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THE INFLUENCE OF BINDER MIXTURE ON THE PERFORMANCE OF HYDRAULIC MORTAR FOR BUILDING RENDERS

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Extended Abstract

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ABSTRACT: Nowadays it's frequently to use mixed mortars in which the binders are cement Portland and hydraulic lime for the execution of building renders. In a way, the composition of the mortars used in construction is executed in an empirical way without any scientific knowledge support having, also, confirmed in some cases several problems in the behavior of the wall renders done with these types of mortars. Furthermore, the actual scientific knowledge about this kind of mortars isn't enough and the develop work in this area is relatively scarce.

The primary objective of this investigation has been the understanding of the influence of specific binders such as cement Portland and hydraulic lime on the behavior of mixed mortars used in building renders. The main objective was to study and evaluate the behavior of the mixed mortars with different quantities of cement and hydraulic lime used in theirs compositions.

Therefore, in the beginning of this thesis it was studied two types of mortars with equal volumetric trace (1:3) and similar consistency formulated with cement and hydraulic lime. The water-binder ratio of the mortars prepared with cement and hydraulic lime was established in way to guarantee 65±1% of consistency. These two mortars were the jumping point for the formulation of twenty different kinds of mixed mortars in binder quantity and in water-binder ratio. The studied formulations were object of characterization in fresh and hardened states. The characterization in the fresh state was gotten through the determination of the consistency, the determination of the bulk density and the estimate of the air voids volume and the determination of water retention. The characterization in the hardened state was done with the help of several experiments at 28 days of age and it was elaborated, at a mechanical and physical level, in prismatic specimens and as wall renders layers applied in ceramic bricks.

This particularly investigation had for base other works of experimental nature and it went in the curse of fulfilling the void of knowledge about the proprieties of this hydraulic mortars specially in the matters of binders influences of its dosage and the water-binder ratio.

It had been, also, determined some direct relations between the cement quantity and some of the properties gotten thru the carried assays.

KEY-WORDS: Cement; hydraulic lime; mixed mortars; water-binder ratio; Influence of the dosage of binder

1. Introduction

Nowadays it's frequently to use mixed mortars in which the binders are cement Portland and hydraulic lime for the execution of building renders. In a way, the composition of the mortars used in construction is executed in an empirical way without any scientific knowledge support having, also, confirmed in some cases several problems in the behavior of the wall renders done with these types of mortars. Furthermore, the actual scientific knowledge about this kind of mortars isn't enough and the develop work in this area is relatively scarce.

This particularly investigation had for base other works of experimental nature and it went in the curse of fulfilling the void of knowledge about the proprieties of this hydraulic mortars specially in the matters of binders influences of its dosage and the water-binder ratio.

The main objectives of this study are to evaluate the hydraulic binder mixture on the behavior of mortars in terms of its characteristics in fresh and hardened stages, in order to its application on buildings plasters and also to evaluate the components proportions influence of in hydraulic mortars.

2. Experimental definition

2.1. Compositions definition

For the experimental campaign 2 different kind of sand were used with which 22 types of mortars were prepared. The grain size curve of the used sands is presented as follow, Fig. 1.

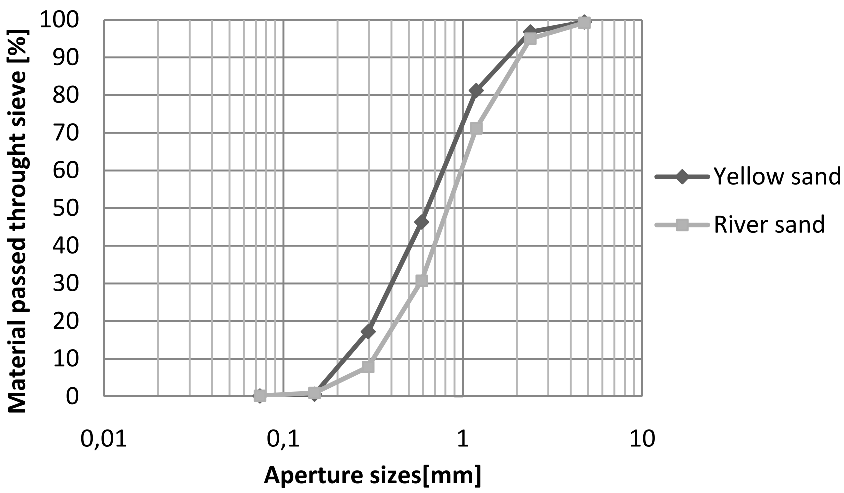


Fig. 1 – Aggregate grain size distributions

Table 1 –Dmax, Dmin, Fineness modulus and voids volume

Sands	Max. Particle size, $D_{máx}$	Min. Particle size, D_{min}	Fineness modulus	Voids volume (%)
River sand - A1	2,38 mm	0,149 mm	2,6	36
Yellow sand - A2			3	

It must be referred that the aggregates used through all mortars production have been dried to constant mass, being then placed at rest till reaching ambient temperature. This procedure intends to reduce the influence of the aggregate's moisture in the mixture.

Comparing the two types of mortars (see Table 1), the particle size are the same as well as their voids volume distinguishing only in the fineness modulus matter. Therefore, although similar particles size the yellow sand is a little thicker than the river sand implying in a larger specific surface. Larger specific surface, bigger the water amount it's needed.

Concerning the binder-aggregate ratio, it has been adopted a volume ratio of 1:3. It is intended that the produced mortars are as close as possible to the actually used at construction sites in what concerns workability. This investigation was divided in three stages with different purposes in each one. The sand was composed by 50% of A1 and 50% of A2.

The influence of the mixture binder on the mortars behavior was based on 22 formulations of mortars, of which 2 are the reference mortars (A.CH and B.Cim), 10 are defined based on A. CH as base composition and the remaining 10 formulations studied have been established with B.Cim as reference, Table 2.

Table 2 – Definition of analyzed compositions

Mortar	Weight proportion				Water/binder ratio	Flow value [%]
	HL	Cem	A1	A2		
A.CH	1	0	2,2	2,3	0,82	64
B.Cim	0	1	2	2,1	0,60	66
A.CH.1	0,9	0,1				69
A.CH.2	0,75	0,25				83
A.CH.3	0,5	0,5	2,2	2,3	0,82	94
A.CH.4	0,25	0,75	(4,5)			102
A.CH.Cim	0	1				122
B.Cim.1	0,1	0,9				65
B.Cim.2	0,25	0,75				55
B.Cim.3	0,5	0,5	2	2,1	0,60	36
B.Cim.4	0,75	0,25	(4,1)			34
B.Cim.CH	1	0				36
A.65.1	0,9	0,1			0,81	64
A.65.2	0,75	0,25			0,78	65
A.65.3	0,5	0,5	2,2	2,3	0,75	66
A.65.4	0,25	0,75	(4,5)		0,73	64
A.65.Cim	0	1			0,66	65
B.65.1	0,1	0,9			0,60	65
B.65.2	0,25	0,75			0,62	65
B.65.3	0,5	0,5	2	2,1	0,66	65
B.65.4	0,75	0,25	(4,1)		0,71	66
B.65.CH	1	0			0,77	66

The influence of dash in mortars of hydraulic binder was supported on the analysis of the characteristics of 12 formulations of mortars with the same consistency (65±1%), of which 2 are the reference mortars, 5 were defined based on A. CH and the other with B. Cim as a starting point.

All binder mixtures in the formulation of mortars studied were done with cement Portland CEM II/B-L 32,5 N and hydraulic lime NHL5. These mixtures have been established having as starting point the reference mortars, a single binder mortar, in which, they represent both the 100% of cement (B. Cim) or hydraulic lime (A. CH) and 0% of cement (A .CH) or hydraulic lime (B. Cim).

The water dosage, adopted in the different formulations studied, was defined to allow the analysis of mortars with the same water/binder ratio as their mortar of reference and with the same consistency (corresponding to a flow value of 65±1%).

A total of 132 prismatic samples (40x40x160mm), 44 eight-hole ceramic bricks (coated with mortar on one side) were prepared in order to test them using the methods described below after curing times of 28 days.

All the types of test samples being studied were kept in wet cure conditions since it casting until the dates of test, inside a chamber room at a 20±2ºC temperature and a 95±5% relative humidity.

2.2. Tests performed

The following tests were carried out.

Fresh mortar characterization tests

Consistence by flow table, bulk density, estimate of voids volume and water retentivity.

Hardened mortar characterization tests

Mechanical tests: ultrasound propagation, flexural and compressive strength, rebound hammer and pull-off.

Physical tests: water suction by capillarity, water absorption by immersion (after 48h), porosity accessible to water, bulk and real density, wetting-drying and water-absorption under low pressure.

3. Tests and results

Considering the whole data obtained in the mentioned tests, those results were considered of major importance for this study are presented below.

3.1. Fresh mortar tests

Mortars mixtures were prepared based in EN 196-1:1990. Bulk density and estimated volume of voids and retained water of fresh mortars were determined accordingly with EN 1015-6:1999 and EN 1015-8:1999, respectively.

The study began with the determination of water/binder ratio needed to obtain a flow value of 65±1% of the reference mortars, A.CH and B.Cim. The water binder ratio that was idealized to the two mortars were 0,82 to the hydraulic lime mortar (A.CH) and 0,60 to the cement mortar (B.Cim). Viewing Fig. 2 it can be concluded that when the cement content increases the flow value also increase. According with Fig. 3, the opposite is observed, with the raise of the cement content the water/binder ratio decreases.

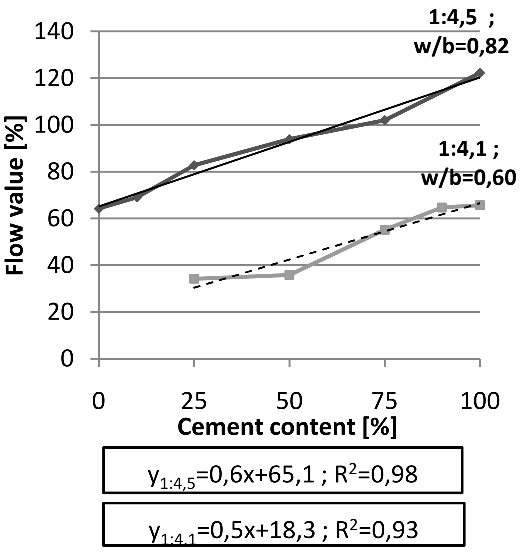


Fig. 2 – Relationship between flow value and cement content

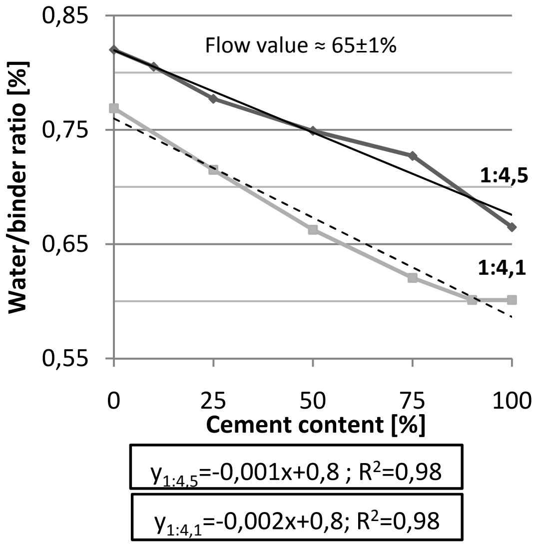


Fig. 3 - Relationship between water/binder ratio and cement content

In matters of bulk density results it was shown that hydraulic lime mortars result is higher than the cement mortar.

The voids volume test shows that cement mortar presents a higher value when compared with the hydraulic lime mortar, about 8% difference. It appears that the mortars with high flow value present low voids volume when containing high cement content. Presenting the mortars in normal consistency, 65±1%, the results obtained are more consistent reaching the conclusion that higher cement content higher the voids volume.

Referring to the water retentivity test, it was concluded that mortars with higher hydraulic lime retain more water than mortars with higher cement content. According to the mortars, high cement content implies low water retentivity value (WRV).

3.2. Hardened mortar tests

3.2.1. Physical characterization

Tests of porosity accessible to water, bulk and real density were carried out on 2 specimens for each mortar. These results are important to this study because the porosity of the several mortars it's the key explanation for many of the characteristics and behavior of the test samples.

In matters of porosity accessible it was noticed porosity decreases with the raise of the cement content of the mortars, Fig. 4 and Fig. 5. This was also observed in the real density analysis. The opposite was encountered in the bulk density analysis that when compared with the real density appears to be contrary behavior.

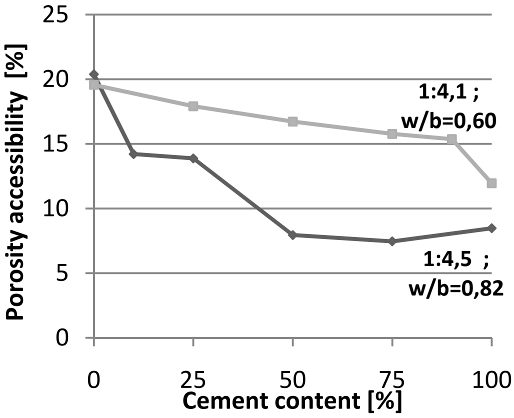


Fig. 4 - Relationship between porosity accessible and cement content on mortars with defined w/b

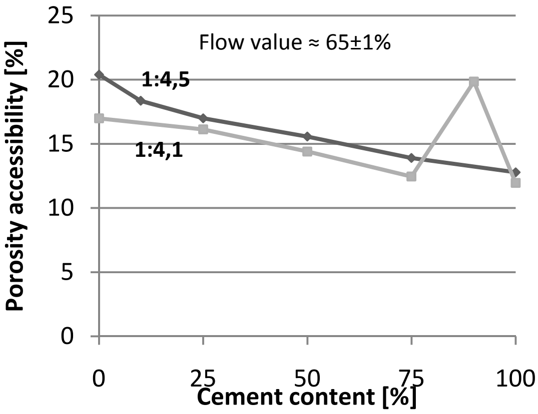


Fig. 5 - Relationship between porosity accessible and cement content on mortars with flow value of 65±1%

The water suction by capillarity was evaluated on one specimen of each mortar and it was determined the capillarity coefficient that portrays the initial absorption speed and the asymptotic absorption that value the total amount of water absorbed.

In this test was verified the high aptitude of lime in terms of water absorption. Despising the results obtained on mortars with dash of 1:4,5, it can be establish that higher cement content of the mortar implies low water absorption capability has it can be seen in Fig. 6 and Fig. 7.

For the water absorption by immersion at 48h, T_{48h}, the results were carried out on one specimen for each mortar and based on LNEC E394 specification. The same conclusion of the previous test can be transcribed here, Fig. 8 and Fig. 9.

The wetting-drying test was evaluated on 2 fragments of each mortar. The specimens were allowed to dry at 23±4ºC and 55±20% relative humidity and were periodical weight in order to obtain the drying curve that plots the moisture content in material versus time. Mortars with high cement content take more time to dry, this was the general conclusion reached by the development of this test, Fig. 10 and Fig. 11.

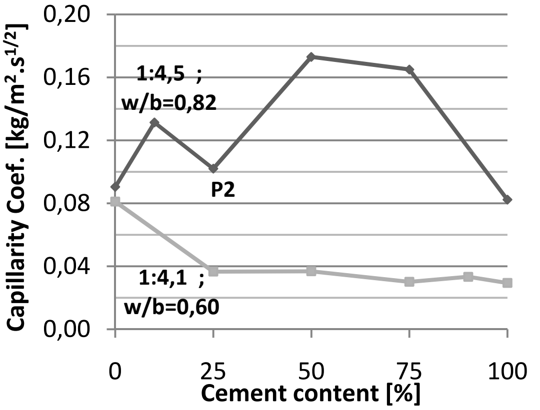


Fig. 6 - Relationship between capillarity coefficient and cement content on mortars with defined w/b

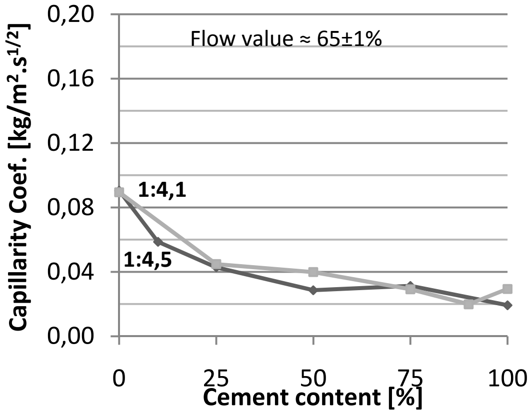


Fig. 7 - Relationship between capillarity coefficient and cement content on mortars with flow value of 65±1%

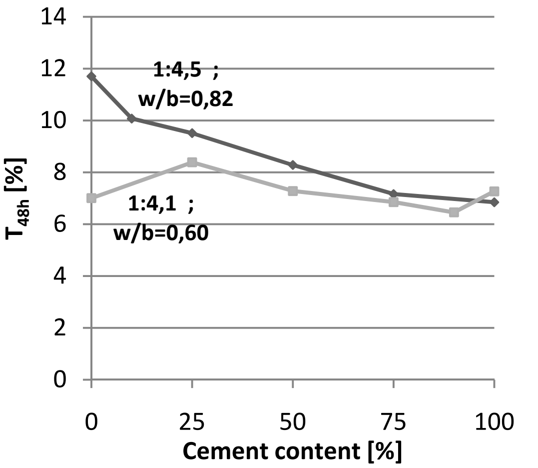


Fig. 8 - Relationship between absorption by immersion and cement content on mortars with defined w/b

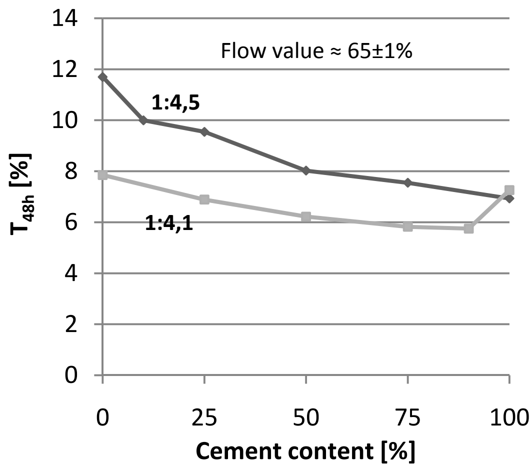


Fig. 9 - Relationship between absorption by immersion and cement content on mortars with flow value of 65±1%

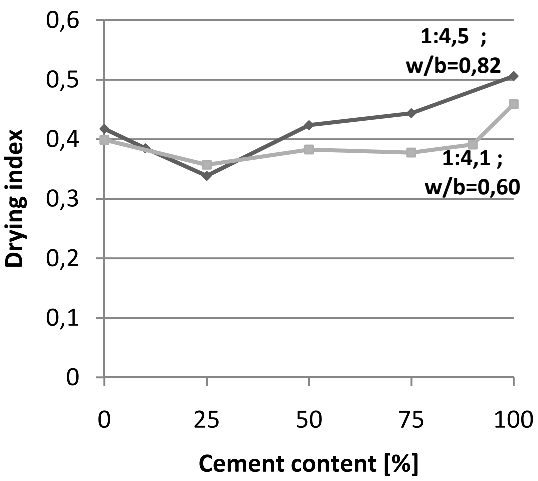


Fig. 10 - Relationship between drying index and cement content on mortars with defined w/b

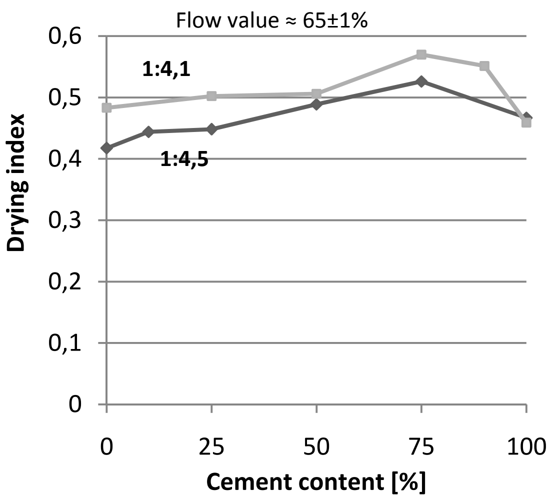


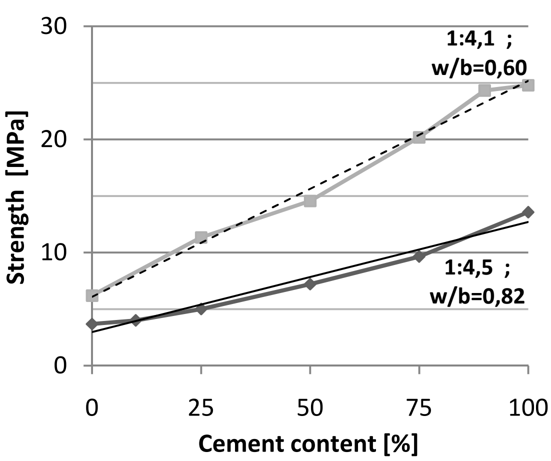
Fig. 11 - Relationship between drying index and cement content on mortars with flow value of 65±1%

3.2.2. Mechanical characterization

Tests of flexural strengths were carried out on 5 specimens for each mortar. Compressive strength tests were performed on 6 fragments of each specimen resulted from the flexural test.

In Fig. 12 and Fig. 13 it's visible that compressive strength is related with cement content. The higher the cement content gets, the higher compressive strength will be. This can also be verified in the flexural test.

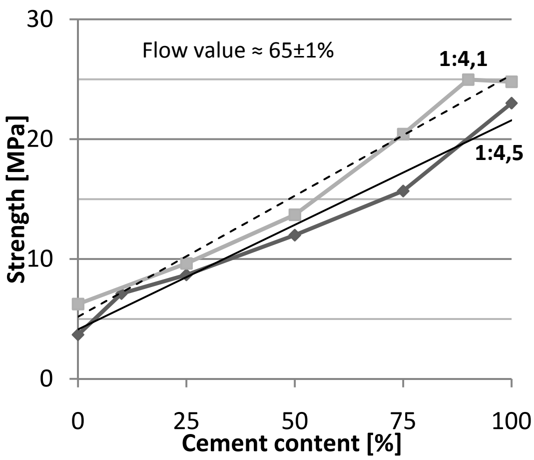
The velocity of ultrasound was measured with the same purpose on all prismatic specimens that were used for the flexural test. The measurements of the propagation velocity of longitudinal ultrasonic waves performed in transmission mode with cylindrical transducers.



$y_{1:4,5}$=0,097x+2,97 ; R^2=0,97

$y_{1:4,1}$=0,191x+6,08 ; R^2=0,99

Fig. 12 - Relationship between compressive strength and cement content on mortars with defined w/b



$y_{1:4,5}$=0,175x+4,13 ; R^2=0,97

$y_{1:4,1}$=0,202x+5,19 ; R^2=0,98

Fig. 13 - Relationship between compressive strength and cement content on mortars with flow value of 65±1%

Also it manifests the relationship of the ultrasound and the other two tests in the way that the higher the velocity of the ultrasonic waves the higher will be the value of the flexure and compressive test, Fig. 14 and Fig. 15.

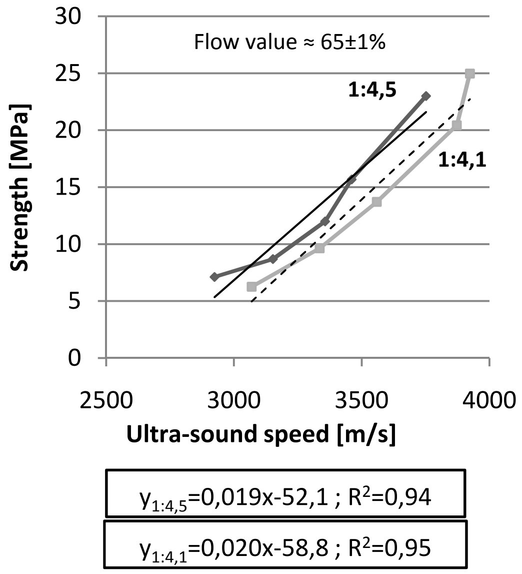


Fig. 14 - Relationship between compressive strength and ultra-sound speed on mortars with flow value of 65±1%

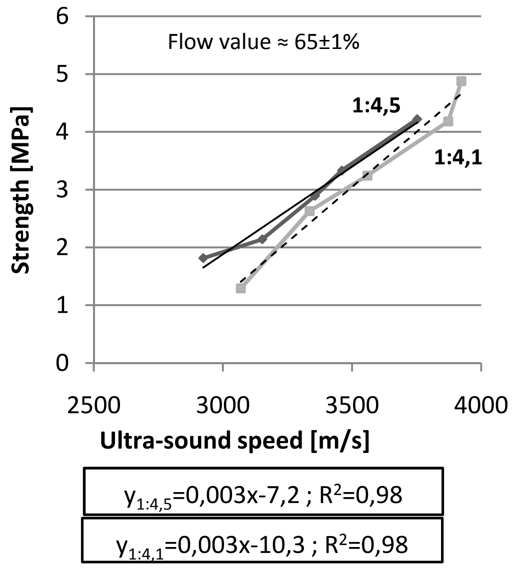


Fig. 15 - Relationship between flexural strength and ultra-sound speed on mortars with flow value of 65±1%

3.2.3. In situ tests

The water absorption test was performed in order to establish the permeability capacity of the render. With the results obtained by this test is very perceptive the influence that cement content has in the mortar permeability. The higher the cement content lower will be the water absorption, Fig. 16 and Fig. 17.

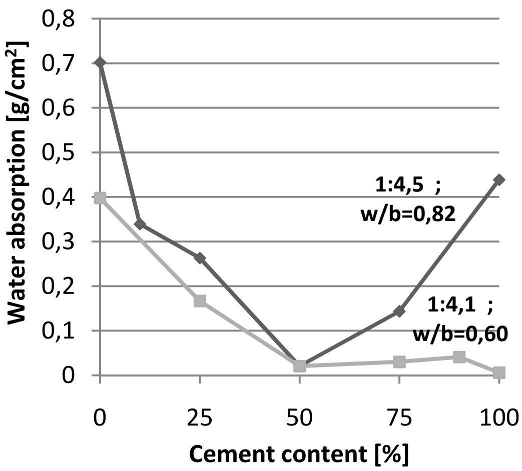


Fig. 16 - Relationship between water absorption and cement content on mortars with defined w/b

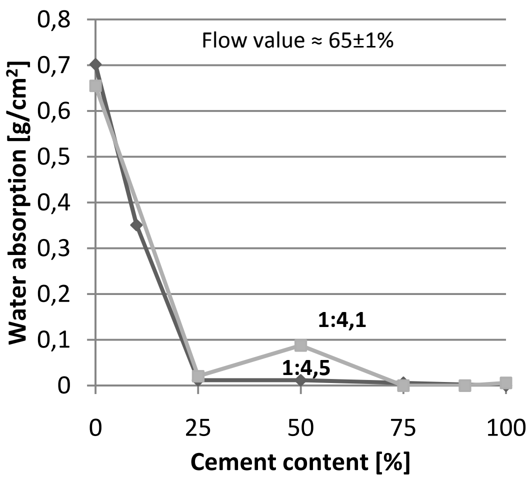


Fig. 17 - Relationship between water absorption and cement content on mortars with flow value of 65±1%

The rebound hammer test was carried out in order to evaluate the mechanical strength of mortars applied as renders. It is intended to check the uniformity of the mortar layer by measuring the rebound of the incident mass after an impact. Strong mortars produce greater rebound.

In figs its visible that mortars with high rebound results have higher compressive strength. Therefore this test is a truthful way of obtain compressive strength, qualitatively.

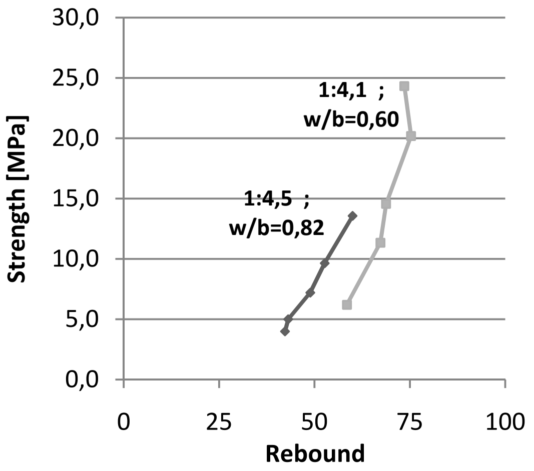


Fig. 18 - Relationship between compressive strength and rebound on mortars with defined w/b

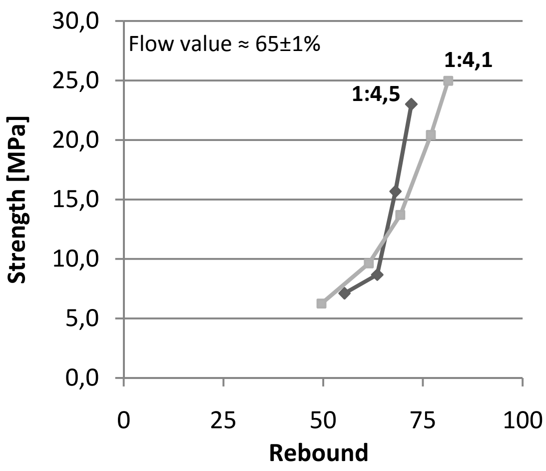


Fig. 19 - Relationship between compressive strength and rebound on mortars with flow value of 65±1%

The pull-off test was intended to evaluate the mortar/substrate adhesive strength and it was performed three pull-off tests on each brick. The relationship between the strength and the cement content is already expected therefore these results come only to confirm that the greater cement content in the mortar the greater will be it strength.

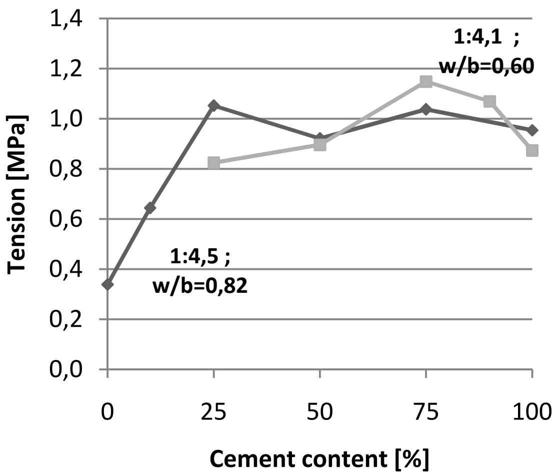


Fig. 20 - Relationship between adhesive strength and rebound on mortars with defined w/b

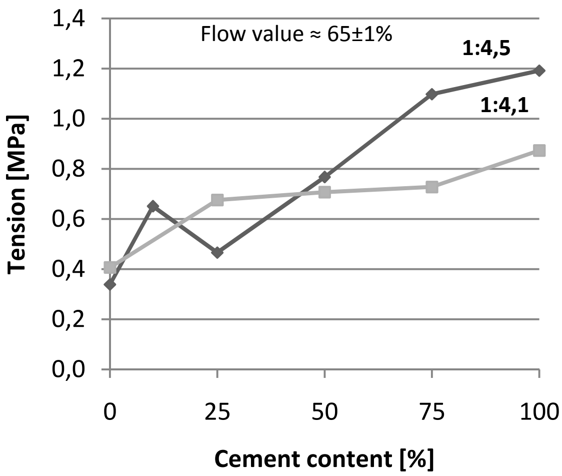


Fig. 21 - Relationship between adhesive strength and rebound on mortars with flow value of 65±1%

4. Conclusions

This study is a contribution to the general knowledge about the influence of binder content on the behavior of hydraulic renders. For this 22 types of mortars were elaborated and characterized in the fresh and hardened stages, through a large number of tests performed at 28 days of age. The variables in the analysis performed are the mixed content of binders and the amount of mixing water. Of these 22 only 4 mortars are simple, in other words, mortars with a single binder. For all mortars were adopted a volumetric proportion of 1:3 that is usually used in construction. The mortars of mixed binders are the result of some careful combination weight proportions adopted to better analyze the behavior of these changes in the levels of binder.

A fact which has occurred and that it was expected was that a cement mortar requires less mixing water than a hydraulic lime mortar to obtain the same consistency. This was more obvious when it was noted that, as it was altering the levels of hydraulic lime content and replacing with cement, it became increasingly more fluid. And when was altered the cement content in the mortar for hydraulic lime content it showed up progressively more dry, maintaining the water/binder ratio.

In this work it was noticed that the fresh characteristics of mortars are different then the characteristics in hardened state regarding to the test results to determine the density and air voids.

The hydraulic lime mortar is the one that needs greater amount of mixing water but is also the one that holds the most, which was reflected in the water retention test.

It was showed clearly the influence of cement in the mortar as the smallest percentage of this binder present on its constitution takes larger influence in the water absorption. The higher the cement content the lower the amount of water absorbed by the mortar.

Other conclusion stated was that greater cement content improves the superficial strength and adhesive strength to the support. However the permeability of the render is highly affected resulting in almost totally impermeable renders which is an important aspect to have in consideration.

References

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