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PROPERTIES OF CONVENTIONAL CEMENT AND THIN LAYER MORTARS

Ash Ahmed and John Kamau
Civil Engineering Group, Leeds Beckett University, UK
E-mail: a.r.ahmed@leedsbeckett.ac.uk

Abstract: Mortar for masonry is important because it provides the linkage between masonry units so enabling the composite to behave as a single material. The type of mortar used determines the flexural and compressive strength of the masonry, so in this paper, a range of mortars are examined. These include traditional designation (iii) (1 cement: 1 lime: 6 sand), designation (iv) (1 cement: 1 lime: 9 sand) mortars as defined in BS 5628: Part 1, and two thin layer mortars. The conventional mortars were formed using both CEM I 42.5N or CEM II 32.5N PC (Portland Cement) to BS EN 197; Part 1 in order to ascertain the difference these two cements have on the properties of mortar. The thin layer mortars show remarkably high compressive strength.
Keywords: Cementitious Mortar, Thin layer mortar, Masonry, Compressive strength.

INTRODUCTION

Mortar is a very important material in civil engineering as it bonds together bricks and blocks in dwellings. Traditionally there are two different types of mortars: lime and cement. Lime mortar is the oldest type and has been used for centuries. This was the preferred type of mortar until cement mortars were developed. The disadvantage with lime mortars is that it gains maximum strength after 90 days, this can delay construction time which can confer negative economic implications. The main advantage with cement based mortars is that it reaches maximum strength in only 28 days. There are four different designations of cement mortars as shown in Table 1.

Table 1: Different designations of cement based mortars and respective mean and minimum compressive strength at 28 days, as per BS 5628 [1].

Mortar Designation	Cement:Lime Ratio	Sand Ratio	Known as	Compressive strength (N/mm^2)
(i)	1:0 to 0.25$^{1}/_{4}$	3	1:3	16.0
(ii)	1:$^{0.5}$	4	1:$^{1}/_{2}$:4	6.5
(iii)	1:1	6	1:1:6	3.6
(iv)	1:2	8/9	1:2:9	1.5

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With decreasing strength, there is increased flexibility, i.e. designation (iv) has the greatest flexibility. Typically, designations (iii) and (iv) are used with low density blockwork, however, over the last 15 years or so, thin layer mortars have become increasingly popular as they provide greater flexural strength for the wall [2]. Thin layer mortar, as the name implies, is a special type of adhesive mortar with a mortar thickness of only 3 mm (in comparison to 10 mm for conventional mortars, including lime). Although the layer is very thin, the mortar forms a very strong bond with the blocks. Furthermore, as the greatest heat loss through a wall is through the mortar layer, reducing the mortar bed thickness can improve the thermal insulation of the dwelling [3]. This paper reports the findings of a study undertaken to verify the mechanical properties of different conventional cement and thin layer mortars as this can to an extent, explain why only 3mm joint thickness is required for thin layer mortars.

EXPERIMENTAL

Experimental work was undertaken to establish the mechanical properties of three mortars types (designations (iii), (iv) and thin layer). A series of tests were carried out to evaluate the cube compressive, tensile and flexural strengths of conventional mortar prepared using CEM I 32.5N and CEM I 42.5N Portland cement and two types of thin layer mortar designated type A and B. The two cements were selected as there is no guidance on cement choice in the British code although there is some data on mortar strengths in Table 1 of BS5628:Part 1 [1], the relevant parts of which are reproduced as Table 1 of this paper. Flow properties of these mortars were also established. Sample preparation and testing were carried out in accordance with appropriate Standards as documented in this paper. The paper is divided into two main parts. The first part gives details of test materials and mortar properties and this is followed by the test results.

TEST MATERIALS

Cement

The first set of tests was carried out using 42.5N PC to BS EN 197: Part 1- CEM I [4], these being repeated using 32.5N PC to BS EN 197: Part 1- CEM I.

Lime

Bulk hydrated lime was used in the mortar production. It contained between 95.0 to 97.0% calcium hydroxide.

Sand

Soft building sand was used. The particle size distribution of the sand is given in Table 2. Tests were carried out in accordance with BS 1200 [5] and the results indicate that the sand used complies with the requirements of the BS 1200:1976 [5].

Table 2: Sand Grading Test Results

Sieve Aperture Size	Mass of sand passing sieve (g)	Mass of sand retained by sieve (g)	Cumulative sand passing sieve (%)
6.30mm	1160.5	0.4	99.97
5.00mm	1160.5	0.0	99.97
2.36mm	1158.7	1.8	99.81
1.18mm	1151.3	7.4	99.17
600μm	980.2	171.1	84.43
300μm	199.4	780.8	17.18
150μm	34.2	165.2	2.95
75μm	8.2	26.0	0.71

SPECIMEN PREPARATION

Conventional Mortar

Conventional mortar samples of designations (iii) and (iv) were produced to establish fresh and mechanical properties. Water was added so that the workability was consistent and corresponded to a 10mm penetration of the dropping ball test as suggested in BS 5628. The flow properties were determined in accordance with EN 1015; Part 3 [6]. The flow values obtained for all mixes fell within a range of between 186 to 188 mm.

Thin Layer Mortar

Again, mortar samples were produced to establish fresh and mechanical properties. Different thin layer mortars, either type A (provided by H + H Celcon) or type B (provided by Clan). Manufacturer’s mixing guidelines, given in Table 3 were strictly followed - the mixture was stirred for approximately 10 minutes until a lump free paste was obtained and the workability was consistent and corresponded to a 9.5 mm penetration of the dropping ball test. The flow values obtained for all mixes fell within a range of between 154 to 156 mm. Both thin layer mortars were manufactured in accordance with EN 998-2:1997 [7].

Table 3: Mortar Mixing Preparation.

	Mortar A (H + H Celcon)	Mortar B (Clan)
Mortar Weight (kg)	25	25
Water Content (litres)	4.4	5 / 5.5

Properties examined

A range of properties were examined during experimental work as shown in Table 4. In all testing, three specimens were broken at each test age (Table 4). Tests were carried out in accordance with EN 1015:Part 11 [8].

Table 4. Mortar Properties and Testing Regimes.

Mortar Property	Specimen	Test Age
Compressive cube strength	100 x 100 x 100 mm	1 - 28 days
Tensile strength	Dog bone	28 days
Flexural strength	40 x 40 x 160 mm	28 days

Test specimens were demoulded after 24 hours of casting and then transferred into an Environmental Chamber where a constant temperature of 20 °C and relative humidity of 95% was maintained throughout.

RESULTS

Compressive strength development of Mortar

The compressive strength development of both conventional mortars (designations (iii) and (iv)) for both cement types are given in Table 5 and Figure 2 while Table 6 summarises the 28-day cube compressive, flexural and tensile strength test results of both designations (iii) and (iv) mortars.

Table 5: Compressive Strength Results for designations (iii) and (iv) mortars

Curing Age (Days)	Compressive Cube Strength (N/mm^2)			
	42.5N PC		32.5N PC	
	Designation iii	Designation iv	Designation iii	Designation iv
1	3.7	1.9	1.9	0.6
2	5.2	3.9	2.7	0.9
5	7.6	6.6	5.0	2.0
7	9.2	8.0	6.0	2.5
14	13.9	11.8	8.2	3.4
28	15.2	14.2	9.1	3.8

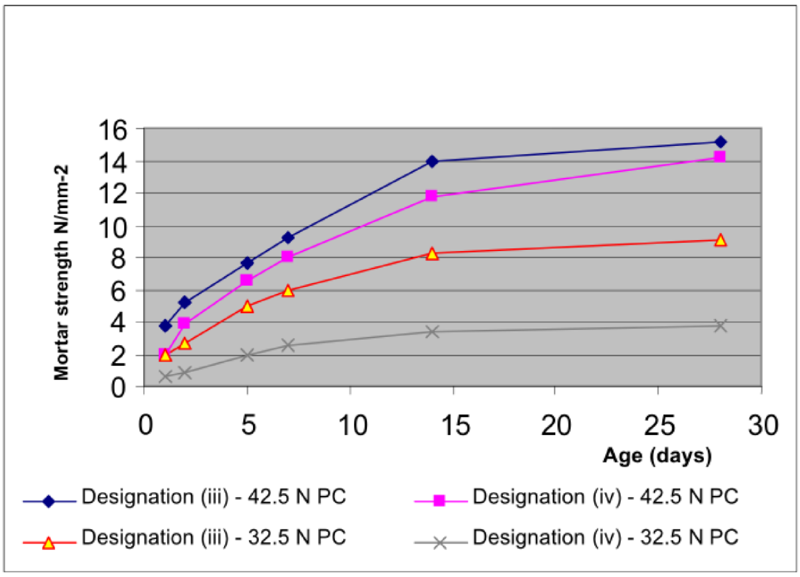

Figure 1: Strength development of conventional mortars

Table 6: 28-day Strength Results of Designations (iii) and (iv) Mortars

Cement Type	Mortar Designation	Compressive Strength (N/mm^2)	Flexural Strength (N/mm^2)	Tensile Strength (N/mm^2)
42.5 N PC	iii	15.2	5.1	4.8
	iv	14.2	4.8	4.5
32.5 N PC	iii	9.1	2.9	2.5
	iv	3.7	1.5	2.0

DISCUSSION

With 42.5N PC, the compressive strengths for designations (iii) and (iv) mortars are approximately 5 times greater than that specified in BS 5628. With the 32.5N PC cement mortar, the 28 day strength is 2.5 times that specified in the code. Variations are probably due to different mortar consistencies and possibly type of sand used.

Thin Layer Mortar

The compressive strength results of thin layer mortars cured up to 28-days are given in Table 7 and plotted on Figure 3 while Table 8 summarises 28-day compressive cube, flexural and tensile strength test results of these mortars.

Table 7. Compressive Strength Results of Thin Layer Mortar)

Curing Age (Days)	Compressive Cube Strength (N/mm^2)	
	A (n*)	B (n)
1	7.5 (2.0)	2.9 (0.8)
3	11.9 (3.3)	5.8 (1.6)
7	14.9 (4.1)	8.6(2.4)
10	16.0 (4.4)	10 (2.8)
14	17.0 (4.7)	11.5 (3.2)
21	17.4 (4.8)	11.8 (3.3)
28	17.6 (4.9)	12 (3.3)

*n: bracketed numbers indicate how many times the thin joint mortars are stronger than the BS5628 : Part 1[1] specification for a designation (iii) mortar.

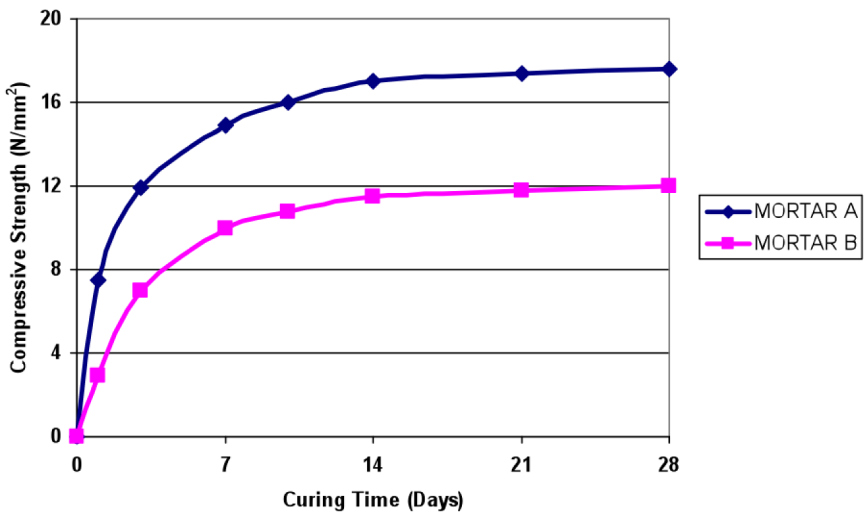

Figure 2: Compressive Strength Development for Thin Layer Mortars.

Table 8: 28-day Strength Results of Thin Layer Mortars

Thin Joint Mortar	Compressive Strength (N/mm^2)	Flexural Strength (N/mm^2)	Tensile Strength (N/mm^2)
A	17.6	4.6	1.9
B	1 2.0	3.6	1.7

Thin Layer Mortar A had a compressive strength nearly 50% greater than Mortar B but both mortars exceed the strength requirement of designation (iii) mortar as specified in BS 5628:Part 1[1] by significant amounts. The bracketed numbers in Table 7 indicate how many times stronger these mortars are over the 28 day strength of designation (iii) mortar. Mortar

A at one day, is twice the 28day BS 5628 specified strength, whilst mortar B at one day is 0.85 the BS 5628 28-day strength and at 3 days, it is 1.6 times the 28 day strength. Both mortars give remarkably consistent flexural strength results using wallettes despite their discrepancy in strength [2]. For the conventional mortars reported in this paper, the strength development is approximately 60% after 7 days, however, for the thin layer mortars, nearly 75% of the final strength is reached after 7 days curing.

CONCLUSIONS

- Key strength properties of three mortar types (designations iii, iv produced using 32.5N and 42.5N PC) and thin joint-mortar have been established.
- Strengths of mortars produced using CEM II 32.5N PC are considerably lower than those obtained for 42.5N PC mortars.
- Mortar strengths from both CEM II 32.5PC and CEM I 42.5PC mortars exceed the values given in BS 5628; Part 1.
- The Thin Layer Mortar type A was stronger than Thin Layer Mortar type B at all ages.
- With both thin layer mortars 70% of the total strength was reached after 7 days curing.
- With both thin layer mortars, the strength at 3 days was at least 1.6 times (3.3 for mortar A) the 28-day strength for designation (iii) mortar as required in Table 1 of BS 5628:Part 1.

Acknowledgement

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References

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[5] BS 1200 – Specifications for Building Sands from Natural Resources.

[6] BS EN 1015-3 – Methods of Test for Mortar for Masonry – Part 3: Determination of consistence of fresh mortar (by flow table).
[7] BS EN 998-2 - Specification for mortar for masonry. Masonry mortar.
[8] BS EN 1015-11 - Methods of Test for Mortar for Masonry. Determination of Flexural and Compressive Strength of Hardened Mortar.