Experimental study of the influence of the addition of limestone fillers on the fluidity coupled to the compressive strength of a self-compacting concrete.

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ABSTRACT

Concrete formulation is the process of selecting components and their proportions to produce a material with specific properties prescribed in the standards (Eurocode), including consistency, strength and durability.

Malagasy companies are struggling to produce contemporary works. For this purpose, limited budgets are devoted to the composition of new concretes. One of the most promising is self-placing concrete. For the realization thereof a percentage of calcareous filler is added to the cement paste. The purpose of this experimental study is to study the effects of the influence of the percentage of addition of fillers in the concrete on its consistency as well as the influence of these two parameters (concrete slump and percentage of addition of fillers) on the compressive strength of hardened concrete.

For this experimental study, the preparation of numerous 16x32 cm cylindrical specimens was planned, using local materials, ie CEM II A-P 32.5 UT PM cement, and crushed aggregates from sedimentary rock. The concretes are formulated using the grain granulometry following the Dreux-Gorisse method supported by the BetonLab software. A cure in the open air was adopted for the test tubes made.

This work presents the results of studies concerning, on the one hand, the properties of concrete in the fresh state (consistency as a function of the addition of limestone fillers) and, on the other hand, the compressive strength at 28 days of the concrete. The set of experimental results obtained constituted a database which allowed us to compare through a statistical analysis the models presented in the literature and the results of the tests.

Keyword: *Limestone filler, Concrete slump, Self-consolidating concrete, Crushed aggregates, Compressive strength*

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1. INTRODUCTION

Cement concrete is today one of the most used building materials in the world. The advantages of a concrete construction regardless of its use are good mechanical strength, good sealing and long service life compared to other materials.

As early as 1908, a cement made from limestone had already been discovered in order to obtain a hydraulic binder that was not attacked by seawater or sulphate waters. Since many are the improvements made to this material. Nowadays scientists are working on new generation concretes including self-compacting concrete. Self-compacting concrete is a very fluid cement concrete capable of being put into place even in the most complex formwork only with the effect of gravity. Which methodology would then improve fluidity without neglecting mechanical resistance in the formulation of a self-compacting concrete.

First, we present the results of the characterization tests of the materials used for the formulation of the specimens that we will study.

Then in a second part we expose the experimental method used in the context of this research. In particular the passage of the formulation of the different concretes, substituting a volume of the cement by an equivalent volume of limestone fillers. The different mixes resulting from the different formulations are then subjected to the Abrams cone spreading test to ensure the fluidity of the concrete. We then check the compressive strengths of the different test pieces.

A third part is devoted to the results of the research, the discussions generated by these results to arrive at new perspectives that would allow us to improve this material.

2. RESULTS OF THE CHARACTERIZATION TESTS OF THE MATERIALS USED

2.1 Cement

In this study, CEM II A-P 32.5 UT PM cement was used. Composite Portland cement for class 32.5 tropical use containing from 80% to 94% clinker, a cement specifically intended for work at sea. The use of this cement is in compliance with NF P 15-301 according to Eurocode standards. Considering an exhibition of our work in a marine environment, where it would eventually be exposed to severe conditions.

The analyzes concerning the chemical composition and the mineralogical composition of the binder were carried out at the National Laboratory of Public Works of Madagascar while those concerning the physico-mechanical characteristics within the Laboratory of the University of Antananarivo-Civil Engineering Department.

Table-1: Chemical characteristics of cement

Chemical and mineralogical composition of cement	CaO	SiO_2	Al_2O_3	Fe_2O_3	SO_3	MgO	CaO_{libre}	C_3S	C_2S	C_3A	C_4AF
[%]	60,41	21,91	5,19	2,94	1,60	2,19	1,01	58,2	18,5	9,3	8,2

Table-2: Physical characteristics of cement

Physical and mechanical characteristics of cement	Unit	Value
Apparent density	kg/m3	1020

Absolute density	kg/m3	3000		
Normale consistency	%	27		
Blaine specific surface	cm²/g	3480		
Start of taking	h	1,4h		
End of take	h	4,5h		
Mechanical resistance		2d	7d	28d
Compression	MPa	7	24,17	30,25
Flexion	MPa	2,97	5,3	8,127

The test results show that the cement meets the requirements of its class. This type of cement is not usually used for the manufacture of prestressed concrete because of its low strength class, however, it is well suited to the most common uses of the building.

2.2 Mixing water

For the manufacture of various concrete, drinking water was used, distributed by the public service network of the City of Antananarivo. The chemical analysis of this water was carried out at the Institut Pasteur laboratory (Antananarivo, Madagascar). The results are presented in the following table. They meet the requirements of XP P 18-303.

Table-3: Composition of mixing water [mg/l]

Ca	Mg	Na	K
200	150	175	12
Fe	Al	Cl	SO_4
0,3	0,2	200	250

2.3 Plastizer

The adjuvant used is a new generation fluidiser based on modified phosphonate, with a density of 1110 kg.m^{-3}; pH = 4 ± 0.5; chlorine ion content ≤ 0.1%, Na2O content equivalent ≤ 0.3% and dry extract = 30 ± 1.5 (%). The recommended range of use is 0.3 to 3% of the weight of the binder.

2.4 Aggregates

The aggregates used come from the Ivondro quarry (east coast of Madagascar on the RN2 PK 338 + 200). This quarry has the ability to supply the region. These aggregates are marketed in different granular classes, including 0/3 sand and 5/8, 5/15 and 16/25 gravel.

The aggregates must be subjected to various characteristic tests which will make it possible to appreciate the quality of those ones so as to be in conformity with the standards. The quality of aggregates is important because it directly affects the physico-chemical and mechanical properties of concrete.

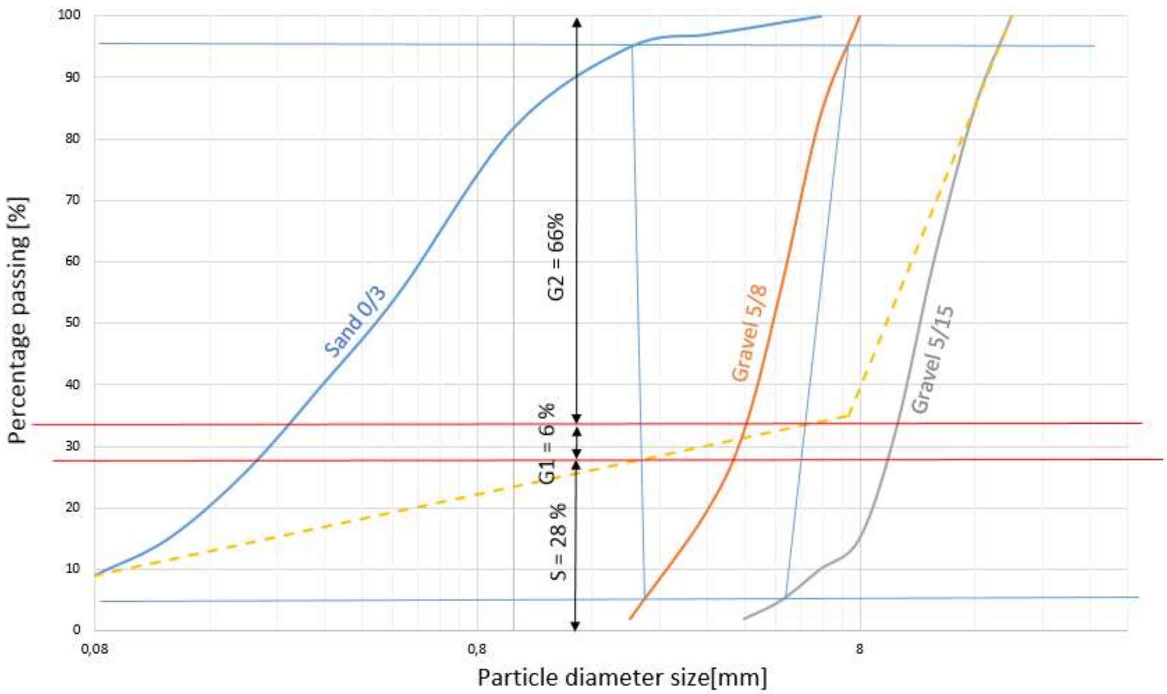

Chart-1: Granulometric curve of aggregates used

Table-4: Properties of aggregates

Properties of aggregates	Granular class			
	0/3	5/8	5/15	16/25
Apparent volumetric mass [kg/m^3]	1427	1349	1423	1369
Absolute volumetric mass	2498	2584	2588	2566
Sand equivalent test [%]	63	-	-	-
Cleanness test [%]	-	1,92	1,3	0,73
Coefficient of finesse	2,94	-	-	-
Fine content [%]	17	-	-	-
Los Angeles test [%]	-	$\frac{4/6.3}{27}$	$\frac{6.3/10}{31}$	$\frac{10/14}{31}$
Micro Deval test [%]	-	$\frac{4/6.3}{15}$	$\frac{6.3/10}{11}$	$\frac{10/14}{8}$

Sand is a rolled river sand of 0/3 particle size, it meets the requirements of the NF EN196-1 standard. In the framework of this study, it was used as it is without any washing for the realization of the recommended concrete formulations, in spite of its modulus of coarse fineness as well as the slight discontinuities that the granulometric curve presents.

On the other hand, the gravel has a satisfactory cleanliness (<3%), a favorable shape (A <30%) as well as a good resistance to shocks and wear, with a coefficient LA <40% and MDE <35%.

3. EXPERIMENTAL PROCESS

The fluidity of a self-compacting concrete is the main quality of it. Indeed its fluidity allows it to be placed in formwork under the effect of gravity. However, there are many parameters that can affect the fluidity of a concrete such as the change in the ratio Water / Cement or W / C or through the addition of fluidizing adjuvant.

In this research, we chose to add a quantity of limestone filler in the cement paste to evaluate its influence on the fluidity of the concrete. This led to the realization of several tempered concrete from different formulations.

In addition we check the compressive strength of each formulation to evaluate the relationship between fluidity and compressive strength of concrete. We carried out the tests thoroughly then a stistical study can be conducted. For this reason, several test pieces have been studied experimentally for each parameter. Each resistance measure is therefore the average value obtained on the specimens containing the same composition.

The concretes were made according to the standards. The materials previously dried in the oven at 110 ± 5 ° C, are introduced into the mixer in the following order: gravel (5/8, 5/15), cement, sand and water. After dry mixing of the order of 1 minute, the mixing water is added and kneading is continued for 2 minutes. The fresh concrete is put into place in the molds without vibration, to ensure the self-placing quality of it.

The test campaign includes the optimization of the granular skeleton of concretes, firstly by the Dreux-Gorisse method [Dreux 1998] then optimized using the BetonLab Software developed by Thierry Sedran and François de Larrard in 2008.

Among the properties studied, we will present the results concerning compressive strengths at 2, 7, 14 and 28 days, measured in the laboratory on standard cylindrical specimens kept in the air because no specific cure was retained.

4. RESULTS AND DISCUSSIONS

The purpose of the experimental program is to study and measure the fluidity of a concrete in order to improve its self-placing quality. In this article we will study the influence of the addition of limestone filler in different percentage to appreciate its influence on the consistency of concrete. Then we will evaluate the influence of this parameter on the compressive strength of hardened concrete.

4.1 Optimization of the granular skeleton

The optimum G / S ratio has been determined for concrete whose composition is specified in the following table.

Table-5: Concrete composition

Sand + Gravel [kg/m^3]	Cement [kg/m^3]	Water [kg/m^3]
1370,25	400	443

According to the Baron-Lesage method, several batches were made for the concrete presented above and the G / S ratio was modulated from 0.6 to 1.6. The following figure shows that the optimum experimental ratio is 1.2 for which the slump test is maximum of 5.8 centimeters.

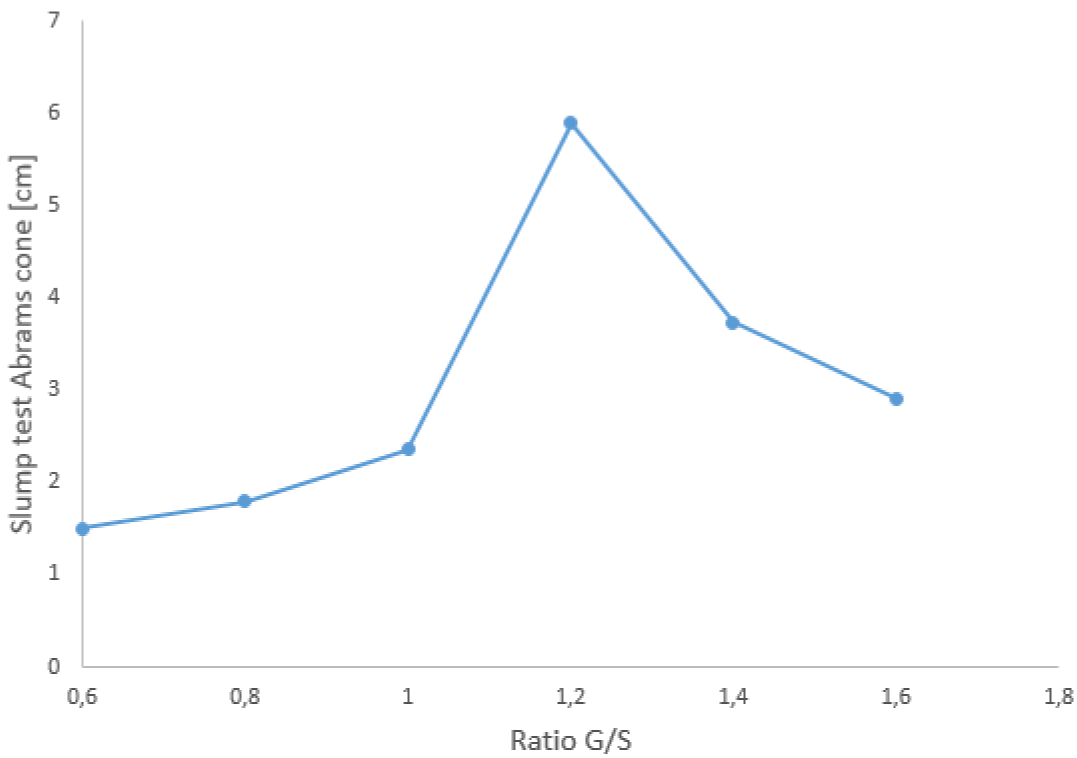

Chart-2: Figure: optimization of the G / S ratio according to the subsidence

4.2 Influence of limestone filler on the fluidity of concrete

The Abrams cone spreading test is most commonly used to characterize concrete on site. It makes it possible to measure the consistency of a concrete which is a quantity which serves to characterize the aptitude for its implementation. The test was carried out in accordance with the requirements of standard NF EN 12350-8 using the Abrams cone.

4.3 The different formulations

We keep the ratio G / S constant equal to 1.2. The other components will also remain unchanged to highlight the influence of the addition of limestone filler. The cement will be dosed at 400 kg.m^{-3}, the superplasticizer will be equivalent to 3% of the volume of cement and we add a volume of mixing water of the order of 400 kg.m^{-3} of concrete. The addition of limestone filler will be for the different formulations BAP1, BAP2, BAP3 and BAP4 respectively equal to 10%, 15%, 25%, 30% and 45% of the volume of cement.

Table-6: Table: Abrams cone spreading test results

Formulations	BAP1	BAP2	BAP3	BAP4
Percentage of limestone filler addition	10	15	30	45
Spreading [cm]	598	663	721	719

4.4 Compressive strength

Table-7: Compressive strenght

Samples	Percentage of limestone fines [%]	Duration [days]	Compressive strength [MPa]
BAP1	10	1	7
		7	31
		28	38
		90	42
BAP2	15	1	8
		7	36
		28	42
		90	43
BAP3	30	1	13
		7	33
		28	42
		90	48
BAP4	45	1	7
		7	27
		28	44
		90	47

We present in the table above the influence of the interaction of the addition of limestone filler on the behavior of the resistance of the different concrete formulations.

First of all, it should be noted that at 28 days the test pieces reached the safety limit according to standard NF EN 206-1. The maximum strengths are observed in the mortars which have a 30% substitution of the volume of cement which reaches 48 MPa. The evolution of the compressive strength is increasing as a function of the addition of limestone fillers up to a threshold of nearly 30%, which can be explained by the effect of the fillers which makes it possible to improve the density of the general matrix, more specifically the paste-aggregate transition zone [Lawrence, 2000]. These results are consistent with the work of [Topçu, 2003], [Felekoglu; 2007] and [Michel; 2007].

However, the compressive strength could decrease by increasing the rate of fillers when the mixing water is not sufficient because the hydration of the cement caused by the fineness of the fillers absorbs water.

5. CONCLUSION

The manufacture of self-compacting concrete (BAP) requires a volume of mineral addition so as to increase the volume of dough thus achieving the fluidity that is the specificity of this new generation of concrete. The limestone filler by its great availability is a predominant addition.

The characterization of limestone fillers is a preponderant stage when it is desired to study the relationships between their physicochemical properties and the flow properties of a fresh cementitious matrix.

It is clearly shown that fineness greatly improves the flow of concrete.

A robustness study has further shown that by varying the volume of calcareous filler, the compressive strength of self-compacting concretes gradually varies and it reaches a sufficient strength to ensure the safety of the structure. However, we observe a saturating effect of limestone additions for an addition of the order of 100 kg.m^{-3}.

Despite the importance of these properties in understanding the fresh and hardened behaviors of self-compacting concrete, the analysis showed that the majority of the studies that deal with self-compacting concrete incorporating a calcareous filler are essentially concerned only with properties of the concrete. The physico-chemical properties of the filler used is only very little studied. Thus, the filler seems well integrated in the formulation and it becomes a secondary component not taken into account in the analysis of the observed properties of the concrete. The effectiveness of the superplasticizer will depend on the composition properties of the fillers, related to the presence of impurities such as clays in particular.

It is therefore wise to ask the question in the context of this research if all limestone fillers, also conform to the standard that is proper (NF P18-508) can they enter the formulation of a self-compacting concrete?

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