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EXPERIMENTAL INVESTIGATION ON THE EFECT OF MARBLE POWDER ON THE PERFORMANCE OF SELF-COMPACTING CONCRETE (SCC)

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Abstract: The self-compacting concretes (SCC’s) are characterized by their high fluidity so that they could be placed without any vibration. The effect of fillers addition on the behavior of SCC in fresh and hardened state is of great importance. This incorporation of marble powder aims to preserve the environment and to widen its use in the future in SCC formulation.

The present research experimental program examines the effect of the partial substitution of cement with marble powder on the characteristics of self-compacting concrete in fresh and hardened state. Thus, the marble powder (MP) was introduced into the composition of self-compacting concretes at dosages of 10%, 20% and 30%. Three water cement ratios (W/C) of 0.4, 0.5 and 0.6 were maintained for the studied mixtures. The reference one with 100% of cement served as a control concrete mix. Finally, it can be concluded that such valuation of the marble waste could be beneficial for self-compacted concrete formulation.

Keywords: *Self-Compacting Concrete (SCC), Marble powder (MP), Mechanical proprieties, rheological characteristics, environment.*

INTRODUCTION

The self-compacting concrete was developed in Japan in 1988. It represents one of the most important advances in the technology of concretes in the last two decades. The SCC can be considered as a material of high performance, which could be placed

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under the influence of its own weight without any mechanical vibration to adapt itself in a desired shape even in the case of a very small spacing between the steel reinforcement.

The easy placement under only the effect of the gravity, required a very high fluidity of materials but It is as well essential as the concrete preserves a satisfactory stability and a perfect homogeneity. These two contradictory properties are obtained by a high quantity of fine particles of fillers coupled with a high water cement ratio W/C corresponding to a fixed dosage of super-plasticizier admixture. The local materials in any region of the world form the first natural product of construction appropriate to this region given that it was able to resist the climatic changes of the same region in the past. Algeria with its vast area includes a heterogeneousness of local materials which deserve to be valuated, like the dune sand, clays, tuff, pozzolan, the marble powder and others which are still up to now under valorized (Belagraa et al., 2016; 2017).

Topcu et al, (2009) investigated the effect of waste marble powder on the properties of SCC. It was concluded that the fresh properties had not been affected up to 200 Kg/m^3 marble dust content, mainly the workability. It was reported that the air content increased by using marble waste in the SCC mixtures. The mechanical properties at hardened state had decreased for a higher dosage of marble addition above this level. Consequently, if the positive effect of marble dust incorporation is to be considered on fresh and hardened sate of SCC a new method could be developed for dosages of marble waste below 200 Kg/m^3 (Topcu et al, 2009).

Other researchers pointed out that using marble powder in the SCC formulated revealed higher strength at a given water cement ratio compared to traditional concrete mix. The mean strength for SCC mixes with marble powder was 25 % higher than reference concrete (Alyamac And Ince, 2009). A similar conclusion was observed for SCC containing limestone and chalk powders (Zhu and Gibbs, 2005).

According to the research work undertaken by Corinaldesi and al (2010) on the use of marble powder as a substitution of cement and sand for SCC mortars and concretes, they noted that 10 % replacement of marble powder proved to be effective in assuring good cohesiveness of mortars and concrete at fresh state. But in terms of mechanical performance the 10 % substitution of sand by marble powder provided maximum compressive strength at the same workability level compared to the reference mixture after 28 days of age. Moreover, an even more positive effect of marble powder was noticed at early ages, due to its physical filler ability (Corinaldesi V., Moriconi G and Naik T R., 2010).

Recent studies on the use of marble powder combined with pozzolana for SCC formulation is reported to enhance the rheological properties of mortars and concrete based on this addition for ternary cement. However, a reduction of compressive strength was observed with pozzolana and marble addition compared to control concrete(Belaidi et al., 2012).

In this frame of idea, the use of the marble waste fillers in the composition of the SCC, the present research work investigated the marble waste fillers incorporation to see the effect of such addition on the properties of SCC when using a dosage up to 30 % of marble powder addition in the due formulation of SCC mixtures. Also, the generated marble waste could be with a positive impact on the environment level by the valuation of the local materials in concrete composition in the field of the construction. Hence, it reduces the dust and CO_2 gas emissions in the atmosphere when used as cement replacement.

NOMENCLATURE

SCC, refers to Self-Compacting Concrete.
MP, refers to Marble powder.
BAP0, refers to SCC as control mix without Marble Fillers.
BAP1, refers to SCC with 10 % MP and W/C = 0.4.
BAP2, refers to SCC with 10 % MP and W/C = 0.5.
BAP3, refers to SCC with 10 % MP and W/C = 0.6.
BAP4, refers to SCC with 20 % MP and W/C = 0.4
BAP5, refers to SCC with 20 % MP and W/C = 0.5
BAP6, refers to SCC with 20 % MP and W/C = 0.6.
BAP7, refers to SCC with 30 % MP and W/C = 0.4.
BAP8, refers to SCC with 30 % MP and W/C = 0.5.
BAP9, refers to SCC with 10 % MP and W/C = 0.6.
$R_{(c)}$, refers to the compressive strength of concrete.
$R_{tf,}$ refers to the tensile strength of concrete.
W (%), refers to the absorption of concrete.
P (%), refers to the porosity of concrete.

EXPERIMENTAL PROGRAM

MATERIALS

The used Cement is a CEM II /B 42.5 grade delivered from the Lafarge cement plant with a specific density of 3.1. As fine aggregates, the originally siliceous river sand was used. Two fractions of limestone crushed gravel (3/8, 8/16) were utilized. Marble fillers powder of fraction 0,08 mm having a density of 2.67 was kept at variable dosages for the experimental program. Also, the local super-plastizier MEDAPLAST SP40 delivered by GRANITEX manufacturer and a drinking water from the laboratory of civil engineering for concrete mixtures formulation were used (Dreux and Festa, 2000). The properties of the different materials are presented in table 1, table 2, table 3 and figure 1.

Tab. 1. The chemical and mineralogical composition of cement and marble powder used

The chemical composition of cement (%)										
Constituents	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	L.O.I	Σ
Clinker	27.77	7.00	2.29	56.91	3.38	2.30	0.12	0.51	2.73	100
Marble powder	0.48	0.10	0.12	54.54	0.72	0 .46	0.079	0.053	43.55	100

The mineralogical composition of clinker (%)				
Constituents	C_3S	C_2S	C_3A	C_4AF
(%)	58 - 64	12 - 18	6 - 8	10 - 12

The mineralogical composition of marble powder (%)							
Constituents	Calcite	Dolomite	Quartz	Illite	Chlorite	Kaolinite	CO2-XRD
(%)	98.55	0.14	0.12	0.11	0.39	0.68	43.4

Tab. 2. The physical properties of cement and marble powder used

Physical properties of cement and marble powder used		
Properties	Cement CEM II / B 42.5	Marble powder
NormaL consistency	25,2 %	/
Initial setting (mn)	155	/
Final setting (mn)	280	/
Specific density (g/cm^3)	3,1	2.68
Fineness (cm^2/g)	3995	5500
Bulk density (g/cm^3)	1,1	0,97

Tab. 3. The properties of aggregates

Aggregate size	Bulk density (Kg/Cm^3)	Specific density (Kg/cm^3)	LA (%)	Porosity (%)	Compacity (%)	Void ratio	W (%)	Fineness modulus (%)
Sand(0/5)	1.41	2.51	--	40.87	59.13	0.69	0.39	1.94
Gravel(3/8)	136	2.58	25	2.5	58.87	0.70	0.64	/
Gravel(8/15) *	1331	2.58	19	41.13	62.67	0.60	0.73	/

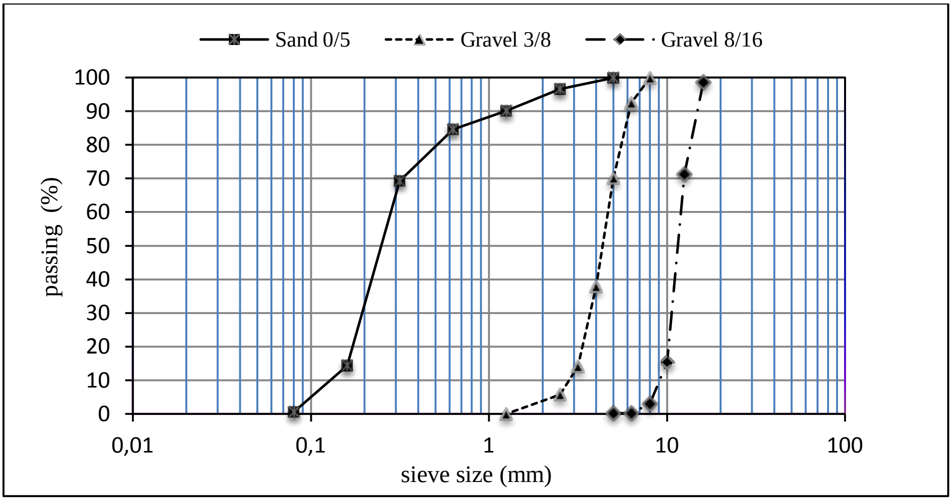

Fig 1. Sieve analysis curve for gravel and sand used.

COMPOSITION OF SCC MIXTURES

The necessary conditions allowing to guarantee the self-compacting and easy placing while based on compositions proposed in the specialized literature were respected in the due formulation of SCC mixtures (AFGC, 2000; Behim and Boucetta , 2009; Assié, 2004; Turcry, 2004; Diederich , 2010). It is fondmental to make the choice for the proportioning of constituents of SCC in one cubic meter (1 m^3) by having the following parameters, a proportional of gravel to sand relationship of G/S equal to one (G/S= 1) and a water cement ratio (W/C) of 0.4, 0.5 and 0.6. A determined dosages for the superplastizier admixture (1.7 % of the weight of cement) and variable percentages of 10, 20 and 30 % of marble powder addition were maintained for this program. To be able to compare the performances of various concretes independently of the cement factor, we fixed the dosage of the latter at 420 kg / m^3. A total of ten mixtures beside a control concrete mix at (100 % of cement) were prepared.

RESULTS AND DISCUSSION

FRESH STATE

L- BOX TEST

The characteristic tests at fresh state of concrete following the batching as recommended by the French Association of Civil Engineering (AFGC, 2000); the flow table, the L-box test and the sieve stability test in the aim of estimating the fluidity and the static and dynamic segregation of the SCC mixes were realized.

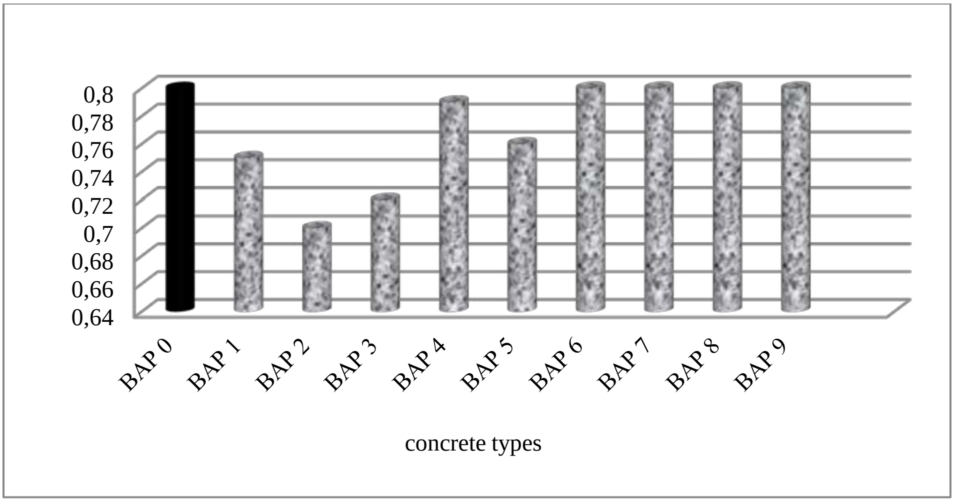

Fig. 2. L box test results for the different concretes types

Figure 2, shows the results obtained for the L box test. The test is exploited through the occupancy rate relationship of the concrete heights in bottom and in the beginning of the box which must as a rule be upper to 0,8 according to the recommendations (AFGC, 2000). The BAP 7, BAP 8 and the BAP 9 (W/C = 0.6) are more fluid than the other concrete types, because of the higher W /C ratio.

The mixtures with marble powder presented occupancy rates being closer to the control mix, one can say that the partial replacement of the cement by the marble powder reaching 30 % has no effect on the mobility of the concrete in a confined medium.

FLOW TABLE TEST

The values of the flow diameter are usually fixed between 60 and 75 cm for SCC mixtures. It can be noticed that the values of the spreading of control mix (without addition of marble fillers) is 70 cm . While for the concretes with addition is situated between 55 to 60 cm for the SCC mixtures with W/C = 0.4, (61 to 67 cm, 69 to74 cm for W/C = 0.5 and 69 to 74 cm for mixes with W/C = 0.6, consequently.

These values show that most of the tested compositions present a spreading upper to 60 cm, that expresses greater fluidity. This high fluidity could be attributed to the use of the dosage of super-plastizier as 1.7 % of the weight of the binder. For the same ratio of W/C, the partial substitution of a part of cement by marble powder leads to a lower fluidity, hence a limited flow table diameter of the SCC mixture, in comparison with the witness. However, this increase of the marble powder dosage is resulting greater values for the flow diameter but it remains lower than that of the control one (BAP0). Finally, at the dosage of 30 % the concrete with the bigger fluidity (BAP9) having a W/C ratio equal to 0.6 in regards to other SCC types with additions and It is similar to the control mix.

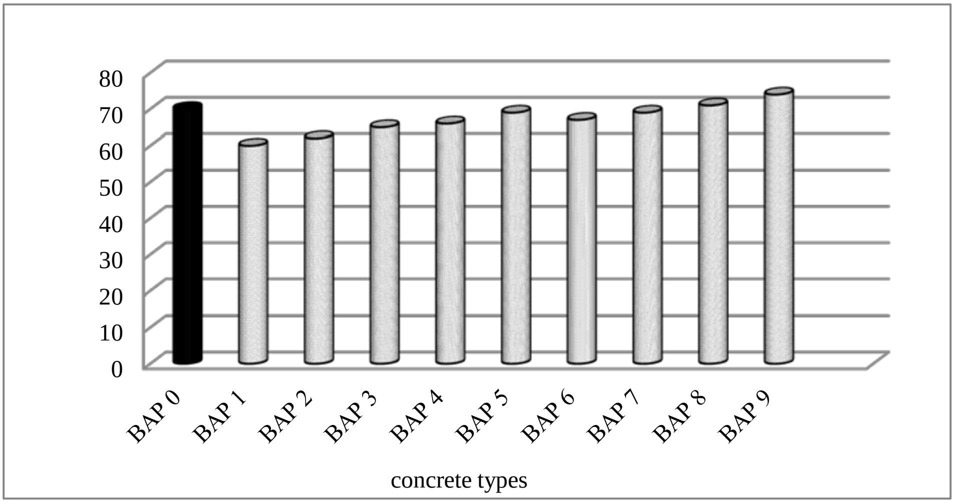

Fig. 3. Flow table test results for the different concrete types

One could conclude that the introduction of the marble fillers has no meaning effect on the workability of the tested SCC's types.

SEGREGATION INDEX

The percentage in weight of slurry having crossed the sieve compared with the weight of the initial sample expresses the stability of the concrete.

From figure 4. the results obtained which showed that the SCC's present an index of segregation inferior to 15 % for either the concrete witness mix and other concretes with marble powder additions. This reflects a sufficient stability, SCC's having a value of the resistance for the segregation lower than 15 % offer a self compacted concrete of very good quality.

The increase of the substitution amount of the cement by the marble powder at dosages of 10 %, 20 % and 30 % leads to a successive reduction in the quantity of necessary water to obtain the SCC satisfying the characteristics recommended by the AFGC. This gives some explanation by the fact that the marble powder in addition to the filler physical role could contribute to an improvement of the fluidity when coupled to the superplastizier admixture used SP 40. The due fact is that the partial replacement of a part of the cement by the marble powder gives a mixture with a less water demand.

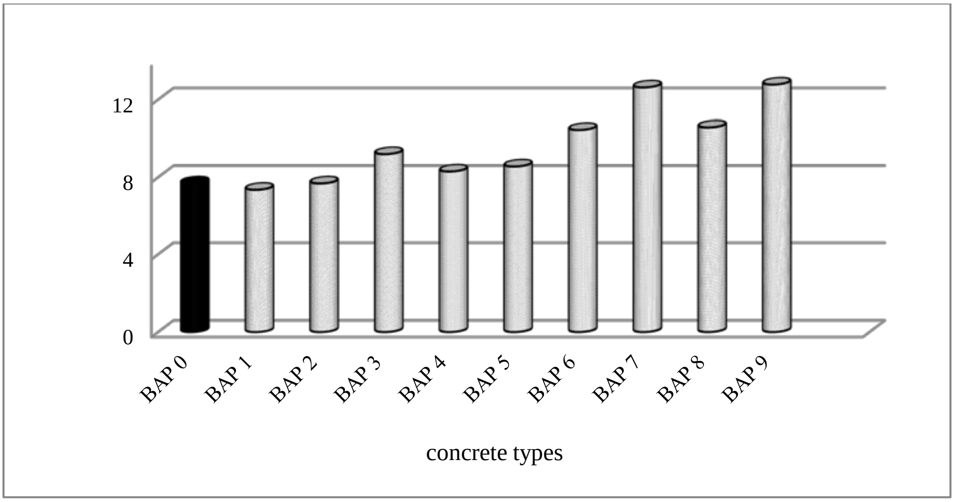

Fig. 4. Segregation index test for the different concrete types

HARDENED STATE

THE COMPRESSIVE STRENGTH R_C

The mechanical response in compression test allows to control the quality of the hardened concrete. It is about the most common current methods used so far.

It can be observed that for all the SCC mixtures the compression resistance increases with the age of the concrete in a normal development of strength according to the age of testing 7, 14 and 28 days (figure 5).

It is noticed that the dosage of the ratio F/C=20% gives a higher compressive strengths relatively to the SCC mixtures with F/C = 10% and F/C = 30%. The compressive strength of the SCC with addition of marble powder are lower than that of the control mix at the age of 7, 14 and 28 days whatever the water cement ratios adopted in the experimental program.

This decrease of the resistance in compression is translated by the fact that the content of replacement introduced which led to the reduction of hydrate components in the cement based material. And these are responsible of the strength development in the SCC matrices with marble powder addition.

It is evident that the increase of W/C ratio is resulting in more a reduction of the strength; nevertheless, the witness mix resistance remains high compared to those containing the marble powder addition. Consequently, except for its physical role of filling the voids in concrete matrix, no activity as inerte constituents could be attributed to the marble powder.

This allows the aquisition of SCC mixtures with acceptable performances (Belaidi et al, 2012).

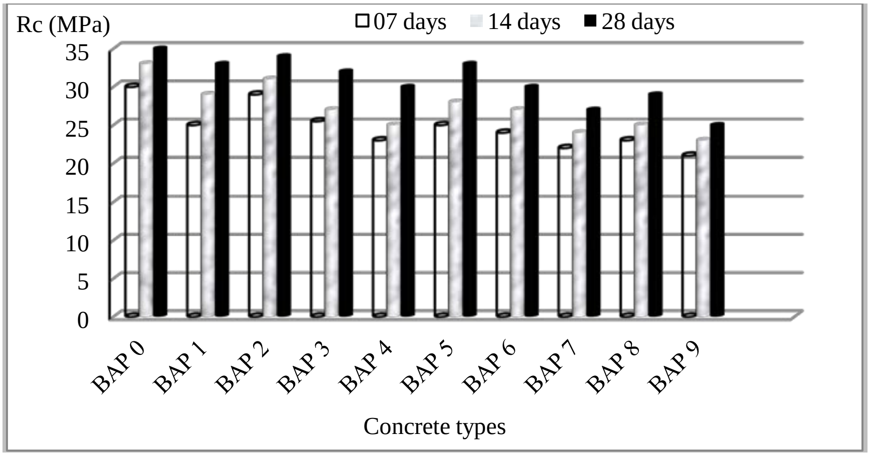

Fig. 5. The compressive strength (Rc)for the different concrete types at 7, 14 and 28 days of age

TENSILE STRENGTH (R_{TF})

It can be observed that for all the SCC mixtures the tensile strength resistance increases with the age in a normal development trend (figure 6). The increase at a dosage of 20 % is remarquable for the tensile strength of this mix compared to 10 % and 30 % percentages of marble powder SCC mixes. The addition of filler of marble led to the reduction of the tensile strength in regards to the witness concrete at the age of 7, 14 and 28 days for three water cement ratio used so far. As reported for the compressive strength all this is translated by the fact that the content of the SCC mixtures of inert replacement addition of MP instead of the active clinker.

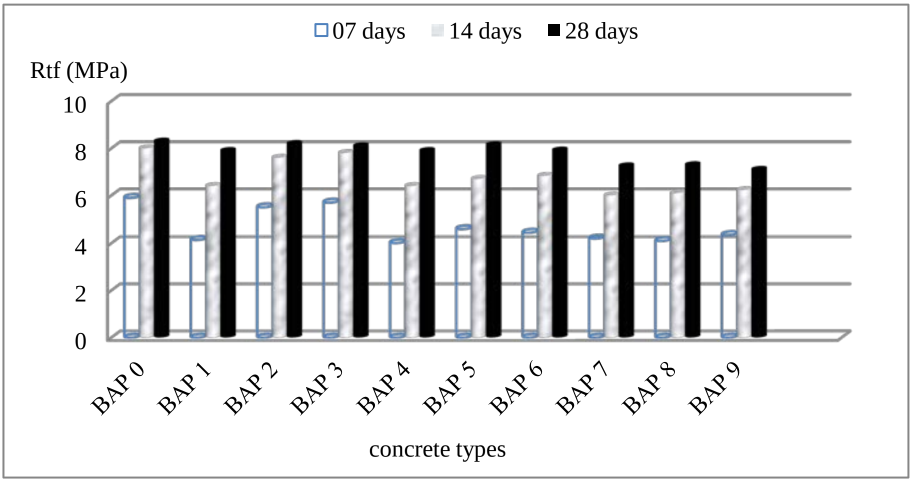

Fig. 6. The tensile strength for the different concrete types

ABSORPTION TEST

It is marked in this test the influence of water cement ratio W/C regarding the SCC concrete absorption rate. From figure 7, the marble powder dosage increases the absorption of SCC mixes in comparison with witness concrete (without addition). This may be due to the increase of water demand of these mixes to achieve the required fluidity.

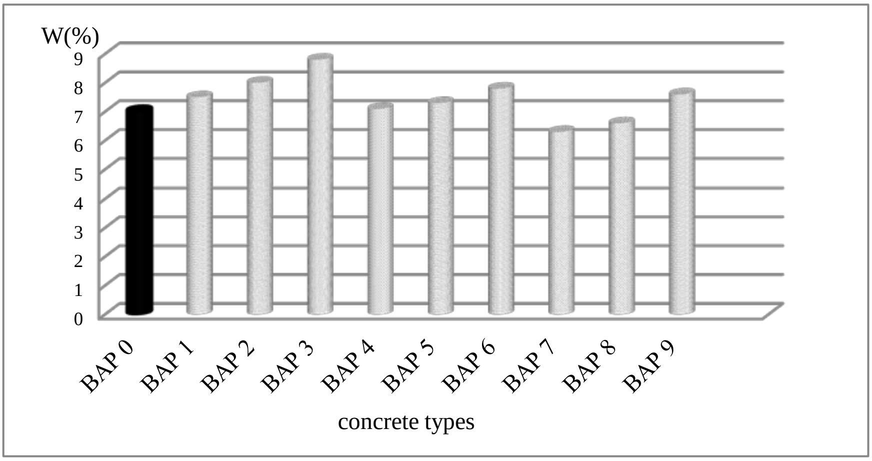

Fig. 7. The absorption W (%) as a function of concrete types

POROSITY TEST

The obtained results for porosity test are reported in the following figure 8.

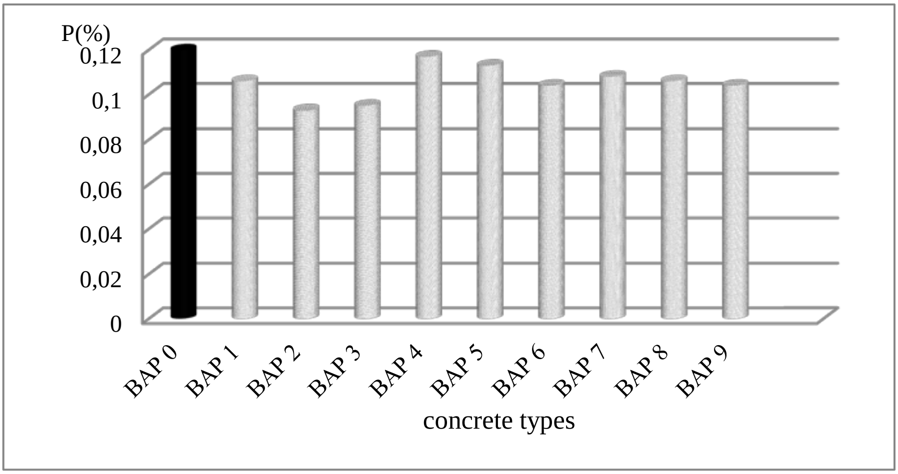

Fig. 8. The porosity for the different concrete types

It can be noticed from figure 8, that the increase of the dosage of marble powder causes a decrease of the porosity of the concrete at the percentage of 10 % and over compared to the concrete witness mix. The latter type is with a great homogeneity and low air content as the voids are filled with marble powder fines.

CONCLUSION

Self-compacting concretes are extremely fluid allowing the easy placement by gravitation and without vibration. These concretes are distinguished from traditional concretes by their properties in the fresh state, higher fluidity, better stability and more robustness. These exceptional particularities impose a higher dosage of cement in the paste to a denser matrix, which allows to keep reasonable heat release during the hydration process. This experimental study highlighted the possibility of using the marble powder waste as addition in the composition of the Self Compacting Concrete. The characteristic tests undertaken on SCC's at fresh state proved a satisfactory fluidity and a good stability as acquired properties at dosages of marble powder reaching 30 %. This could be attributed to the addition of marble powder coupled with a superlastizier which results a homogeneous mix, without segregation and caractérized by easy placing in confined densified steel reinforcment elements. Furthermore, at hardened state, the SCC with marble powder percentages less than 20 % presented acceptable compressive and tensile strengths in regards to the control. In addition, limited porosity and lower absorption are watched for SCC mixtures at these dosages up to 20 % of partial cement replacements by marble powder additions, which reveals enhanced sustainibility .

Finally, it could be concuded that the marble powder waste incorporation could be advantgeous for SCC formulation at the economic and the environmental levels.

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