not Newtonian fluids, but they present a viscoelastic behavior (Fig. 1). The grout flow properties can often be described approximately by using a Bingham model (Fig. 1) defined by two factors: plastic viscosity and yield stress [4].

The large number of grout constituents and their various actions on the rheological properties lead to use experimental methods to optimize the material in the fresh state.

The addition effect of limestone filler, silica fume and superplasticizer on the rheological performance of concrete has been studied by several authors [5–18]. However, the conclusions on this effect are sometimes contradictory. Because, some of these studies show that the addition of a fine powder will increase the water demand due to the increase in surface area. This belief is supported by test results showing that the addition of fine silica fume particles increases the water demand to attain specific workability levels. However, in certain cases, it is reported in these literatures that the use of fine mineral admixtures can reduce the water demand.

In addition, some of these authors show that a moderate silica fume dose decreases the viscosity and the yield stress of the mortar while the other authors show that the yield stress and plastic viscosity of the Bingham model have greatly increased with the increase of silica fume percentage in cements with a constant E/L ratio.

For this, the aim of this work is to study the effect of these additions using a new, simple, fast and economical approach allowing to characterize visually the grout flow. This approach is based on a Marsh cone coupled to a Plexiglas horizontal channel (Fig. 2).

Marsh cone is a standardized, simple and effective tool (P18-358 or NF EN 445 [19]) that characterizes globally the relative fluidity of the cement pastes. The principle of characterization is to measure, for a given volume of grout, the time taken to flow through a nozzle.

Visualizing the flow profile, the use of a Plexiglas horizontal channel allows to characterize the filling capacity of grout, so its yield stress (Fig. 3).

The capacity of a fluid to pass through obstacles and to fill the formwork of different shapes and configurations is called the "filling capacity".

In our case, the filling capacity of grout represents the nearest flow profile to "fluid grout" profile (Fig. 3). This filling capacity is thus characterized by a flow length equal to the maximum length of horizontal channel and $h2$ tends towards $h1$ (Fig. 5b).

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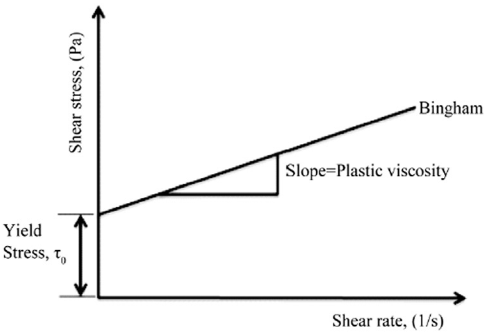

Fig. 1. Yield stress and plastic viscosity.

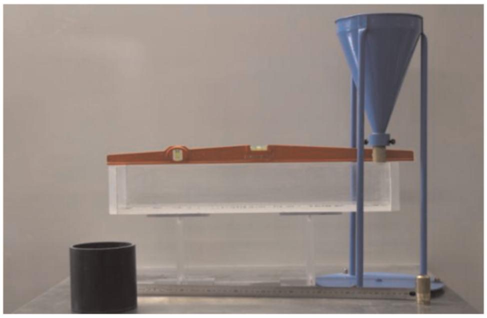

Fig. 2. Marsh cone and Plexiglas horizontal channel.

2. Experimental study

The experimental study is based on the measurement of flow time in the Marsh cone by varying the dosage of superplasticizer, the type and the amount of additives.

The proposed experimental design in this study is similar to the approach of Benaicha et al. [20] characterized by V-Funnel coupled to a Plexiglas horizontal channel to characterize the self-compacting concretes. In this work, to characterize the grouts, the V-Funnel is replaced by a Marsh cone and the used horizontal channel is a reduced model of the Plexiglas canal used by Benaicha et al. [20]. This experimental tool is presented on the Fig. 4.

The first stage is fill out the Marsh cone by 1 l of grout, the second step involves opening the Marsh cone orifice and start a stopwatch to measure the emptying time of Marsh cone through a 10 mm diameter orifice.

The last step is to measure the final height and the initial height as well as the length of flow in the horizontal channel. Two cases can be observed: the length of the flow may be less than (Fig. 5a) or equal to the channel length (Fig. 5b).

According to these experimental aspects, $h1$ varies from 5 cm to 15 cm, $h2$ varies from 0 to 5 cm and the drain time exceeds 7 s (it is the time of water drain).

To minimize the errors of this experience and improve the representativeness of each measure, we repeated the handling 6 times for each type of grout.

At 5 min after the start of mixing (Fig. 6 and Table1), the flow time is measured. This later allows to provide the grout fluidity.

The longer this time is, the more viscous the grout is. Inversely, the shorter the time is, the more fluid the grout is. Moreover, the $h2/h1$ ratio and the length L allow for the characterization of the grout filling capacity.

2.1. Materials

The preliminary phase consists in the grout manufacturing from cement CEM I 52.5R CE CP2 NF, originate from Beaucaire Marseille plant-Calcia Cements, by varying the percentage of superplasticizer TEMPO 16 manufactured by SIKA France, the dosage of limestone filler marketed by Carmeuse and silica fume Sikacrete HD manufactured by SIKA France. The amount of cement is 500 g. All grout were prepared using the same Water/Cement ratio (W/C=0.4). The physical and chemical characteristics of cement, limestone filler, silica fume and superplasticizer are presented in Table 2.

In a given formulation, the knowledge of each constituent influence on the grout behavior allows for the identification of its percentage and its role.

2.2. Effect of superplasticizer dosage

The type and dosage of superplasticizer are very important to have the most stable fluidity. For different dosages of superplasticizer in relation to cement mass, the variation of flow time is presented in the following figure (Fig. 7).

Fig. 7 shows that the flow time decreases even less rapidly depending on the dosage in superplasticizer. The curve obtained indicates two essential points that govern the rheological behavior of cement–superplasticizer combination studied: (i) the critical dosage corresponding to the saturation point (deviation of the curve: flow time=f (superplasticizer dosage)) is in the order of 1%. (ii) The degree of fluidity for this critical dosage is in the order of 22 s. It should be pointed out that the flow time and the saturation point may differ from one composition to another. This depends on the way and the content in which the ingredient are added.

Beyond the saturation point, the addition of superplasticizer does not improve any more the grout fluidity but it only increases the risk of sedimentation and delays the cement setting time [22] (Fig. 8).

Beyond 1% of superplasticizer, the flow profile remains the same, but a bleeding (water film on the channel surface) appearance is observed.

Plexiglas horizontal channel is used to identify the problems of bleeding and characterize the filling capacity. Figs. 9 and 10 illustrate the evolution of $h2/h1$ ratio and flow length L depending on the superplasticizer dosage.

Figs. 9 and 10 show that from 1% of superplasticizer, the ratio $h2$ is equal to $h1$, while the flow length remains constant after 0.5%

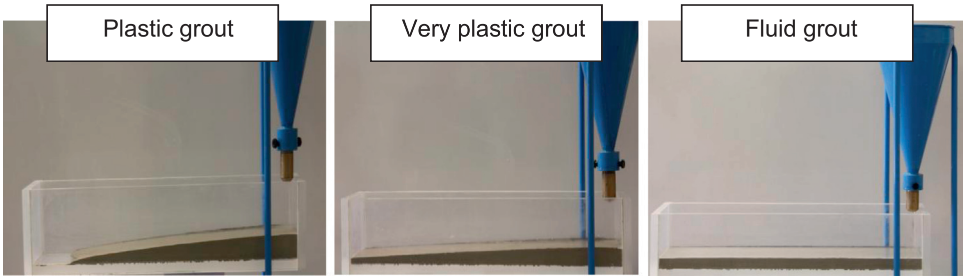

Fig. 3. Profiles flow depending on the grout viscosity.