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Rheological Behaviour of Fresh Cement Pastes Formulated from a Self Compacting Concrete

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RESUME

The mineral additives and additives are introduced into the concrete to improve their rheological behavior in the fresh state, and their mechanical properties and durability in the cured state. In this study two sets of tests were conducted on self-placing pastes composed with marble waste as a mineral addition. The first series consists in determining the spreading of this pasta with the mini-cone; the second series consists in determining their shear threshold using the HAAKE RHEOSTRESS 1 rheometer.

A correlation between the results obtained on the results of spreading and those of the shear threshold, for the various compositions considering the influence of the super plasticizer and a viscosity agent is sought.

1. Introduction

The development of self-compacting concretes (BAP) and high-performance concretes is especially related to progress in the field of admixtures and the use of mineral additions [1-2]. Several models for predicting the rheological behavior of concretes is developed [3-5].

These models require control of the properties of concrete constituents, particularly the rheology of pasta [4-6]. Indeed, today's concretes are often composed of mineral additions, this presence has effects on the behavior of cementitious pastes and therefore the rheological behavior of concrete and all related properties, it is therefore necessary to study in their presence. In this study, we are interested in the rheological behavior of self-compacting (very fluid) pastes that are used in the composition of self-compacting concrete (BAP). The study is based on rheological test results using the HAAKE RHEOSTRESS 1 rheometer (Figure 1) and mini-cone spreading by varying the percentage of addition in the pasta, the amount of water, the super plasticizer dosage and the viscosity agent dosage. The ultimate goal of this study is to propose a rheological model that will correlate the results of spreading tests to the mini cone to those measured using the rheometer. The model will make it possible, from simple mini cone spreading tests, to predict the shear threshold of pasta.

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2. MATERIALS AND EXPERIMENTAL PROCEDURES

2.1 Materials Used

The cement used is a CEM II / A 42.5 manufactured by the Lafarge cement factory located in Algeria conforming to the NF EN 197-1 standards. The super plasticizer used is a MEDAPLAST SP 40, the viscosity agent is CIMCIL L25; both adjuvants are produced by Granitex (Algeria).

The marble powder used is of economic interest because it is a recovery powder from waste marble. The waste is supplied in the form of a wet paste. The dough is dried; the clumps obtained are crushed and then sieved to recover fines with a diameter of less than 80 μm.

2.2 Experimental procedures

Two experimental programs are conducted. The first program to characterize the pasta rheology using the rheometer (Fig.1). The principle of the test is to shear a sample of dough between two trays with horizontal surfaces, one at rest and the other mobile (plane-plane geometry). This rheometer is equipped with a Rotor valve with an imposed speed. After adjustments, the gap between the two plates was validated to 1.5 mm. The tests are carried out at a temperature of 20 ° C (± 1 ° C). The protocol followed for our tests is: a pre-shear at 10 s-1 for 2 minutes before each ramp up speed. This step makes it possible to destructor the material and to obtain a state of reference identical to all the pastas. Then an increasing linear ramp of speed from 0 to 70 s-1 for 5 minutes is applied. The second program is carried out using the hollow frustoconical mini-cone for measuring pasta spreading (Fig. 1). Its dimensions in mm are: 40 of height, 70 of greater diameter and 80 of smaller diameter. The cone is placed in the center of a glass plate and filled with paste. It is then lifted to allow the dough to drain; two perpendicular measurements of spreading are performed.

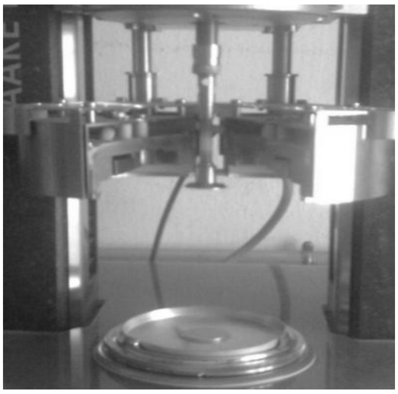


Figure 1– Haake Rheostress 1

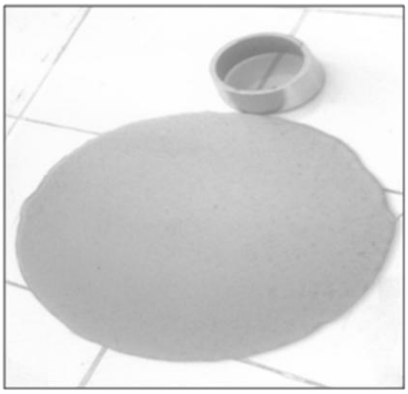


Figure 2– Spreading Test at the Mini-Cone.

2.3 Formulations studied

The compositions tested are summarized in the form of groups with each time one or two components that vary, they are formulated at constant masses is 500 g.

Abbreviations: SP: super plasticizer dosage; AV: viscosity agent dosage; W: water; C: cement; PM: marble powder. SP and AV are expressed as a percentage of the cement mass. The groups are summarized as follows:

• Groups (1, 2 and 3) formulated as follows: Group 1 [W/ (C + PM) = 0.40], Group 2 [W / (C + PM) = 0.45] and Group 3 [W / (C + PM) = 0.50]. For these 3 groups, 7 values of C / PM were tested and for each value of (C / PM fixed) one has a variable SP.

• Groups (4, 5 and 6) formulated as follows: Group 4 [W/ (C + PM) = 0.40], Group 5 [W / (C + PM) = 0.45] and Group 6 [W / (C + PM) = 0.50]. For these 3 groups we have (C / PM) = 2, the variable SP then the variable AV. For these cases, for a composition, the value of AV was first varied; then for each value of AV the SP was varied.

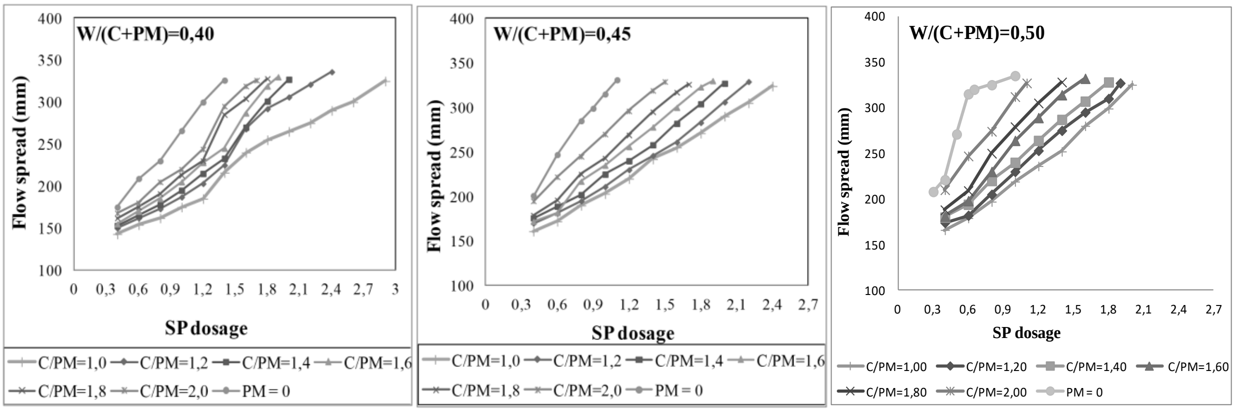
3. RESULTS AND DISCUSSIONS

3.1 Results at the Mini-Cone

The analysis of the results leads to understanding the combined effect of marble powder MP, SP and AV on the flow of self-placing pastes.

3.1.1. Results of Groups 1, 2 and 3 (without AV)

Figs. 3a, 3b and 3c correspond to the results of spreading as a function of the variation of the SP and of the C / PM ratio, ie the amount of PM in the pasta formulated at the same ratios.



(3a) (3b) (3c)

Figure 3– Evolution of SP and C / PM spreading of Group 1, 2 and 3.

The figure 3 show that the spread for a given composition, the same ratios W / (C + PM) and C / PM, increases with the increase of the SP.

On the different mixtures, for the ratio W / (C + PM) fixed for example at 0.40 and for a fixed SP, the spread decreases with the increase of the quantity of the PM in the dough is therefore with the C / PM decreasing. In other words, for the same SP, the less marble powder is put into the composition, the more the dough is spread out well.

In fig. 4, we have shown the curves of variation of the spreading as a function of the C / PM ratio for an SP fixed at 1% that for the pasta formulated at different ratios W / (C + PM). Thus, for the example of the case where (W / (C + PM) = 0.40), the results show the increase of the spreading, 175 mm with a ratio of (C / PM = 1) and 220 mm for a report (C / PM = 2).

Now the SP is fixed, the substitution of the cement by the PM has an inversely proportional effect on the spreading of the paste. In this case, in order to thin the dough, the SP dosage must be increased.

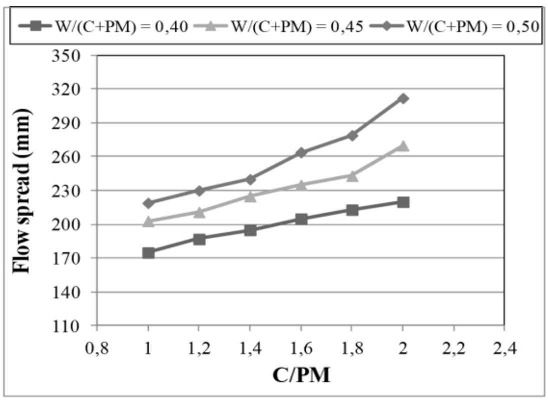


Figure 4– Evolution of the spread according to C / PM for a SP fixed at 1% and W / (C + PM) variable.

Certainly, the sprawl increases with the increase of the ratio (W / (C + PM)), ie with the quantity of water.

3.1.2. Results of Groups 4, 5 and 6 (with AV)

Because the results obtained on groups 4 and 6 are similar to those obtained on group 5, we have not shown in fig. 5, than those in group 5.

We then represented the spreads as a function of the variation of the SP in the abscissa and the AV from one curve to another, the C / PM ratio is fixed at 2, the pasta is formulated at a ratio: W / (C + PM) = 0.45.

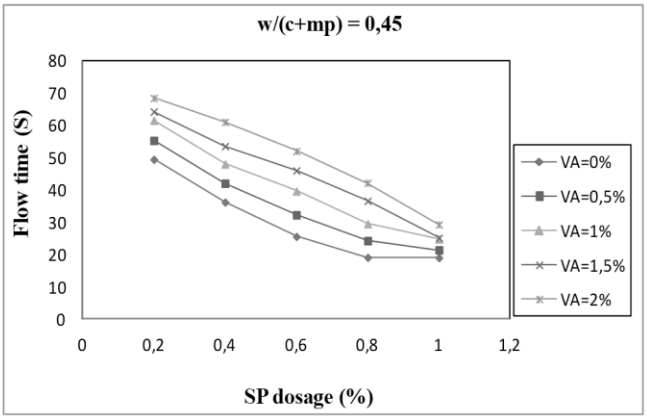


Figure 5– Evolution of the Spread According to the sp Dosage for Group 5

The results of figure 5 show that the introduction of the viscosity agent in the different compositions does not have a great influence on the spreading measurements.

The same behavior was observed on the other two groups formulated at a ratio W / (C + PM) = 0.40 and 0.50.

Indeed, on the three groups of pasta studied the difference in spreading between the pasta formulated at 0% of AV and the pasta formulated at 2% of AV, the spreading decreased on average by 18 mm, which is not important.

When the super plasticizer, its action is not influenced by the presence of the viscosity agent because the spread evolves in the same way, with the same differences, between the pasta with different viscosity agent dosages. This suggests that there was no chemical interaction between these two adjuvants.

3.2 Rheometer Results

In this part we studied the rheometer behavior of the different self-placing pastes tested without and with the viscosity agent. We studied the combined influence of PM content and SP on the shear threshold.

The rheograms recorded on the tested pasta follow a law of the Herschel-Bulkley type which is expressed by the relation (1). This result is consistent with what is found in the literature [6-7].

$$\tau = \tau_0 + b(\gamma)^c \qquad (1)$$

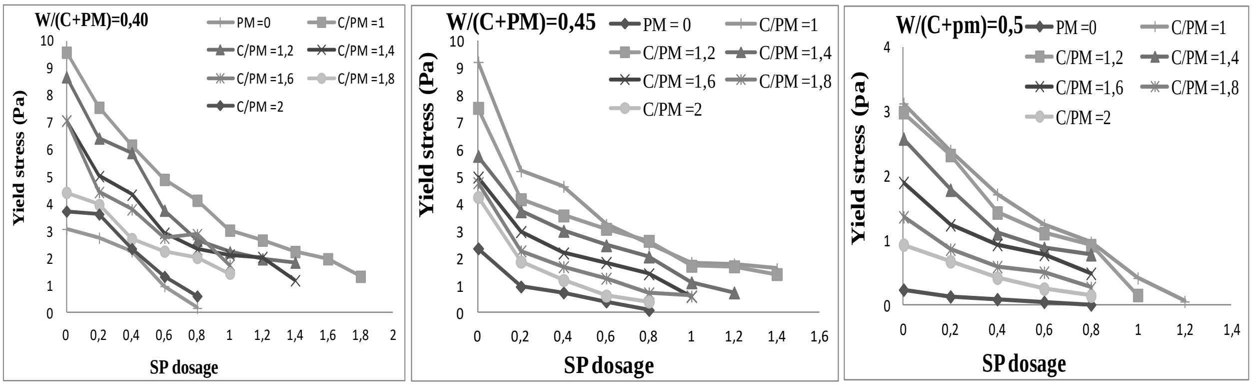
Where: τ0 is the shear threshold that corresponds to the ordinate at the origin of the rheogram, represents the shear rate, and b and c are constant in the model (rheological flow characteristics). As a reminder: when c = 1 and $\tau 0 \neq 0$, we find the Binghamian behavior; when c = 1 and $\tau 0 = 0$, we find the Newtonian behavior.

For (c> 1) the pasta has a rheo-thickening behavior and for (c <1) the pasta has a rheofluidifying behavior.

The curves obtained change parameters depending on the amount of powder added and the presence or absence of the superplasticizer or the viscosity agent.

3.2.1. Shear Threshold Results for Groups 1, 2 and 3 (without AV)

In fig. 6 the shear threshold versus SP curve is shown for groups 1 , 2 and 3 pasta.



(6a) (6b) (6c)

Figure 6– Evolution of shear threshold versus SP of pasta groups 1, 2 and 3.

In these figures, it can be seen that for these pastes the measured shear threshold values decrease with the increase of the SP, while keeping the ratios W / (C + PM) and C / PM constant. When the substitution of the cement by PM, the more the PM increases (C / PM decreases), the higher the shear threshold, and therefore more super plasticizer is needed to fluidify the formulated pastes with the same ratio (W / (C + PM)). So the threshold increases with the substitution of the cement by the PM by keeping the SP constant.

On the other hand, it is also noted that the threshold values decrease with the increase of the ratio (W / (C + PM) that by comparing the three groups of graphs of figs 6. The observed decrease is slight between the same pulps with ratios (W / (C + PM) = 0.40 and 0.45) However, this drop is important between the ratio pulps (W / (C + PM) = 0.45 and 0.50).

3.2.3. Group 4, 5 and 6 Shear Threshold Results (with AV)

In figure 7 are shown the results of the shear threshold as a function of the variation of the AV and the SP, the ratio C / PM is fixed at 2.

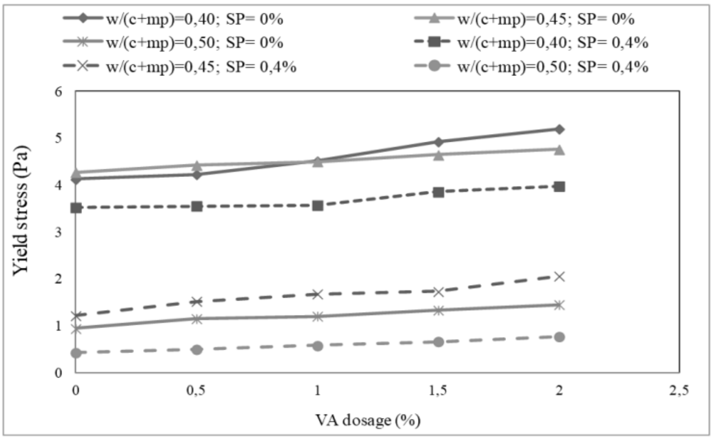


Figure 7– Evolution of the Shear Threshold as a Function of AV and SP of the Pasta of Groups 4, 5 and 6.

For figure 7 it is noted that for these pasta the values of the measured shear threshold evolve with a slight increase with the increase of the AV, while maintaining (W / (C + PM), C / PM and SP) constant. This result is consistent with the use of viscosity agents which are often used to make viscous materials without affecting their fluidity (shear threshold).

In addition, in the presence of the viscosity agent, it is found that the introduction of SP at a dosage of 0.4% has lowered the shear threshold. The drop produced between formulas without SP and those at 0.4% SP is uniform (remains almost constant with the variation of AV) because the curves evolve in parallel.

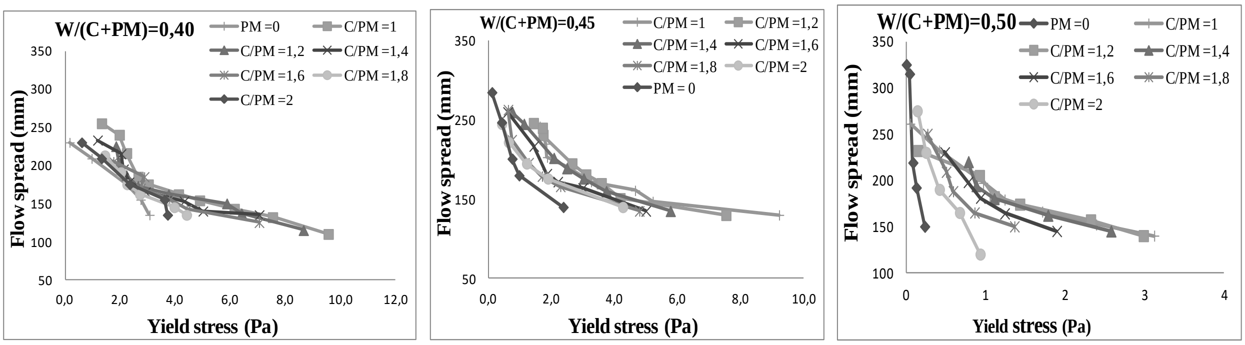
On the other hand, we note that the threshold values decrease with the increase of the ratio (W / (C + PM)).

4. CORRELATION BETWEEN SHEAR THRESHOLD AND SPREADING OF SELF-PLACING PASTES

The spread measurement results obtained at the mini-cone were used to establish a correlation with the shear threshold obtained by the rheometer.

4.1. Correlation between Spreading and Shear Threshold of Group 1, 2 and 3 Results (without AV)

In figure 8 we have shown the experimental results of spreading as a function of the measured shear threshold values for pastes formulated without AV.



(8a) (8b) (8c)

Figure 8– Correlation between spread and shear threshold for Group 1, 2 and 3.

These results confirm those of several authors [8].

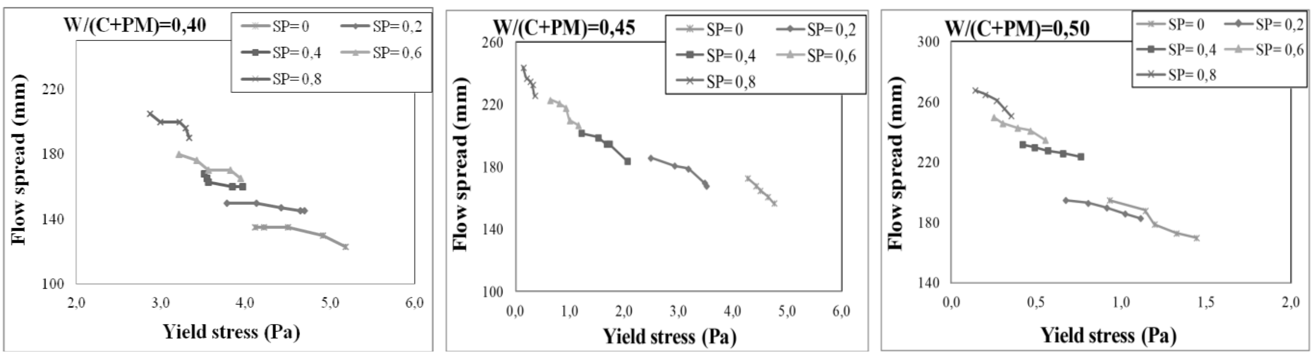
For the three cases of results shown in figure 8, it can be seen that there is indeed a correlation between the spreading results measured with the mini-cone and those measured with the rheometer. This representation, spread according to the shear threshold, for pasta formulated with the same ratio (W / (C + PM)) with the same quantity of water, without the viscosity agent, allows us to observe:

• the spread decreases with the increase of the shear threshold and thus the reduction
Of the SP.

• The spread decreases with the increase of the shear threshold and thus the decrease of the ratio (C / PM) is with the increase of the quantity of the marble powder.

4.2. Correlation between Spreading and Shear threshold of Group 4, 5 and 6 Results (with AV)

The results shown in figure 9 correspond to those of the correlations between the spreading results and the rheometer; results of pasta formulated with the same ratio (W / (C + PM)) is therefore with the same amount of water and a ratio C / PM = 2 in the presence of the viscosity agent.



(9a) (9b) (9c)

Figure 9–Correlation between spread and shear threshold for Group 4,5 and 6

The results of figure 9 show that:

• The spread decreases with the increase of the shear threshold and therefore the increase of the VA.

• The spread decreases with the increase of the shear threshold and thus the reduction of the SP. In general, the measured shear threshold values do not exceed 10 Pa for all the pulps tested.

5. CONCLUSION

This study focused on the rheological behavior of self-placing cementitious pastes for which we have replaced a part of cement with marble powder from marble waste. Two test programs were conducted: the first using the mini-cone to measure pasta spreading; the second using the HAAKE RHEOSTRESS 1 rheometer to measure the shear threshold of the pasta.

According to the results obtained, it can be concluded that for the case of self-placing pastes, the higher the SP, the more the flow of these pastes approaches the Newtonian flow; it is due to the dispersing effect of (SP).

In terms of correlation, in general, spreading is a decreasing function of the shear threshold regardless of the value of the ratio W / (C + PM) and the C / PM ratio of the pasta. The increase in (SP) increases the spreading of pasta and lowers the shear threshold.

For pastes without (AV) and fixed (SP) a substitution of the cement by the marble powder decreases the spreading at the mini cone and increases the shear threshold.

The introduction of the viscosity agent into the different compositions does not have a great influence on the spreading measurements and the shear threshold measurements.

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