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THE INFLUENCE OF HARDENING CONDITIONS ON THE PHYSICAL PROPERTIES OF MORTAR

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Abstract

One aspect of our investigation concerning the spacing of movement joints in masonry walls involved the short term and long term deformation of mortar embedded in masonry. This paper deals with determining the influence of humidity conditions during hardening on the physical properties of mortar.
In this study mortar prisms were made out of one type of Portland/Blast-furnace cement mortar and eight different hardening conditions were evaluated.
During the test period, the weight and length of the specimens were measured and at the end of the measuring period the strength of the prisms was determined.
Results indicated that the hardening conditions influence the final material properties of the mortar. It was concluded that it is important to control the hardening conditions of the mortar to optimise the spacing of movement joints.

Key Words

Mortar prisms, hardening conditions, humidity, movement joints

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1 Introduction

Today, in the Netherlands, due to a lot of regulations, many movement joints are seen in masonry walls. These movement joints are sometimes unsightly (figure 1).
That is why, some years ago, at Eindhoven University of Technology, an investigation concerning the spacing of movement joints was started. The project aims at answering the question “When, where and at what spacing should movement joints be used?”.
One aspect to reach this goal was to get a better understanding of the short term and long term deformation of mortar embedded in masonry. The study was started, by looking at the separate materials: mortar and brick. As far as known by the authors there is no literature or research done on this subject. This paper deals with determining the influence of humidity conditions on the physical properties of mortar (Drysdale et al 1999 p 154).

Figure 1
Movement joint in an office building

2 Specimens

2.1 Mortar

In this study mortar prisms were made out of one type of Portland/Blast-furnace cement (CEM II/III) mortar.
The mortar used in this research was a dry, pre-mixed mortar of mortar quality M 7,5 – type II/III, according to the Dutch standard (NNI 1991). The ingredients were Portland cement CEM II / B-V 32,5 R, Blast-furnace cement CEM III / B 42,5 LH HS, sand, limestone powder and additives.
Table 1 shows the material properties of the mortar, given by the manufacturer and tested according to Dutch standards (NNI 1988a, 1988b, 1991, 1999).

Table 1 Mortar properties according to the manufacturer

Property		
water-dry mortar factor	0,14	mass/mass
flow	175	mm
density fresh mortar	1900	kg/m^3
air content	14	%
density hardened mortar 28 days	1790	kg/m^3
flexural strength 28 days	3,1	N/mm^2
compressive strength 28 days	9,0	N/mm^2
shrinkage 91 days	< 0,75	mm/m

2.2 Prisms

The specimens were mortar prisms with a nominal size of 160 x 40 x 40 mm, made in a steel mould (figure 2).

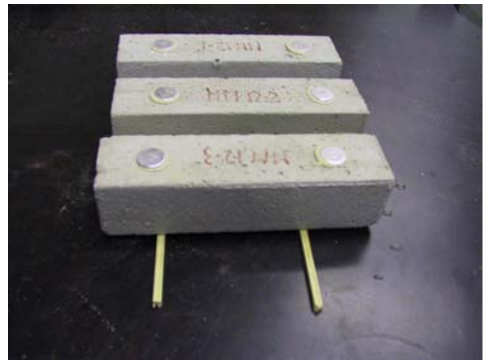

Figure 2 Mortar prisms

3 Test setup

3.1 Hardening conditions

Eight different hardening conditions were evaluated, whereby the initial period of higher relative humidity varied (figure 3).

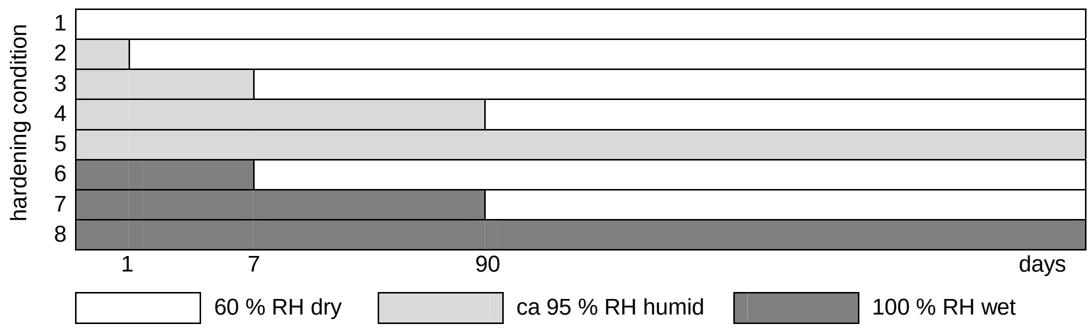

Figure 3 Hardening conditions (all 20 ^{o}C)

All the mortar prisms were stored in a climate room (20 ^{o}C / 60 % RH) under the following conditions:

Dry: free lying, on wooden strips (figure 2).

Humid: on wooden strips, in a plastic bag, with a small water container and damp cloth (figure 4).

Wet: on aluminium strips in a container filled with water (figure 5).

Figure 4 Humid mortar prisms storage

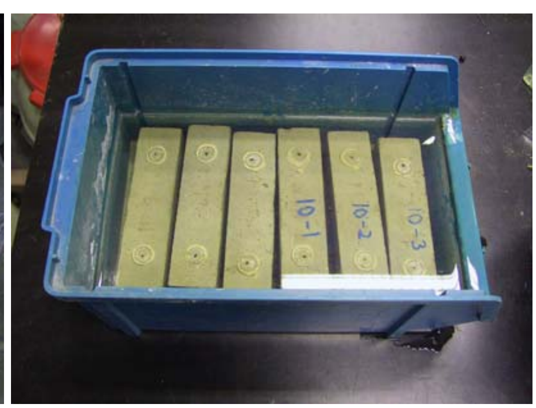

Figure 5 Wet mortar prisms storage

3.2 Test series

Tests on two series of specimens were caried out, one in 2001-2002 and the other in 2003-2004. In table 2 the number of specimens for each hardening condition in the different series is shown.

Table 2 Number of specimens in each series

hardening condition		Series 1 (2001)	Series 2 (2003)
1	dry	6	3
2	1 day humid	6	-
3	7 days humid	6	3
4	90 days humid	-	3
5	humid	6	3
6	7 days wet	-	3
7	90 days wet	-	3
8	wet	6	3

3.3 Measurements

The following measurements and calculations were carried out:
- The dimensions of the mortar prisms on the first day, directly out of the mould.
- The (change of) weight and the density of the specimens at specified times.
- The (change of) length of the specimens at specified times.
- The flexural and compressive strength of the prisms at the end of the measuring period (after approximately 1 year).

To measure the variation of length, a BAM stress-measuring extensometer, Pfender-type, was used (figure 6). Table 3 gives the specifications according to the vendor (Testing 2004).

Table 3 Specifications of the BAM extensometer

Specification	mm
rated measuring length	100
measuring accuracy	0,001
measuring range	± 0,5

Figure 6 shows the calibration of the extensometer, using an invar-steel bar.
Figure 7 shows the extensometer in measuring position on a mortar prism.

Figure 6 Calibrating the extensometer

Figure 7 Measuring with the extensometer

4 Test results

4.1 Change of weight for different hardening conditions

Figure 8 shows the average test results for the change of weight at specified times for the different hardening conditions of series 1 and 2.

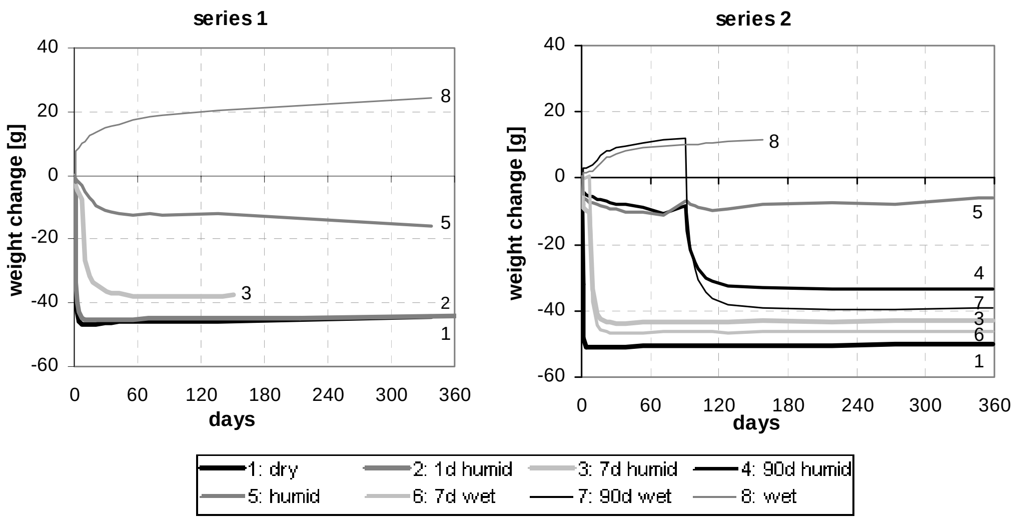

Figure 8: The variation of the weight in series 1and 2

It was found that the weight variation for the different hardening conditions gives the following picture (figure 8):

- Wet specimens show a weight increase (no 8).
- Humid specimens show a slight weight decrease (no 5).
- Dry specimens show a significant weight decrease (no 1).
- When wet and humid specimens are put in a dry environment, after 1, 7 or 90 days (no 2,3,4,6,7) they show a sharp weight decrease, smaller than the weight loss of the dry specimens.

The total change of weight (after approximately 1 year) is determined by subtracting the weight of the mortar prisms at day one from the weight at the end of the measuring period and expressed in percents by dividing this by the weight at the start.
Table 4 shows the average total change of weight and the density at the end of the measuring period for the different hardening conditions of series 1 and 2.

Table 4 Change of weight and density at the end of the measuring period

hardening condition	weight change %		density kg/m^3	
	series 1	series 2	series 1	series 2
1 dry	-5,2	-3,7	1757	1821
2 1 day humid	-8,3	-	1786	-
3 7 day humid	-7,2	-6,9	1756	1832
4 90 days humid	-	-6,0	-	1861
5 humid	-2,9	-0,1	1828	1978
6 7 days wet	-	-7,8	-	1812
7 90 days wet	-	-7,7	-	1826
8 wet	+5,2	+3,3	1994	2037

4.2 Change of length for different hardening conditions

Figure 9 shows the average test results for the change of length at specified times for the different hardening conditions of series 1 and 2.

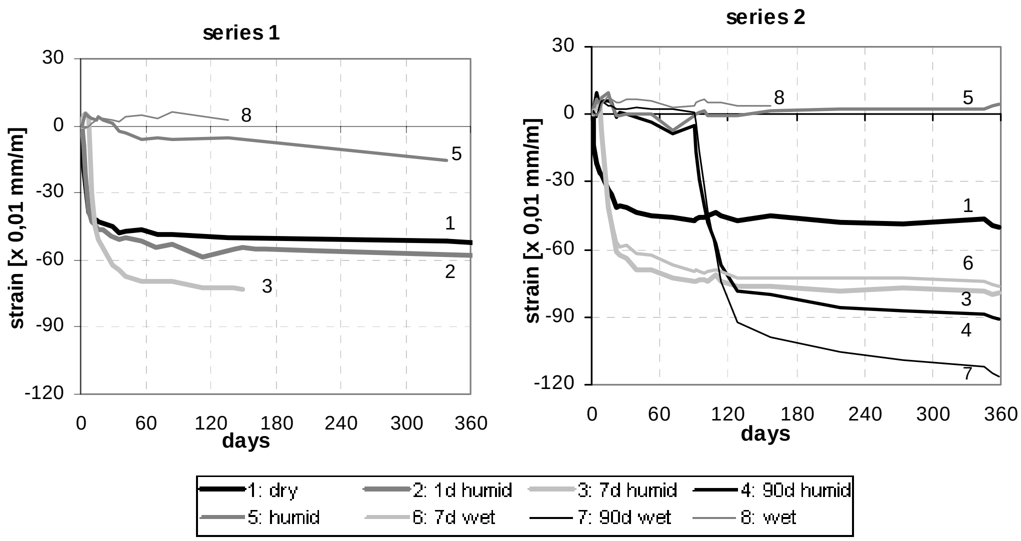

Figure 9 The variation of the length in series 1and 2

It was found that the length variation for the different hardening conditions gives the following picture (figure 9):

- Wet specimens show a slight swelling (no 8).
- Humid specimens show a slight swelling during the first 28 days and thereafter a slight shrinkage (no 5) .
- Dry specimens show a significant shrinkage (no 1).
- When wet and humid specimens are put in a dry environment, after 1, 7 or 90 days (no 2, 3, 4, 6 and 7), they show a sharp length decrease, larger than the shrinkage of the dry specimens and larger for the 90 days specimens (no 4 and 7) than for the 7 days specimens (no 3 and 6).

The total change of length (after approximately 1 year) is determined by subtracting the length of the mortar prisms at day one from the length at the end of the measuring period, expressed in 0,01 mm/m. Table 5 shows the average total change of length for the different hardening conditions of series 1 and 2.

Table 5 Change of length at the end of all the measurements

hardening condition	length change mm/m	
	series 1	series 2
1 dry	-0,55	-0,50
2 1 day humid	-0,56	-
3 7 day humid	-0,73	-0,79
4 90 days humid	-	-0,91
5 humid	-0,22	+0,04
6 7 days wet	-	-0,76
7 90 days wet	-	-1,16
8 wet	+0,02	+0,04

4.3 Mechanical properties of the mortar at different hardening conditions

Table 6 gives the average test results for the flexural and the compressive strength at the end of the measuring period (after approximately 1 year) for the different hardening conditions of series 1 and 2.

Table 6 Mechanical properties at the end of the measuring period

hardening condition	flexural strength N/mm²		compressive strength N/mm²	
	series 1	series 2	series 1	series 2
1 dry	1,41	1,41	4,75	4,30
2 1 day humid	1,94	-	5,00	-
3 7 day humid	3,70	3,33	10,88	10,31
4 90 days humid	-	4,71	-	17,98
5 humid	4,47	3,95	16,48	19,37
6 7 days wet	-	2,39	-	7,77
7 90 days wet	-	4,05	-	16,49
8 wet	3,18	3,17	14,77	13,64

Table 6 shows that the longer the prisms were stored in a humid/wet environment, the higher the compressive and flexural strength of the mortar was.
Specimens that were still humid/wet during testing gave a lower strength.

5 Conclusions

Results indicated that the hardening conditions influence the final material properties of the mortar. The longer the prisms were stored in a humid environment the higher the final shrinkage, density, compressive strength and flexural strength of the mortar after drying was (factor of 2).
This conflicting situation of a higher strength together with a higher shrinkage, calls for a right balance in curing masonry. Ideal curing conditions and curing time should optimize the strength of the mortar with the shrinkage. Therefore it was concluded that it is important to control the hardening conditions of the mortar. This in turn would lead to optimisation of the spacing of movement joints.

Needless to mention, it should be borne in mind that mortar hardened in a steel mould is not the same as mortar hardened between bricks, like in masonry (Vermeltfoort and v.d. Pluijm 1991, Vermeltfoort 1998, Drysdale et al 1999 p 154), but this investigation is a first step to understand the short term and long term deformation of mortar embedded in masonry (see 6 New research).

The results show that the tests are reproducible. Repeating the tests after more than 1,5 years, with a new batch of mortar, gave the same picture for the weight and length variation and the same size order for the mechanical properties.

6 Subsequent research

In the future this research will be continued by tests on other masonry mortars and thin bed layer mortars. There will also be studies on specimens in which mortar and bricks will be combined, like couplets and larger specimens to wall size (figure 10), under controlled conditions and outdoors.

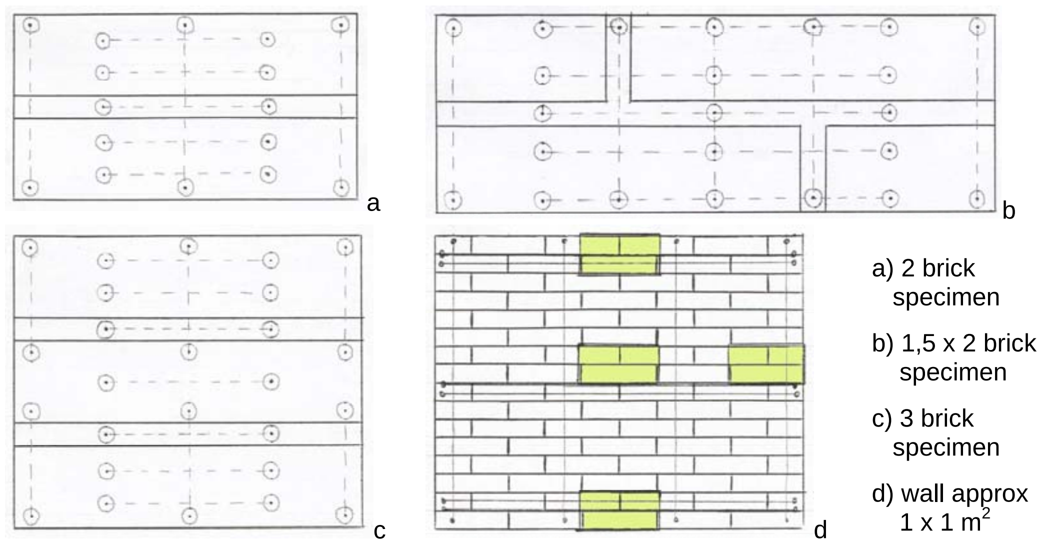

Figure 10 Ideas for new specimens

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