Experimental and comparative study on the characteristics of self-levelling mortar for optimisation with marble as aggregate

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ABSTRACT: The aim of this study is to investigate the characteristics of self-levelling mortar. Nine new syntheses of mortar were produced with marble as aggregate and maximum grain size of 4mm keeping constant the amount of aggregates. In some syntheses, superplasticiser and stabiliser were used. The characteristics of damp mortar of all compositions were determined. Moreover, experimental tests for the calculation of bending and compressive strength were carried out on specimens of each synthesis. Measurements of drying shrinkage and water absorbability of specimens of each composition were taken. Finally, a comparative study of the results was carried out in order to characterise the new syntheses as self-levelling or not depending on achieving their characteristics.

INTRODUCTION

For decades, many structural materials were used in constructions all over the word. Nowadays, concretes and mortars are the most widespread materials used in this field. The more technology advances, the more these two materials develop and improve. New kinds of concrete and mortar appear all the time, as well as new technologies applied to them. A new type of mortar, recently developed, is the *self-levelling* mortar, which due to its unique property of flowing and spreading has the ability to fill formwork and encapsulate reinforcing bars only through the action of gravity and by maintaining homogeneity. This ability is achieved by designing mortar synthesis in such a way as to have suitable inherent rheological properties. Consequently, it can be described as *self-levelling* mortar that is not subjected to any external energy input from vibrators, tampering or similar actions during casting. The self-levelling mortar can be used in most applications where the traditional vibrated mortar is used.

METHODOLOGY

Nine new mixtures were formed. The differences between these syntheses involved the amount of water, cement and the use or not of superplasticiser and stabiliser (Table 1). Experimental tests were then carried out in order to determine first, the characteristics of damp mortar of all compositions and, then, the mechanical properties of these mortars. Experimental tests for the calculation of bending and compressive strength were also conducted. Measurements of drying shrinkage and water absorbability were taken on each composition. Then, a comparative study of the results was carried out. Finally, useful conclusions were reached based on the outcomes of the experimental study-tests.

Table 1: Composition of mixtures.

Syntheses	Cement (Kg/m^3)	Aggregates (Kg/m^3)	H_20 (Kg/m^3)	Superplasticiser	Strabiliser
A	510,32	1530,96	260,26	NO	NO
B	510,32	1530,96	260,26	YES 1% w cem	NO
C	510,32	1530,96	260,26	YES 1% w cem	YES 0.7%of cem
D	380,00	1530,96	193,80	NO	NO
E	380,00	1530,96	193,80	YES 1% w cem	NO
F	380,00	1530,96	193,80	YES 1% w cem	YES 0.7% w cem
G	380,00	1530,96	228,00	NO	NO
H	380,00	1530,96	228,00	YES 1% w cem	NO
I	380,00	1530,96	228,00	YES 1% w cem	YES 0.7% w cem

Damp Mortar Tests

The damp mortar tests that took place are the following *slump-flow test* and the *V-Funnel* test.

Slump-flow Test

This test method covers the evaluation of the deformability, workability and flow properties of freshly mixed levelling mortar from observation of the deforming speed and the spread diameter of deformed sample under the self-weight [4]. This test method is intended for use with highly fluidised mortars made with superplasticiser.

V-funnel Test

This test method covers the evaluation of the narrow-opening passability, which involves viscosity of freshly mixed self-compacting concrete from observation of the flowing speed of the sample through the specially designed funnel under its own weight [4]. This method also covers the evaluation of the segregation resistance of freshly mixed self-compacting concrete by the observation of the variation on the flowing speed due to the difference of samples remaining period in the funnel. The target values are: slump-flow 24-26 cm (Figure 1a); V-Funnel 7-11 seconds (Figure 1b).

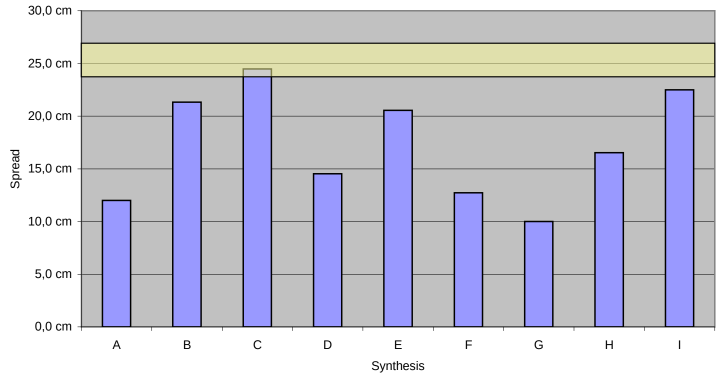

Figure 1a: Slump-flow test results of the prepared mixtures.

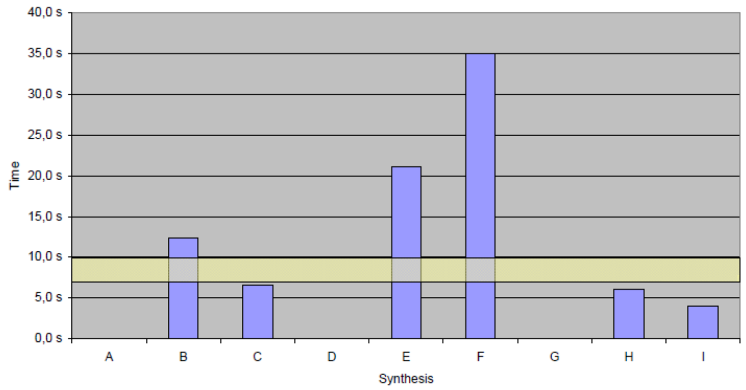

Figure 1 b: V-funnel flow test results of the prepared mixtures.

Compression Test

Compression of the specimens was conducted according to ELOT EN 12390.03 standards. The compression tests were carried out by an AVERY machine with a maximum load capacity of 250 tonnes. The results can be seen in Table 2.

Table 2: Compressive strength.

Average Compressive Strength (MPa)	
A	51,86
B	54,82
C	55,76
D	70,15
E	60,79
F	61,99
G	54,98
H	39,65
I	40,02

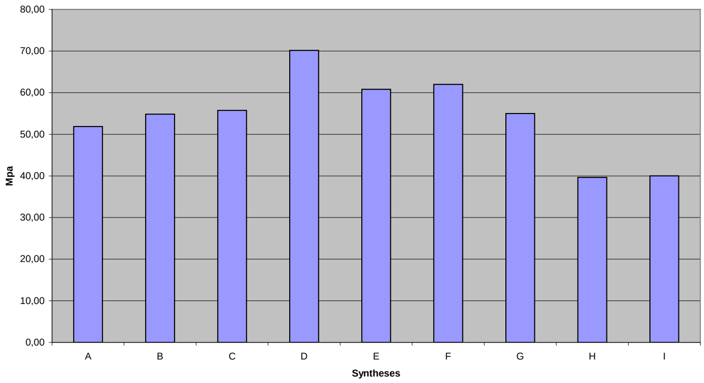

Figure 2: Average compressive strength.

Bending Test

Bending of mortar specimens, having dimension of 40 x 40 x 160mm, after being submerged in water for at least 28 days was conducted. The results are presented in Table 3.

Table 3: Bending strength.

Average Bending Strength (MPa)	
A	8,22
B	9,47
C	9,97
D	10,11
E	10,49
F	10,65
G	8,73
H	8,41
I	7,53

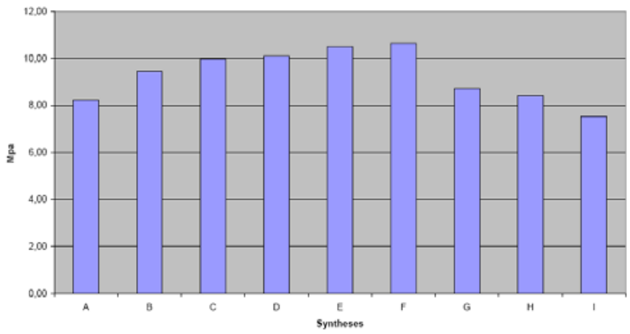

Figure 3: Bending Strength (MPa).

Drying Shrinkage Test

The specimens were kept in a controlled environment (21 ˚C and 60% relative humidity) and measurements were taken daily during the first days of the tests and, less frequently, during the last days when the shrinkage is smaller. The results can be seen in Figures 4 to 6.

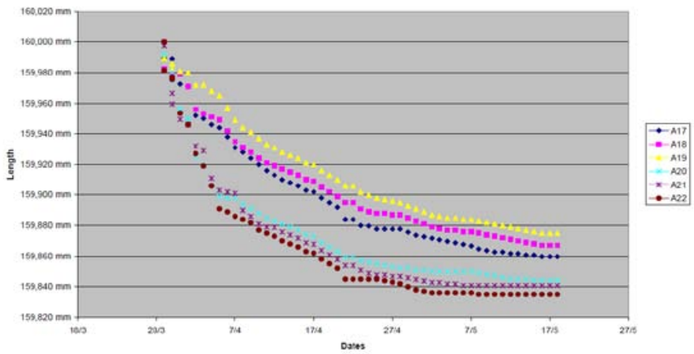

Figure 4: Specimens lengths.

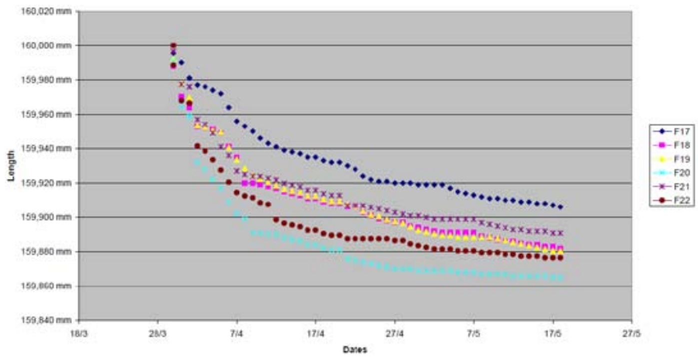

Figure 5: Specimens lengths.

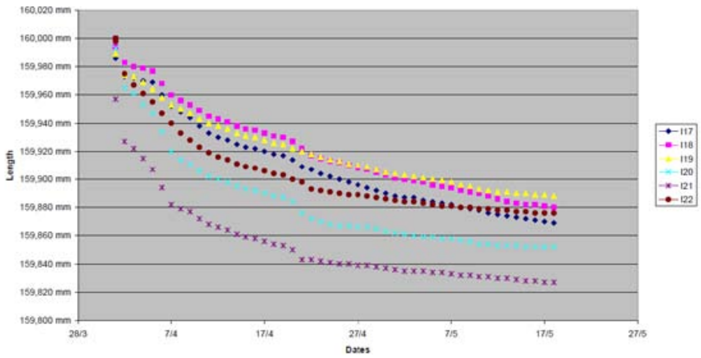

Figure 6: Specimens lengths.

Water Absorbability Test

Sterile water was added to cover 2±1mm from the base of the specimen. Measurements were taken at specific time intervals of up to 662 min.

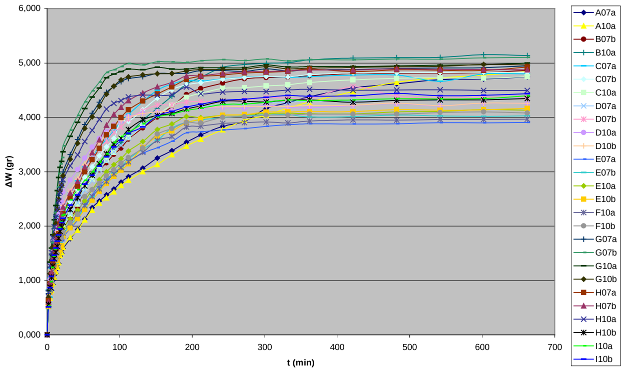

Figure 7: ΔW (gr) – time (min).

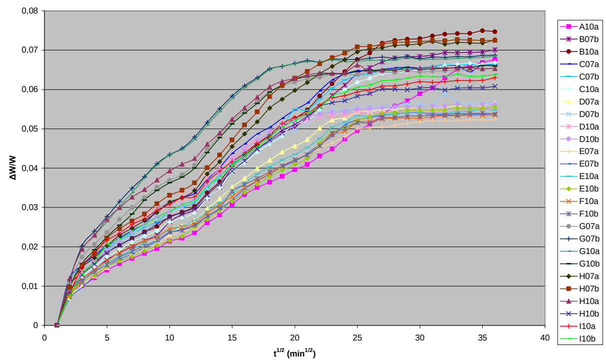

Figure 8: $\Delta W/W$ – time$^{1/2}$ (min$^{1/2}$).

Segregation Observation

To examine the segregation that may occur to each synthesis, large prismatic specimens were constructed. The dimensions of these specimens were 150 x 150 x 700 mm. These specimens were bent up to the point of their fracture and the resulting fracture surface of each was examined for features of segregation. At the end, the specimens were sprayed with Phenolphthalein to examine the amount of cement carbonisation in each case. The results were as shown in Table 4.

Table 4: Segregation observation.

Syntheses		Optical Analysis
A	1.	Few big pores
	2.	Strange segregation
B	1.	Minimum segregation
	2.	Minimum pores
C	1.	No segregation
	2.	Very few, little pores
D	1.	Minimum pores
	2.	No segregation
E	1.	No segregation
F	1.	Many pores
	2.	Darker colour because of humidity
	3.	Broken grains
	4.	No segregation signs
	5.	Specimen failure, during bending at the edges
G	1.	Many pores
	2.	No segregation signs
H	1.	No segregation
	2.	Few big pores
	3.	Vertical failure
I	1.	No segregation
	2.	No pores
	3.	Vertical failure
	4.	Specimen failure, during bending at the edges

RESULTS AND DISCUSSION

The first target was to achieve Self Levelling Mortar (SLM) features to our mixtures. This was done by two damp mortars tests: Slump-flow and V-funnel flow.

For the first synthesis A, the water/powder ratio was equal to 1.16 and that satisfied the ratio by RILEM's guidelines, which is 0.8-1.2. Superplasticiser was added to synthesis B and superplasticiser and stabiliser to C (as shown in Table 1) in order to achieve the characteristics of SLM. Syntheses A and B did not match the damp SLM characteristics. It was observed that synthesis C can almost be characterised as Self Levelling Mortar because the target value of the Slump-flow test was achieved and the value of the V-funnel test was almost the desired one. Further research could be carried out to achieve the V-funnel test target value by adjusting the content of superplasticiser and stabiliser.

Then, new syntheses of mortar were created *by using the same amount of aggregates*. It was decided to try to achieve the required characteristics at first by changing the amount of cement and water that mortar contains and then adding admixtures to it. By reducing the amount of cement and increasing the amount of water, a better flow and plasticity was achieved. Of course, this is something that is not very popular in production because many problems can appear as segregation and bleeding are increased and final strength is decreased.

Therefore, by following RILEM's guidelines for a maximum cement content of 380kg/m^3 and by keeping the water/cement ratio out 0.51 (380x0.51 = 193.8Kg) synthesis D was produced. As it can be seen in Figures 1a and 1b, the characteristics of SLM were not achieved. Syntheses E and F were constructed by adding superplasticiser and stabiliser (as shown in Table 1). The target values of the Slump-flow and V-funnel tests were not achieved, although they were approximated a lot.

Then, by keeping the cement stable, the water/cement ratio was changed from 0.51 to 0.60 (which is the maximum permitted water content *ELOT 480.01*) and synthesis G was constructed. The new water amount was 228kg/m^3 (cement value was invariable at 380kg/m^3) (see Table 1). The characteristics of SLM were not achieved. Then, specific amounts of superplasticiser and stabiliser were added (as can be seen in Table 1) and the final two syntheses H and I were produced. As before, the characteristics of damp SLM were approximated to a satisfactory degree.

Strength

It was expected that the synthesis consisting of admixtures would have a slightly different strength than those of the same synthesis without any admixtures. It was also expected that the more water a synthesis consists of, the less strength it will have.

Comparison of Syntheses A – B – C by Compression Tests

Synthesis B had a better compressive strength than synthesis A, and synthesis C had the best strength of all. This confirms our assumption. Synthesis A is *normal* mortar. Its compactivity resulted from vibration. Therefore, it was not possible to achieve high compactivity. By adding superplasticiser (synthesis B) better compactivity was achieved and the volume of voids was reduced significantly. Therefore, it is completely reasonable that the mortar's strength would increase to higher levels as the lost strength is balanced by the compactivity achieved once the admixture is added. Then, by adding stabiliser (synthesis C), aggregates were stabilised and the composition became more stable and compact. Consequently, the strength was expected to increase.

Syntheses C – D Comparison in Compression Strength

Synthesis D had a better strength in compression than synthesis C. That is because in synthesis D the amount of water used was reduced. This is in agreement with the assumption. Even though the content of cement paste is reduced, aggregates are the ones that give strength. Consequently, by reducing the amount of water the strength is increased as expected.

Syntheses D – E – F Comparison in Compression Strength

The results met our expectations. After adding the admixtures, the strength had decreased. Then, by adding the stabiliser in synthesis F, the strength slightly increased but again was at a lower level than the one in synthesis C.

Syntheses D – G Comparison in Compression Strength

Syntheses D strength was better than the one in syntheses G. This is reasonable because the amount of water contained is greater in synthesis G. So as it was expected that strength would drop.

Syntheses G – H – I Comparison in Compression Strength

Once more, the initial assumption was right. So, strength decreased when the superplasticiser was added, and then it increased slightly by adding the stabiliser. However it remained below strength in synthesis G.

Bending Strength

Bending strength follows the logic of compression strength. As it can be seen, the strength decreases as the water volume rises and also decreases when admixtures are added. The same reaction of strength in bending appears in compression as far as A-B-C syntheses are concerned. The small increase in E synthesis followed by another small increase in F synthesis is due to compactivity, as improved compactivity is achieved by the use of admixtures.

Drying Shrinkage

By observing the drying shrinkage curves, the conclusion that can be reached is that specimens from different syntheses show almost the same attitude. This makes mortars with admixtures capable of replacing ordinary mortars due to similar characteristics, as far as drying shrinkage is concerned.

Water Absorbability

By observing the water absorbability curves, it can be seen that the syntheses reaction have many similarities. This makes mortars with admixtures capable of replacing ordinary mortars due to their similar characteristics, as far as water absorbability is concerned. Further research should be conducted in this field to confirm the above conclusions.

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