PRISMS STRENGTH BUILT WITH THIN JOINT POLYMERIC MORTAR COMPARED TO REGULAR MORTAR JOINT

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ABSTRACT

The need of rationalization of inputs and processes in civil construction has increased the levels of innovation, stimulating the creation of new methodologies in the masonry industry. The production of masonry is one of the main bottlenecks in the building system, and has been the target of several optimization initiatives. Accordingly, new mortars have emerged in the market with different properties, performance and characteristics in order to improve productivity. Among those are the polymeric-mortars. These mortars are known as "non-cement mortars" which have the great advantage of being supplied in packs "ready-to-use", without the need for adding water and mixing prior to their application.

The purpose of this study was to analyze and compare the compressive strength of several types of block prisms, built with polymeric mortar, with horizontal joint thickness ranging from 2 to 3 mm, and with traditional cement-lime mortar of 10-mm thickness. The blocks included in the study are: structural clay blocks, and two strengths of structural concrete blocks. The study evaluated the characteristic compressive strength, the elastic modulus and the type of rupture of each masonry type.

A statistical analysis was performed to compare the differences in the results found for each mortar type.

The thin-bed joint, non-cement, mortar prisms presented higher axial compression strength than that of regular mortar joint types. As for the elastic modulus result differences occur only for the higher strength blocks.
The study should be continued in order to analyze differences on actual walls specimens, which could present different results from what was observed in the prism behavior.

KEYWORDS: thin mortar, concrete block, compressive strength, elastic modulus

INTRODUCTION

The need of rationalization of inputs and processes in civil construction has increased the levels of innovation, stimulating the creation of new methodologies in the masonry industry. The production of masonry is one of the main bottlenecks in the building system, and has been the target of several optimization initiatives. Accordingly, new mortars have emerged in the market with different properties, performance and characteristics in order to improve productivity. Among those are the polymeric-mortar types. These mortars are known as “non-cement mortars” which have the great advantage of being supplied in packs "ready-to-use", without the need for adding water and mixing prior to their application.

In the last years several polymeric mortars started to be marketed in local Brazilian masonry industry. These mortars are usually bedded without the need to add water and result in joint thicknesses of 2 to 3 mm.

The thickness of the mortar bedding joints is a key factor influencing masonry strength influencing. The usual thickness in regular mortar construction is 10-mm. Camacho (1995) reports studies on concrete blocks prisms were the compression strength was reduced 11% when the bedding joint thickness was increased from 6 to 10 mm, and a reduction of 52% when the thickness was of 20 mm. Then it is common knowledge that the smaller the joint thickness, the higher is the prism strength of non-grouted masonry.

Mohamad (1998) indicate increases of 34% resistance in results of smaller thicknesses prisms when compared with test results of prism thicknesses of 7 and 10 mm joints. The test results are shown in the table below

Table 1 - Influence of joint thickness on prism strength, MOHAMAD (1998).

Mortar Compressive Strength (Mpa)	**Block Compressive Strength (Mpa)**	**Joints thickness (mm)**	**Prisms Compressive Strength (Mpa)**	**Prism / block strenght ratio**
4.9	15.7	7.0	11.7	0.75
5.4		10.0	8.8	0.50

According to ABNT NBR 15961-2: 2011 horizontal mortar joints should have a thickness of 10 mm.

Controversially sometimes the higher prism strength will not lead to higher-compression strength masonry for very thin mortar joint (equal or less than 3 mm). Eurocode 6 EN 1996-1-1 indicates a considerably reduction on masonry strength for mortar joints of 3-mm or less, even though the prism strength of this masonry type can be higher that the strength of the same masonry type with a 10-mm joint.

OBJECTIVE

The purpose of these tests was to evaluate the strength of hollow clay and concrete block prisms built with a polymeric mortar (marketed with the name of DunDun) with a very thin joint when compared with prisms built with regular cement-lime mortar of 10-mm thickness.

METHODOLOGY

This paper presents the experimental results of a series of prisms tests built with structural clay blocks, and two strengths of structural concrete blocks with two types of mortar: a 2 to 3-mm thick polymeric mortar joint and the regular 10-mm cement-lime joint. All prisms were 2-block high. Full-bedded mortar was used in the regular-mortar prims but only face-shell mortar was used for the thin polymeric mortar (Figure 1).

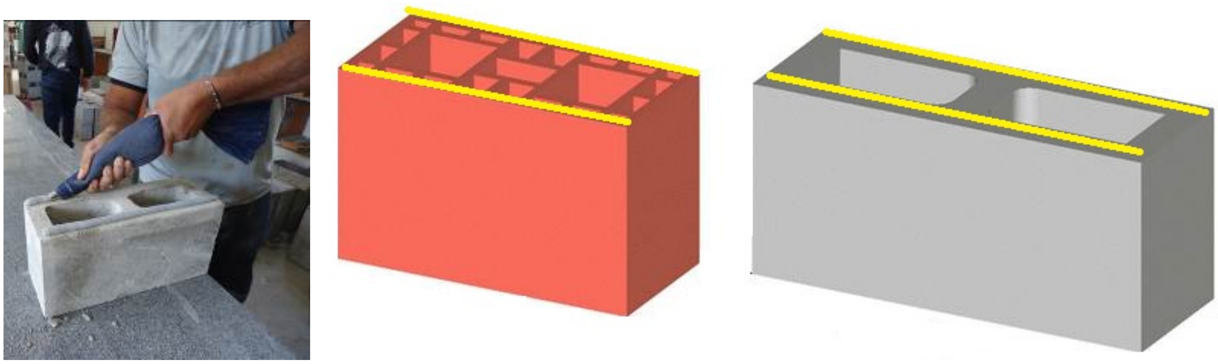

Figure 1 – a) Application process of the polymeric mortar; b) Bedded area for the thin mortar joint.

The table below provides the number of tests and the different combinations.

Table 2 - Test series.

Block type	**test**	**capping**	**Mortar type**	**Block Dimension**	**No. of tests**
1) hollow clay	Block	cement paste	-	Hollow clay = 140x290x190	12
2) hollow concrete 1	Hollow block	cement paste	cement-lime		12
3) hollow concrete 2	Hollow block	cement paste	polymeric	Hollow concrete = 140x390x190	12

* Two different cement-lime mortars were tested, total of 36 block tests and 72 prism tests

The mortar compressive strength was tested according to ABNT NBR 13279 (2005), as shown in Figure 2.

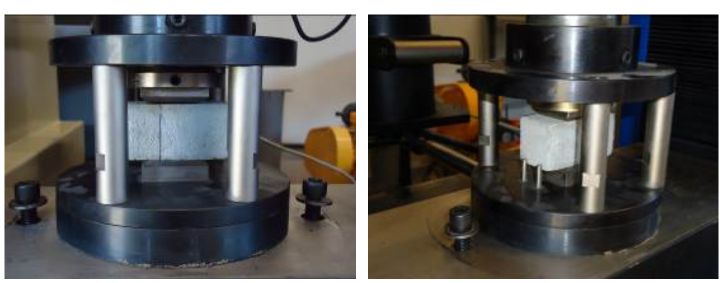

Figure 2 - Test for compressive strength of mortar.

The blocks compressive strength was determined in accordance with item 6 of ABNT NBR 12118, as shown in figures below.

Figure 3 - Testing of concrete and ceramic block

Hollow prisms were tested according to ABNT NBR 15961-2. Figures below show photos of the polymeric-mortar prism after the test.

Figure 4 – Tested Prisms – polymeric mortar.

To obtain the stress-strain curve of the prism, 2-LVDTs were placed on each prism lateral as shown in Figure 5.

Figure 5 - Hollow Prism instrumented with transducers to obtain the displacements.

RESULTS OF AXIAL COMPRESSIVE STRENGHT

The test results are shown below test samples were moulded with polymeric mortar using the same procedure used for regular mortar. The high shrinkage observed in the samples prevented the test samples from becoming viable for this test. New procedures for testing the stand-alone compression resistance of this mortar are currently under study.

Table 3 – Cement-lime Mortars Compressive Strength Results

mortar	Average Compressive Strength (MPa)	Standard Deviation	Coefficient of Variation (%)
1	6.1	0.38	6.2
2	9.1	0.19	2.1

Table 4 - block Compressive Strength Results

block	Average Compressive Strength (MPa)	Characteristic Compressive Strength (MPa)	Standard Deviation	Coefficient of Variation (%)
Ceramic	11.6	10.1	0.91	7.9
Concrete 1	9.2	7.6	1.12	12.1
Concrete 2	16.3	14.9	0.70	4.3

Table 5 – Hollow Prism Compressive Strength Results

Prisms	mortar	Average Compressive Strength (MPa)	Characteristic Compressive Strength (MPa)	Standard Deviation	Coefficient of Variation (%)
Ceramic block	**1**	5.7	4.2	0.40	7.0
	polymeric	4.6	3.9	0.26	5.7
Concrete block 1	**1**	7.4	6.3	0.68	9.2
	polymeric	8.1	6.9	0.33	4.0
Concrete block 2	**2**	11.0	9.3	0.89	8.1
	polymeric	12.8	10.9	1.30	10.2

Table 6 - Prism Elastic Modulus Results

Ceramic (polymeric mortar)	Ceramic (cement-lime mortar 1)

Prism	E (MPa)	mean (MPa)
CP1	2390	**2430**
CP2	2260	
CP3	2680	
CP4	2790	
CP5	2240	
CP6	2200	

Prisms	E (MPa)	mean (MPa)
CP1	4760	**5620**
CP2	6860	
CP3	6610	
CP4	5080	
CP5	5770	
CP6	4660	

Table 7 - Prism Elastic Modulus Results – concrete block 1.

Concrete 1 (polymeric mortar)		
Prisms	**Modulo (MPa)**	**mean (MPa)**
CP1	16760	**12920**
CP2	11760	
CP3	12540	
CP4	12770	
CP5	9130	
CP6	14520	

Concrete 1 (cement-lime mortar 1)		
Prisms	**Modulo (MPa)**	**mean (MPa)**
CP1	11300	**9120**
CP2	9110	
CP3	11430	
CP4	6390	
CP5	8040	
CP6	8470	

Table 8 - Prism Elastic Modulus Results – concrete block 2.

Concrete 2 (polymeric mortar)		
Prisms	**Modulo (MPa)**	**mean (MPa)**
CP1	23560	**21990**
CP2	17500	
CP3	*	
CP4	20410	
CP5	26470	
CP6	*	

Concrete (cement-lime mortar 2)		
Prisms	**Modulo (MPa)**	**mean (MPa)**
CP1	*	**23320**
CP2	21910	
CP3	22980	
CP4	22990	
CP5	25400	
CP6	*	

* Result not considered due to large deviation in relation to other values.

ANALYSIS OF RESULTS

The hypothesis test of Kruskal-Wallis test, with a significance level of 5% was used to statistically analyze the results of the different studies of hollow prisms. One can say that the compared results are equivalent when the value of "p-value" found is greater than 0.05.

Table 9 to Table 14 brings the statistical Kruskal-Wallis test results.

Table 9 – Hollow Prism statistical Kruskal-Wallis test results.

statistical test-Kruskal - Wallis				
Axial Compressive Strength – concrete block 1				
mortar	**Kruskal-Wallis chi-squared**	**df**	**p-value**	**comparison**
polymeric x cement-lime	66.07	1	0.0102	There is a significant difference

Table 10 – Hollow Prism statistical Kruskal-Wallis test results.

statistical test-Kruskal - Wallis				
Axial Compressive Strength – concrete block 2				
mortar	**Kruskal-Wallis chi-squared**	**df**	**p-value**	**comparison**
polymeric x cement-lime	10.00	1	0.0015	There is a significant difference

Table 11 – Hollow Prism statistical Kruskal-Wallis test results.

statistical test-Kruskal - Wallis				
Axial Compressive Strength – ceramic block				
mortar	**Kruskal-Wallis chi-squared**	**df**	**p-value**	**comparison**
polymeric x cement-lime	7.22	1	0.0072	There is a significant difference

As shown in Table 9, Table 10 and Table 11, the prism strength of cement-lime 10-mm joint is statistically different than the prism strength of polymeric thin joint for all blocks types.

Table 12 - Hollow Prism statistical Kruskal-Wallis test results.

statistical test-Kruskal - Wallis				
elastic modulus - ceramic block				
mortar	Kruskal-Wallis chi-squared	df	p-value	comparison
polymeric x normal	8.31	1	0.0039	There is a significant difference

Table 13 - Hollow Prism statistical Kruskal-Wallis test results.

statistical test-Kruskal - Wallis				
elastic modulus - concrete block 1				
mortar	Kruskal-Wallis chi-squared	df	p-value	comparison
polymeric x normal	6.56	1	0.0104	There is a significant difference

Table 14 - Hollow Prism statistical Kruskal-Wallis test results.

statistical test-Kruskal - Wallis				
elastic modulus - concrete block 2				
mortar	Kruskal-Wallis chi-squared	df	p-value	comparison
polymeric x normal	0.08	1	0.7728	No significant difference

Tables 12 to 14 show differences in the elastic modulus for the smaller strength blocks (both clay and concrete) but no difference in the higher concrete strength block, which was built with the also higher strength cement-lime mortar 2.

Since the polymeric joint mainly glues the two blocks together, it is expected that blocks will fail in compression in a similar way they would break if tested separately. In the case of prism with 10-mm mortar joint it is expected that the mortar deform more than the more rigid block leading

to a lateral tension in the block at the mortar joint level and a rupture prior to reaching the maximum resistance of the block.
What was observed in the concrete blocks results is an intermediary behaviour. The prism strength of the thin mortar joint was greater than the 10-mm joint case, but still smaller then the blocks strengths. Elastic modulus (in compression only) was also greater. We should point out that the blocks were regular market pieces and the bedding faces were not grinded prior to the test. This might had lead to not having a full contact in the blocks faces when they were laid with the thin mortar joint. Looking at the concrete prism of Figure 4 one can observe that the blocks did break in compression with a marked vertical crack at the centre that may indicate some stress concentration at this point. Cracks on the compression block test are spread around its perimeter (Figure 3) showing an uniform stress distribution.

The same behaviour was not observed in the hollow clay blocks. Both strength and elastic modulus of the thin mortar joint were smaller than the ones with the regular 10-mm joint. We can speculatively blame this reduction on the block geometry and smaller bedded area of the thin mortar joint. Those were also regular, un-grinded blocks and full contact of the faces may not have occurred. Only the external face-shells were glued in the case of the thin joint, polymeric mortar (regular hollow clay block have four face shells, see Figure 1-b). Looking at the clay block prism in Figure 4 it is possible to observe that only the most external block shell broke.

CONCLUSIONS

From the tests we could observe a higher strength and elastic modulus (compression only) in hollow concrete blocks prims built with a thin polymeric mortar joint when compared to prisms built with regular cement-lime 10-mm joint.

In the case of hollow clay prisms, the same results were not observed (regular mortar joint gave higher strength and elastic modulus), probably because of the block geometry and bedding face area.

The behaviour of a full wall must be tested before we can say the higher strength observed in some of the prisms would also lead to a higher wall strength (this may not be the case).

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