Study of the effect of silica fume on the mechanical response of a self-compacting concrete using non-destructive testing methods (NDT)

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Abstract

The self-compacting concretes are distinguished by an extreme fluidity, allowing their placement without vibration.mineral additions and admixture are two essential components for the formulation of self-placing concretes (SCC). They are introduced into the concrete to improve their rheological behavior in the fresh state, but also to participate in enhancing the mechanical properties and durability of concretes, especially in the case of active additives.

In this study, a test program was performed on self-placing concretes composed of cement and silica fume and lime filler as mineral addition. The rheological parameters (viscosity and yield strees) were measured using the rheometer at the fresh state. Mechanical characterization was performed by means of the direct (compressive) and non-destructive testing methods (NDT), ultrasonic velocity and rebound hammer for the assessment of the mechanical responses in the hardened state.

The results obtained showed an advantageous effect of these combined additions with an optimal dosage of 10% (5 % Silica fume + 5 % Limestone), with regard to the improvement of the rheological and physico-mechanical properties of the self-compacting concrete mixtures studied.

Keywords; Self compacting concretes (SCC), rheological parameters, viscosity, mechanical response, Non-destructive testing methods (NDT).

I. INTRODUCTION

Self-compacting concrete is an innovative concrete; which differs from other types of concrete by its high fluidity that allows it to take its place without any vibration. This type of concrete requires a specific formulation that contains two essential components, admixtures and mineral additions ; these components serve to improve the rheology, mechanical properties and durability of concrete [1, 2].

The purpose of this study is to characterize self-compacting concretes with cement and locally available mineral additives (silica fume and limestone filler) at a variable percentage of 0, 2.5, 5, 7.5 and 10%, simultaneously for two additions in the fresh state and in the hardened state.

II.EXPERIMENTAL PROGRAM

Five different mixtures of concretes were made ; The concrete formulations produced are as follows :

- BAP T → Self- compacting concrete with the addition of 10% limestone fillers (FC) as control concrete.
- BAPI → Self- compacting concrete with the addition of 10% of silica fume (F S).
- BAP II → Self-compacting concrete with the addition of 5% silica fume 5% limestone fillers.
- BAP III → Self-compacting concrete with the addition of 7.5% limestone fillers 2.5% of the silica fume.
- BAPIV → Self-compacting concrete mixes 2.5% limestone fillers 7.5% of the silica fume.

III.RESULTS AND DISCUSSION

A. Characteristics of SCC's at fresh state:

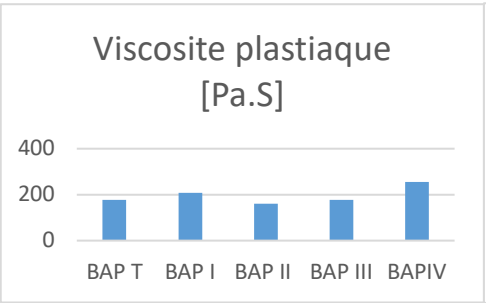

Figure 1. Viscosity for SCCs studied mixtures.

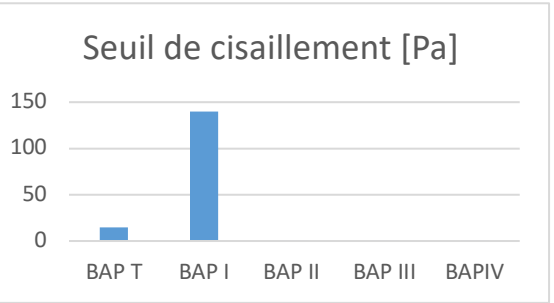

Figure 2. Yield stress for SCCs studied mixtures.

The BAPI yield stress of (10% FS) is much higher reaching (140.06 Pa) versus BAPT of (10% FC) to a value of (14.9 Pa). The other BAPs (BAPII, BAP III and BAPIV) gave low values (0.091Pa) compared to the control concrete which reflect better fluidity and therefore good rheological performance required by the standards in force for BAP (50-150). Pa) [1], [3].

It should be noted a significant viscosity increase of the order of 43% in the BAPIV formulation containing (2.5% FC and 7.5% FS) which records a maximum viscosity value of about 255 pa.s. Also, the BAPI of (10% FS) with an increase of the order of 17% compared to the control. On the contrary, we observe an insignificant decrease of approximately 0.5% for BAPIII of (2.5% FS and 7.5% FC) and 7% for BAPII of (5% FS and 5% FC), the results are almost similar compared to BAPT of (10% FC) with viscosity values 177.84, 160.6 and 178.6 Pa.s, respectively.

The nature and fineness of the addition has an effect on the yield stress and the viscosity of self-compacting concrete. The BAP should have as low a flow threshold as possible so that the flow starts quickly and their viscosity should be moderate to limit the flow time [3], [4].

B. Characteristics of hardened SCCs :

B.1.Destructive tests :

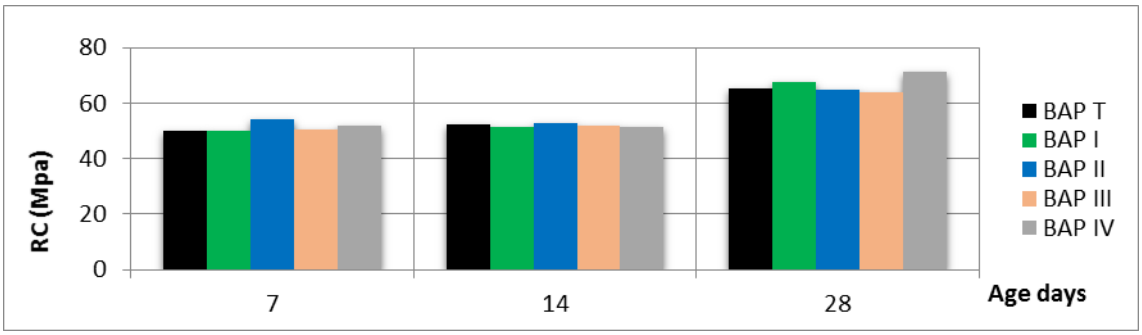

Figure 3. Compressive strength.

It is noted that BAP IV concrete (2.5% FC and 7.5% FS), has a maximum mechanical resistance Rc at 28 days (71.48MPa) compared to other types of concrete, and records an improvement of about 10% compared to the BAPT witness. These fillers are composed mainly of SiO2 for silica fume (FS) and CaCO3 for limestone (FC). These elements accelerate the hydration of C3S, which improves resistance at younger ages. This improvement is explained by the great fineness of the types of additions, which improves the particle size distribution. [1, 4].

B.2. Non-destructive testing :

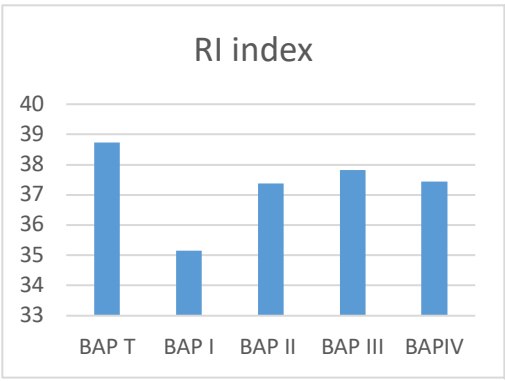

Figure 4. Rebound Hammer Index results.

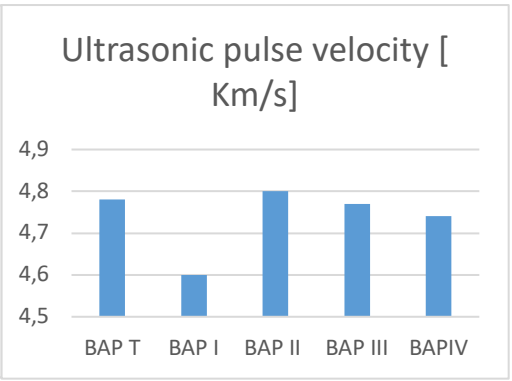

Figure 5. Ultrasonic pulse velocity results.

According to the histogram of the values of the Rebound Hammet (RI) index of the different SCCs, we note that the BAPI (10% FS) gives the minimum value Is (35,16), a reduction of approximately 10% compared to that of the BAPT at 28 days of age. We also note a convergent decline for BAPII, BAP III and BAPIV mixtures with a lower rate of decline that is around 3% compared to BAPT. Ultrasonic pulse velocity propagation, which is above 4.8 Km/s, indicates a concrete of acceptable quality. It is noted that the mixture (10 % FS) records a lower ultrasound speed among all the formulated BAPs, however it remains very acceptable for the probation of

the quality of the manufactured BAP and remains higher than 4.6 Km/s deemed satisfactory. Sometimes it could be said that the conditions of the test run could affect the results obtained from the ultrasonic speed and even be contradictory to the resistance values obtained from the direct crush tests which are considered more reliable in comparison with the ultrasound test. or the Rebound hammer index, the latter which only reflects the strength of the concrete on the surface examined; or that reason it is advised to couple the two non-destructive tests (RI and Vu) for concrete quality control [5] [6].

IV.CONCLUSION

Increasing the concrete limestone filler gives an improvement in the rheological properties and the high dosage up to an optimal rate of 10% silica fume indicates better mechanical properties. The self-compacting concrete combined mixtures based on mixed additions silica fume (FS) and limestone fillers (FC) show better performances in terms of rheology properties (good fluidity, ease of placing and homogeneity) as for the mechanical response enhancement benefits over 60 MPa at 28 days compressive strength.

Finally, it can be concluded that the mineral additions silica fume and combined with limestone fillers remains advantageous for a formulation of performant Self compacting concretes. Further, the outcome of this program allows us to the deduction about the reliability of NDT methods that confirmed much more the compression test results obtained for SCC composites.

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