DETERMINATION OF WATER DEMAND OF DREDGED SEDIMENT IN CONCRETE FORMULATIONS

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ABSTRACT

In mix design of concrete, in addition to effective water that interacts with the cement, we often add a quantity of water equivalent to aggregates absorption used in the mixes. This added water will fill the inter-granular pores, it is not supposed to interact with the cement, or influence the concrete properties. Hence, apart from the granular skeleton compactness and the volume fraction of the aggregates in the mixture is the water to cement ratio, which will influence the workability of the fresh concrete and the mechanical strength.

The absorption of coarse aggregates and sands (≥63 µm) is obtained by the standard EN 1097-6. However, there is no method currently; used to measure the need for water for the fine fraction ≤63 µm, neglect of this fraction may greatly affect the workability of fresh concrete in some cases. Dredged sediments in particular have a fine particle size and the fraction smaller than 63 µm exceed the 50%.

This work aims to compare different tests proposed to estimate water demand of fine dredged sediments. With the proposed method, the results show that the amount of added water has allowed to correctly predict the concrete consistency class in comparison to the reference mix design (without fine sediments). It’s also to note that in addition to consistency, the strength obtained after 28 days of curing was also comparable.

Keywords: Alternative Materials-Water Demand-Mortar-Formulation.

INTRODUCTION

The estimation of the hidden water in the aggregates is the most difficult parameter to master in the formulations. According Aïtcin and Mindess [1], a 2% variation in the free water content in the aggregates, present a water variation of 10% of the total water mixing in 1m3 of concrete. This hidden water called saturated surface dry condition (SSD in America and SSS in Europe). This state is defined in the standard (EN 1097-6) for gravels and sands (4mm≤D≤0.063mm). However there is no way at present to measure the water consumed by the fine fraction (≤63 µm), knowing that the approach is clearly incomplete if we neglect this ubiquitous fraction in formulations, especially when using alternative materials. It is clear that, not taking into consideration this amount of water in the formulations may strongly affect the rheology of concrete in some cases because of the cohesion between the fine particles.

Face to the theoretical difficulty with the presence of fines, and the inability to present to measure the absorption and adsorption granular separately for this slice. The aim of this work is propose à test that allows in real formulation conditions to measure the total water (adsorption and absorption) for fine particles, this water is needed to ensure good concrete rheology. In same principle, this mesure is also suitable for sand-fine mixtures with Dmax≤ 1mm.

In the geotechnical domain, this state of saturation that allows the passage of the behavior of a material less than 400 µm, of a solid state to a liquid state, is the liquid limit of 25 drops per the Casagrande apparatus (NF P 94-051) and 17 mm at Fall cone (NF P 94-052-1). However, in formulations for the fine fraction, water demand (total water) slightly larger than the liquid limit is necessary to ensure a liquid material behavior, this state of saturation is defined as the normal consistency in direction of the standard (EN 196-3) corresponding to 6mm by the Vicat apparatus.

This work therefore aims to determine the normal consistency for alternative materials and formulate mortars by substituting a part of standard sand by alternative materials, with the addition of the absorption water for incorporated alternative material, obtained for normal consistency state, by the Vicat apparatus.

MATERIELS AND METHODES

The Vicat apparatus (Figure 1) is used at the base to measure the water content that allows to obtain a cement paste. This test inspired other researchers [2], [3] to measure the compactness of the powders, where water does not play the same role as the air in a dry stacking, because its presence modifies the surface forces that are dominant for fine particles. In this context, we have proposed using the concept of normal consistency pulp as described in the standard EN 196-3 to replace the demand water test, affected by the subjectivity the operator. Water demand in this case corresponds to the amount of water needed for the needle of Vicat, for reach 6 mm from the bottom of the mold containing the dough.

The amount of water necessary for obtaining a height of 6 mm (normal consistency) per the Vicat apparatus can be obtained by successive trials. To limit the number of tests, it is possible to deduced with interpolation from two points flanking the normal consistency.

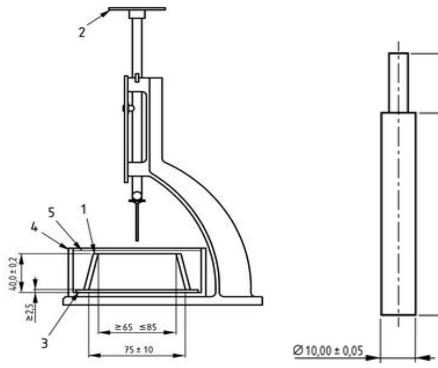

Figure 1: Vicat apparatus (Left) and the needle (Right) for the determination of the normal consistency (NF EN 196-3+A1).

Caption: 1) Mould, 2) additional weight tray, 3) Base plate, 4) Container, 5) Water.

Used materials

In addition to cement 52.5 N, two materials are used in this study; these materials are marine sediment (sediments of Dunkerque) ans river sediment (sediments of Deûle) and foundry sand crushed to 1000 microns. The gradation (Figure 2) as well as the characterization carried out on these materials shows that they have all a fairly high percentage of fines (less than 63 µm), however they is different in nature as shown in Table 1.

Table 1 : Results of characterization of materials studied.

Materials	d≤63µm (%)	Ps (g/cm³)	VBS (g/100g)	Ss (m^2/gr)	MO (%)
Ciment 52,5 N	99	3.21	/	0.36	/
Foundry sand	70	2.67	1.53	6.25	5.64
Sed. Dunkerque	64	2.48	2.90	10.68	10.2
Sed. Deule	23	2.53	0.53	3.62	7.80

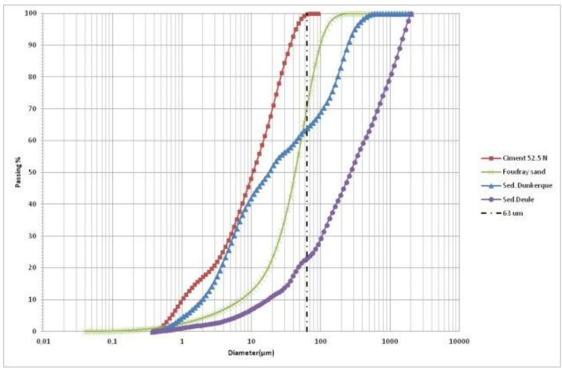

Figure 2: Grading curves for materials studied.

RESULTS AND DISCUSSION

The following table summarizes the results of the Vicat apparatus, for different materials Study.

Table 2: The water content at the normal consistency for the different study materials, obtained by the apparatus of Vicat.

Matériaux	Water content at the normal consistency(%)
Norme	NF EN 196-3
Ciment 52,5 N	28
Foundry sand	25
Sed. Dunkerque	47
Sed. Deule	38

These results confirm that the demand for water to reach the same state of consistency varies like the Atterberg limits, according to the nature of materials , ie the particle size and organic matter content, this conclusion concord with the works of [4]and [5] .

The Figure 3 shows the consistency curve obtained by the Vicat apparatus on the cement 52.5N.

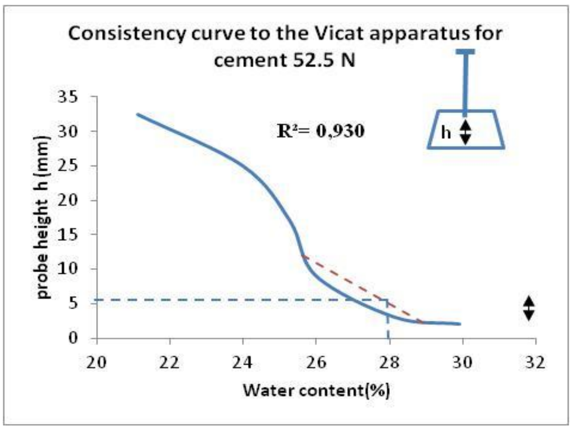

Figure 3: The consistency curve for cement 52.5 N.

Figure 3, allows you to see the shape of the curve obtained by the Vicat apparatus, with a significant correlation between the water content and the penetration of the probe with a $R^2 = 0.93$. Indeed, the probe of the device is sensitive to the water content of the material by the amount of mobilized material. However, it is noted that the test is relatively difficult to achieve and there is no possibility measure beyond the normal consistency (h≤6mm) because the probe touches the bottom of the mold, this prevent to study consistency states beyond the normal consistency, hence the need to focus our future research on device with a better repeatability and more ease in measuring the normal consistency.

In the validation step, it is appropriate to study the influence of using these materials in this normal consistence state obtained by the Vicat apparatus, in the formulation of mortars by the proceed as follow; we have achieved a standard mortar (Standard Sand, Cement 52.5 and tap water) as control sample and the mortars where the standard sand is substituted with foundry sand (Mortar 1), by sediments Deule (Mortar 2) and sediments of Dunkerque (Mortar 3).

The substitution percentages are selected based on the compactness of the mixture (normalized Sand / alternative material). 20%, 30% and 15% correspond to the percentage of substitution CEN sand from foundry sand, sediment Deule and sediment Dunkerque are retained, respectively ensuring the compactness of 0,690 and 0,650 and 0,642 relatively close the compactness of the standardized sand only (C = 0,657), this approach is advocated to eliminate as much as possible the influence of compactness. According to some authors [6], [7], the compactness of the granular structure strongly influences the properties of fresh and hardened concrete. It is important to note that the compaction mode used for the experimental measurement of the compactness is the shock table, since it is the same compression mode that is used in the manufacture of mortar formulations. Table 3 summarizes the results of formulation.

Table 3: Mechanical characteristics of mortars formulated.

	Compactness	W/C	Wc (%)	Workability meter (s)	CS_{28} (MPa)	FS_{28} (MPa)
Control sample	0.657	0.5	/	8±1	46	9
Mortar 1	0.692	0.5	25	3±1	47.5	6.2
Mortar 2	0.650	0.5	39.5	4±1	26	4
Mortar 3	0.642	0.5	38	7±1	38.42	4.7

Where : Wc is water content at the normal consistency,W/C is water to ciment ratio,CS_{28} is Compressive strength at 28 days and FS_{28} is:Flexural strength at 28 days.

The first results relate to the workability of mortars formulated, where we clearly notice that the three mortars formulated are workable, as control sample with flow time workability equal 3 to 7 second. These results are mainly due to the amount of water estimated by the Vicat Apparatus to normal consistency, which is in our approach equal to water demand for alternative materials. Indeed this added water comprises a portion that will be absorbed by the porous aggregates optionally, and the remainder (free water) is going to be trapped at the surface of the aggregates by the capillary forces in relieve the surface tension between the grains and allowing and improved workability.

However this trapped water will added to effective water, and negatively influence on the mechanical properties of mortars as seen mainly for mortar 3 and 4 where we see compressive strength declines of 46 and 17%. These resistance falls are moderate in comparison with that recorded in previous work on river and marine sediments which are of the order of 50% compressive strength loss for river sediments [8] and 34% for marine sediments[9], for equivalent sand substitution percentages. This allows us to conclude that this approach does not solve the correction problem of water completely, because their presence is necessarily compromising, however this method allow to estimate the amount of water which ensures good workability with minimal loss of mechanical properties.

The results obtained for mortar 1, mechanical compressive strength and workability superior to the control sample, are due to the increase of the compactness of the aggregate skeleton by the incorporation of casting sand 20%, in addition to its content of moderate organic matter in contrast to sediments, indeed, according to the work of [3], organic matter is responsible for increasing the plasticity, the withdrawal, a large compressibility.

CONCLUSION

The objective of this study is to define the water demand of fine materials (≤63µm) or fine dominance (fine ≥25%) of Dmax≤1mm in the real conditions of formulation.

The proposed approach and confirmed by this work takes the normal consistency of a fine or fine dominance material, incorporated in a formulation as the optimal state of saturation which saves the loss of workability and minimizes the loss of compressive strength.

A strong correlation between the penetration of the probe of the Vicat apparatus and the water content of the materials studied was recorded and we confirmed by the results of mortars formulated with alternative materials, the reliability of the approach that consist to taking the normal consistency as the state of optimal saturation for alternative materials (fine or thin dominance) in the formulations of mortars, for maintaining the workability and loss minimum strength.

It will be interesting finally, to provide a similar device in the functioning that the Vicat apparatus but with more ease in the realization of test for measuring normal consistency, with better repeatability. Our future work will focus in this direction, on the Fall cone devise used in many geotechnical tests [4] and the rheological measurements of concretes [10].

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