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EN 1015-11 and EN 1015-12: Proposal to update procedures for lime products

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ABSTRACT: The compressive and flexural strengths of mortars and the adhesive strength of the material to a substrate are important properties. Several parameters, like the curing conditions, the type of substrate (concrete or clay brick) and proposed adjustments to the European Standards have been investigated using a variety of different procedures for testing mortar in order to improve the reliability and the reproducibility of the methods. The results obtained are particularly interesting for lime based products, that often do not give realistic results when using the standard procedures described in EN 1015-11 [1] and EN 1015-12 [2]. In this paper, the performances of lime based products have been compared to those made using cement.

Keywords: compressive strength, adhesive strength, lime based products, realistic performances

1 INTRODUCTION

The study has been focused on EN 1015-11:2007 “Methods of test for mortar for masonry. Part 11 - Determination of flexural and compressive strength of hardened mortars” [1] and EN 1015-12:2002 “Methods of test for mortar for masonry. Part 12 - Determination of adhesive strength of hardened rendering and plastering mortars on substrates” [2]. The goals are to ensure realistic performances of compressive, flexural and adhesive properties with lime based mortars through improvements to the European Standards.

2 EN 1015-11 [1] AND EN 1015-12 [2] - REVIEW

2.1. EN 1015-11 [1] Overall review

The EN 1015-11 [1] review has been undertaken in order to widen, improve and simplify the method currently in use. These changes have been discussed at EULA (European Lime Association) and at

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TC51 WG11, where it was recommended that a simple method applicable to many products, based on cement and lime be developed so that realistic outcomes result.

Even if the procedures are really effective for cement based products, air-lime and hydraulic lime materials show low values and un-realistic performances by using the method currently in use. This is probably due to the curing conditions, not being relevant for lime products. Figure 1 shows poor effects which commonly affected lime based products.
Moreover, air-cured lime based products often show hydraulic shrinkage, that can influence the mechanical properties of the mortar. In this regard, EN 1015-11 [1] does not consider any correction to either the flexural or the compressive strength calculation.

Tests have been undertaken in four different laboratories, in order to evaluate the best working and curing conditions for air-lime and hydraulic-lime products. The goal was to obtain a highly effective method, both for cement based mortars and lime based products.
Several products have been studied under different curing conditions (humidity and temperature), and both their mechanical performances and their hydraulic shrinkage have been evaluated. Another important issue is working at the same conditioning temperature. Currently some who are testing to the EN work at 20 ± 2°C while others use 22 ± 2°C. In this programme tests were undertaken at between 18°C and 25°C, in order to understand the influence of temperature. Principally in the summertime, the laboratory temperature can easily reach 20 ± 2°C, so the best solution is working at 21 ± 2°C: this correction does not influence the mechanical performances of the mortars.

Furthermore, a study both of the shrinkage and of the mechanical performances of lime mortars has been undertaken under different humidity conditions, described in Table 1, while a list of the curing conditions studied is in Table 2.

It is evident that lime products, when stored as described in EN 1015-11[1], do not achieve realistic strength values. With lime based products, reducing the storage humidity during the first 7 days, from 95% r.H. to 45% r.H., results in higher carbonation being obtained, but the shrinkage and the curling of the prisms are clearly worsened. The best compromise is reached working at 65% r.H. for the whole conditioning period, before and after demoulding. A study in a saturated CO2 environment has also been made, to evaluate any possible improvement on lime carbonation, but no significant effect has been detected. All the results are shown on Figure 2.

2.2. EN 1015-11[1] Section reviews

A list of the proposed corrections to EN 1015-11[1] follows. Each point discussed below corresponds with the similarly numbers chapter in the European Standard.

Point 7.2: a correction on the compactness method is proposed, in order to simplify and improve the performance for air-lime (above 50%) based mortars. For these the only efficient method is tilting and striking the mould several times. The mechanical resistance is not influenced by the method of compaction, and consequently, the same method should be extended to all the other mortar types. Another proposal concerns the use of gauze. This does not modify the test results nor does it result in any improvement, so the proposal is to remove the gauze use at least for air-lime/hydraulic-lime mortars.

Point 7.3: Curing temperature correction to avoid conditioning lime products at 18 °C, so reducing the impact of air-conditioning (costs and health). A simplified curing is proposed for air/hydraulic lime mortars. The mould shall be cured at (21 ± 2) °C and (65 ± 5) % of relative humidity all the time, without any polyethylene bags, removing the samples from the mould after 5 days. The proposed curing conditions, mentioned in Tables 3 and Table 4, permit one to obtain realistic mechanical performances for air/hydraulic lime mortars.

2.3. EN 1015-122: Review

The UNI Committee has already voted in favor of the EN 1015-12 [2] review for two different reasons:

- The vertical application of mortar on the support is currently the only permitted way to work but it is highly influenced by the ability of the worker. Results using this procedure are not reproducible and highly variable. The horizontal application of mortar is the best way to both avoid the influence of the worker, and also to make the test method easier. Moreover, the horizontal application of mortar is the way commonly used in several Italian and European laboratories, and it is recommended this be adopted.

- Concrete is the only substrate currently allowed in EN 1015-12 [2], but obviously clay brick is another type of support widely used in the building field. Hence, the EN should allow both the substrates, brick and concrete, offering clients the opportunity to make informed choices based on mortar type. Further, mortar and plasters often often crack, when applied on concrete, but do not show this effect, if applied on wet bricks. The UNI Committee, according to EULA TC51 WG11, agree that brick should be included in the procedure, as a standard support. The adhesion test on brick as a support is shown in Figure 4.

Round Robin tests organized across four different mortar producers have been undertaken in order to verify the issues previously described. The adhesion test has been evaluated by applying the mortar to 4 different bricks and on concrete blocks as well. Two different kinds of mortar have been used: a masonry mortar type M5 and a plaster mortar type GP CSII W0. The preparation of the samples was according to EN1015-12 [2] (20±2°C and 65±5% r.H.). Table 5 and Table 6 summarize the results.

The brick types chosen as substrate were analyzed prior to use. The values of salt content, water absorption and mechanical strength have been recorded in Figure 3. Moreover, the influence of brick wetness has also been studied by immersing the brick into water, then waiting for it to dry before the application of mortar. After 15 minutes of immersion (into the water) the brick absorbs 85% of its maximum water capacity. The best performances of adhesion can be reached by waiting 6 hours between the immersion into the water and the starting point of the test.

The Round Robin test has also clearly shown that using the horizontal application of the mortar, instead of the vertical one results in no significant differences on the pull-off values. Nevertheless, the right mortar thickness (10±1mm) is easily obtained (high reproducibility), with horizontal application, as shown on Figure 4, while thickness is influenced by worker ability using the vertical method. Consequently, it is recommended horizontal mortar application on the support should replace the vertical method, currently used in the EN 1015-12 [2].

2.4. EN 1015-12 [2] – Section reviews

As previously described for the Standard EN 1015-11 [1], the main sections in EN 1015-12 [2] which should be changed are:

Point 5.2: extension to aluminum plates. Currently only stainless steel plates are allowed in EN 1015-12 [2]. However, aluminum plates are easily available in the market, and are cheaper than stainless steel plates. The plate type does not modify the test result, so the aluminum plates should be introduced.

Point 5.6: this point has been described in the EN 1015-11 [1] review. The goal is to standardize the storage conditions, by having the same temperature in all the EN norms, and also to save money for the conditioning system.

Point 7.1: as described in the foreword, brick as a substrate should be added to the currently acceptable concrete.

Point 7.2: the application method is important to achieve high test reproducibility. In order to both reduce the influence of the worker, and to make the preparation of the sample easier, the horizontal application of mortar is recommended.

Point 7.4: see the proposal made on EN 1015-11 [1]. The aim here is to modify the curing conditions and to avoid the curing in polyethylene bags for air-lime and hydraulic-lime mortars, making an easier and more realistic test method.

2.5. Conclusions

The standards EN 1015-11:2007 “Methods of test for mortar for masonry. Part 11 - Determination of flexural and compressive strength of hardened mortars” [1] and EN 1015-12:2002 “Methods of test for mortar for masonry. Part 12 - Determination of adhesive strength of hardened rendering and plastering mortars on substrates” [2] are important methods for studying and developing building products. This paper has described issues which should be evaluated in the next review, in order to increase repeatability and reproducibility of the tests in particular for lime products.

Table 1. Humidity conditions evaluated

Before demuolding		After demoulding
40 % r.H. (20 ± 2)° C	5/7 days	+ 21/23 days 65 % r.H. (20 ± 2)° C
Saturated CO_2 (20 ± 2)° C	5/7 days	
95 % r.H. (20 ± 2)° C	5/7 days	

Table 2. Curing conditions for the applied tests and as given in the European Standard

	Temperature	R.H.	DAY	Temp	R.H.	DAY	note
Applied test conditions	20 ± 2 °C	40 ± 5 % CO2 95 ± 5 %	7	20 ± 2 °C	65 ± 5 %	21	
		40 ± 5 % CO2 95 ± 5 %	5				
	18 25 20 ± 2 °C	65 ± 5 %	7	20 ± 2 °C	65 ± 5 %	21	with and without gauze
	18	95 ± 5 %	5+2				with gauze
	20 ± 2 °C	in PE 65 ± 5 %	7	20 ± 2 °C	65 ± 5 %	21	on bricks
Proposed UNI EN 1015-11 [1]	21 ± 2 °C	in PE 65 ± 5 %	2+5 5	21 ± 2 °C	65 ± 5 %	21 23	with gauze, lime < 50% with gauze, lime > 50%
Proposed UNI EN 1015-12 [2]	21 ± 2 °C	in PE 65 ± 5 %	7	21 ± 2 °C	65 ± 5 %	21	lime < 50% lime > 50%
UNI EN 1015-11 [1]	20 ± 2 °C	95 ± 5 % o in PE	5+2	20 ± 2 °C	65 ± 5 %	21	with gauze
UNI EN 1015-12 [2]	20 ± 2 °C	in PE	7	20 ± 2 °C	65 ± 5 %	21	
UNI EN 196-1 [3]	20 ± 1 °C	> 90 %	1	20 ± 2 °C	> 50 %	27	
UNI EN 12004 [4] from UNI EN 1348 [5]	23 ± 2 °C	50 ± 5 %	27	23 ± 2 °C	50 ± 5 %	1	initial adhesion
UNI EN 1504-3 [6] from EN 12190 [7]	20 ± 1 °C	with PE	1+2	21 ± 2 °C	60 ± 10 %	25	PCC

Table 3. New proposal for Table 1 in EN 1015-11 [1]

Type of mortar	Preparation	Storage time at a temperature of (21 ± 2) °C		
		Relative humidity		
		Polyethylene bag		(65 ± 5)%
		In the mould	With the mould removed	With the mould removed
Cement and air-lime/cement mortars with mass of air-lime not exceeding 50% of the total binder mass	7.2.2	2	5	21
Mortar with hydraulic binders	7.2.2	2	5	21
Retarded mortars	7.2.2	5	2	21

Table 4. New proposal for Table 2 on EN 1015-11 [1]

Type of mortar	Preparation	Storage time at a temperature of (21 ± 2) °C Relative humidity (65 ± 5)%	
		In the mould	With the mould removed
Air-lime mortars	7.2.3	5	23
Air-lime/cement mortars with cement mass not exceeding 50% of the total binder mass	7.2.3	5	23

Table 5. Adhesion test results on lime-cement mortar M5

Company	Test	DANESI traditional		DANESI Poroton		STABILA traditional		STABILA Poroton	
		Cored at application	Cored at 28 days	Cored at application	Cored at 28 days	Cored at application	Cored at 28 days	Cored at application	Cored at 28 days
1°	Tensile strenght (MPa)	0.48	0.50	0.45	0.47	0.42	0.38	0.51	0.46
2°	Tensile strenght (Mpa)	0.43	0.27	0.52	0.41	0.36	0.27	0.50	0.44
3°	Tensile strenght (Mpa)	0.52	0.45	0.72	0.61	0.40	0.45	0.72	0.61

Table 6. Adhesion test results on a lime-cement plaster GP CSII W0

Company	Test	DANESI traditional		DANESI Poroton		STABILA traditional		STABILA Poroton	
		Cored at application	Cored at 28 days	Cored at application	Cored at 28 days	Cored at application	Cored at 28 days	Cored at application	Cored at 28 days
1°	Tensile strength (MPa)	0.48	0.50	0.45	0.47	0.42	0.38	0.51	0.46
2°	Tensile strength (Mpa)	0.43	0.27	0.52	0.41	0.36	0.27	0.50	0.44
3°	Tensile strength (Mpa)	0.52	0.45	0.72	0.61	0.40	0.45	0.72	0.61

	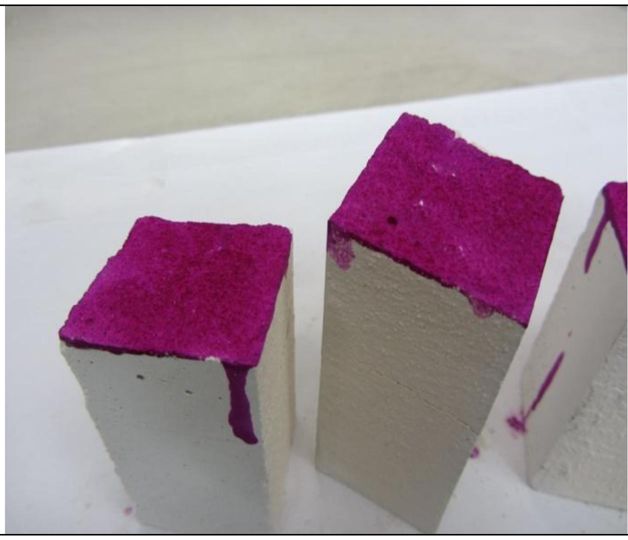
Shrinkage and curling effect on a lime based mortar	A lime based mortar after EN 1015-11 conditioning

Figure 1. Effects commonly evident on lime based products.

CURING CONDITIONS			SHRINKAGE (%)	CURLING (mm - at the middle)	YOUNG's MODULUS (MPa)	FLEXURAL STRENGHT (MPa)	COMPRESSION STRENGHT (MPa)	CARBONATION PICTURES	CURLING PICTURES
40% RH (20 ± 2)°C	5 days	+ 21 days 65% RH	22,71 ± 1,12	5,5 ± 0,7	5790,1 ± 586,9	3,53 ± 0,12	4,77 ± 0,22		
	7 days		22,66 ± 0,29	6,1 ± 0,2	6244,9 ± 209,6	3,8 ± 0,27	5,38 ± 0,84		
saturated CO_2 (20 ± 2)°C	5 days		17,25 ± 1,26	0,4 ± 0,5	4717,2 ± 150,6	2,5 ± 0,18	3,64 ± 0,23		
	7 days		16,13 ± 1,16	1,5 ± 0,5	4553,7 ± 58	2,6 ± 0,18	3,93 ± 0,36		
95% RH (20 ± 2)°C	5 days		17,07 ± 0,95	0,2 ± 0,2	4573 ± 192,5	2,31 ± 0,51	4,26 ± 0,24		
	7 days		16,13 ± 1,16	1,8 ± 0,7	4589,4 ± 108,9	2,45 ± 0,07	3,88 ± 0,16		

Figure 2. Results at different humidity conditions

		TRADITIONAL BRICK	POROTON BRICK	TRADITIONAL BRICK	POROTON BRICK
WATER ABSOPTION (%) EN 772-7		19,45	16,12	15,38	21,55
CONTENT OF SALTS (%)	% Na_2O	1,09	1,30	1,45	1,09
XRF	% K_2O	3,53	2,78	2,68	3,37
TENSILE STRENGHT (MPa) EN 1015-12		0,71 ± 0,14	1,48 ± 0,07	0,86 ± 0,04	1,39 ± 0,07
TENSILE STRENGHT PICTURE					

Figure 3. Brick characterisation.

Horizontal application on a brick

Adhesion test on a brick as support

Figure 4. Horizontal application of adhesive on brick

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REFERENCES

[1] EN 1015-11:2007 "Methods of test for mortar for masonry. Part 11 - Determination of flexural and compressive strength of hardened mortars"

[2] EN 1015-12:2002 "Methods of test for mortar for masonry. Part 12 - Determination of adhesive strength of hardened rendering and plastering mortars on substrates"

[3] EN 196-1:2005 “Methods of testing cement – Part 1: Determination of strength”

[4] EN 12004:2012 “Adhesives for tiles – Requirements, evaluation of conformity, classification and designation”

[5] EN 1348:2008 “Adhesives for tiles – Determination of tensile adhesion strength for cementitious adhesives”

[6] EN 1504-3:2006 “Products and systems for the protection and repair of concrete structures – Definitions, requirements, quality control and evaluation of conformity – Part 3: structural and not structural repair”

[7] EN 12190:2000 “Products and systems for the protection and repair of concrete structures – Test methods – Determination of compressive strength of repair mortar”