Available online at www.pelagiaresearchlibrary.com

Pelagia Research Library

Advances in Applied Science Research, 2012, 3 (3):1848-1853

Pelagia Research Library

ISSN: 0976-8610
CODEN (USA): AASRFC

Durability of block work: the effect of varying water/cement ratio of mortar joint

Nwofor, T.C.

Department of Civil and Environmental Engineering, University of Port Harcourt, Rivers State, Nigeria

---

ABSTRACT

The majority of masonry structures exhibit excellent long-term performance with comparative low maintenance cost. Durability of a masonry structure is influenced by many factors including the durability of both blocks units and mortar joint. In this research the specific influence of the varying water cement ratio of the mortar joint is taken into consideration. Hence the varying water/cement ratio is seen to affect the compressive strength results of the specimens produced for the purpose of this investigation, as it was found that compressive strength of the brick-mortar couplets generally reduces when water-cement ratio value was high. From the foregoing designers should not ignore this factor when targeting a desirable strength for masonry construction.

Keywords: Water/cement ratio, block units, mortar joint, compressive strength.

INTRODUCTION

Block-mortar masonry use, dates back to the early years of Structural Engineering, it is used generally as walling units in buildings. Previous research works have shown that the durability and longevity of this masonry unit is greater than that of any other building material, as is evident in thousands of old block unit buildings around our neighbourhoods, towns and the world in general. When designed and constructed properly, block-mortar masonry can last hundreds of years or more hence it is evident that block-mortar masonry is comparatively superior to other alternatives in terms of appearance and durability when properly prepared.

Through the centuries, tests to determine its properties were by trial and error and the "trade" was passed from generation to generation. There was no real technology prior to the start of this century. Early North American requirements for mortars appeared in the 1924 Report of the Building Code Committee of the U.S. Department of Commerce. ASTM Committee started to develop a mortar specification, which was finally published in 1951[1]. This specification contained requirements for the water retention at the plastic mortar and strength property of hardened mortar. In 1987, Lawrence and Cao[2] attempted to understand the mechanism of bond development between blocks and mortar. Their study showed that block-mortar bond is due to the network of cement hydration products deposited on the block surface and inside the block pores as well. The initial moisture was said to have a role in the penetration of hydration products into the block pores. They concluded that block-mortar bond is essentially mechanical in nature. Adding lime to the mortar mixture appeared to improve the network of hydration products, as there was inadequate evidence for bond strength improvement.

To predict failure of masonry, various equations and models, based on ideas about cement block-mortar interaction have also been proposed. However, these equations and models are not universally applicable since they assume that the contact between the materials is perfect and that the materials are homogeneous which is not the real case.

There are various types of mortar in use today [3] and these mortar can also be classified based on strength and uses, hence, in his research work suggested that a mortar, with high compressive strength might be desirable for a hard stone such as granite pier holding up a bridge deck, whereas softer mortar paste would be preferable for historic walls and soft bricks.

Several factors affecting brick-mortar bond strength such as total curing effect, rate of hydration of the mortar region, was studied by [4]. This study highlights the importance of moisture transport between mortar and brick in influencing hydration of cementation products. His work also suggests that the rate of absorption in the block and the moisture retention in the mortar play an important role in determining the compressive strength of the unit. The effect of grading of sand on the compressive strength has shown a higher strength yield in mortars with coarse sands [5]. Researchers have also suggested that tests carried out on masonry couplets may not necessarily yield result based on their bond strength: Tests conducted by [6] gave the following facts;

- The crushing of weakest block in a wallet specimen often determines the masonry strength rather than the interaction between brick and mortar and may mask the influence of the mortar strength on the masonry strength.
- The failure of masonry specimens using weak mortar is primarily due to loss of bond between mortar and masonry units and in the case of stronger mortars failure is due to less hydration.

In other related woks, mortars used in masonry structures are exposed to aggressive environments and should be designed to resist a range of possible physical and chemical degradations[7], hence to assess the potential long-term performance of masonry mortar, a durability test based on a controlled scratching of the mortar surface, has been developed [8]. A major research program to investigate factors affecting the durability of mortar has also been carried out [9]. The research examines the influence of masonry unit, mortar, cement type, sand, mix proportions and joint finish on the potential durability of the classes of mortar considered. Study has also shown that the durability of mortar improves with increased cement content and also the reduction of water demand of air – entrained agents which can result in reduced bond strength [10,11]

In this present investigation the varying water/cement ratio of the mortar joint which is frequent during construction process is taken into consideration. The masonry units which are sandcrete blocks would consists of dry pressed units in order to maintain consistency in the masonry units used in this research.

MATERIALS AND METHODS

The Scope of work entails testing for the compressive strength of block-mortar couplets. The mortar for binding the block couplet will be made by varying its water cement ratio. Laboratory results obtained will be used in plotting graphs, showing the details and effects of various results obtained.

Materials required to carry out this work will be as follows;

- Sandrete blocks with a 150mm × 225mm × 450mm dimension.
- Ordinary Portland cement for preparing the mortar mix.
- Fine aggregates for preparing the mortar mix.
- Mortar mix prepared with varying water-cement ratios.
- Water for preparing the mix.

Tests to be carried out on the blocks samples will not include the strain test this is because of the non availability of the strain gauge in Laboratories around the region. Limited variations of water-cement ratio in the mortar region will also be tested for due to financial constraints.

Compression test will be carried out on block-mortar couplet samples, varying the water-cement ratio in the mortar region. This will be done by loading the samples in a compression testing machine.

Procedures involved for this work are;
1. Preparing of sandcrete blocks and mortar samples. Mortar samples will be prepared with various water-cement ratio of:- 0.5, 0.6, 0.7. All samples will be prepared with mix ratio of 1:6.
2. There will be 3 number samples per mix ratio
3. Samples will be cured for 7, 14 and 28 days and compressive strength tests will also be carried out on these days.
Based on the test results, the following conclusions are drawn:
1 Replacing red sand with white sand increases the compressive strength, flexural strength, and modulus of elasticity, and decreases the drying shrinkage of the mortar.
2 The type of sand has an insignificant effect on the density and water absorption of the mortar and concrete bricks.
3 Addition of lime to mortar mix adversely affects its mechanical and physical properties.

3. Experimental Procedure

The basic description of experimental procedures was is follows;

- Preparing of sandcrete block samples. Block dimensions were 150mm × 225mm × 450mm (solid). Block samples were prepared with a nominal mix of 1:6 (1:5.5 in mass proportion). Water-cement ratio of 0.5 was used in preparing all samples.
- Preparing and placing of mortar samples on block samples. Mortar samples were prepared with a nominal mix of 1:6 (1:5.5 in mass proportion) and with water-cement ratios of 0.5, 0.6 and 0.7.
- Curing of all prepared samples for 7, 14 and 28days.
- Crushing of samples on 7, 14 and 28days after preparation.

A total of fifty four sandcrete blocks and twenty seven couplets samples were prepared. From the foregoing the first procedure after gathering/acquiring the materials required was to run a bulk density test on the fine aggregate. This was done so that the mix design for the various samples could be calculated for. A nominal mix of 1:6 (volume proportioning) was used. This had to be converted to mass proportion by multiplying the nominal mix (1:6) by the bulk densities of fine aggregate and Ordinary Portland Cement to enable proper weighing of each of the materials required in each couplet sample.

3.1 Mix Design for Sandcrete Block and Mortar Samples

The dimension of the block-mortar couplet sample is as shown in the figure below;

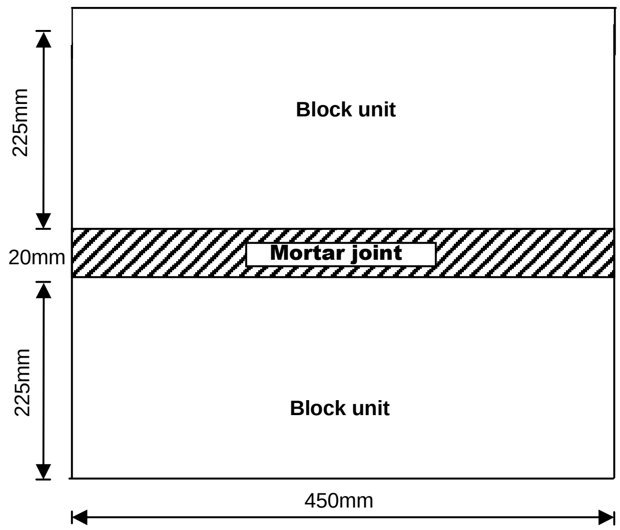

Fig. 1: A typical representation of the experimental block-mortar couplet

From bulk density experiment for fine aggregate, bulk density = $1.32 g/cm^3$

Converting to kg/m^3; $$\frac{1.32 \; x\, 10^6 kg}{1000 m^3} = 1320 kg/m^3$$

Volume of 'control' sandcrete block = 450mm × 225mm×150mm
= $15.1875\times10^6 mm^3$ = $\underline{0.015m^3}$ (in cubic metres)
Increasing volume by 10% to compensate for material losses, required volume therefore = $0.015m^3 \times 1.1$ = $\underline{0.017m^3}$ (required volume)
Weight of control block used = 23kg

Mix Design For Sancrete Block
Bulk density of sand = $1320kg/m^3$
Bulk density of cement = $1428.6kg/ m^3$
Nominal mix for required block sample = 1:6 (volume proportioning)
Converting to mass proportion;
1 × 1428.6 : 6 × 1320 = 1428.6 : 7920

Dividing through by 1428.6 = $\frac{1428.6 : 7920}{1428.6:1428.6}$ 1:5.5 (mass proportioning)

Density of proposed block sample = $\frac{Mass}{Volume} = \frac{23kg}{0.017m3}$ = $1353kg/m^3$

Hence, total mass proportion for a sancrete block sample = 1 + 5.5 + 0.5 = 7
Weight of materials for each block sample;

Cement $\frac{1\ x\ 1353kg/m^3}{7}$ = $193.29kg/m^3$ – cement density in each proposed block.

Therefore weight of cement in block = $193.29kg/m^3 \times 0.017m^3$ = 3.29kg

Fine Aggregate: $5.5 \times 1353kg/m^3 = \frac{1063.07kg/m^3}{7} - fine$ in each proposed block.

Therefore weight of fine aggregate in block = $1063.07kg/m^3 \times 0.017m^3$ = 18.07kg

Water $\frac{0.5\ x\,1353kg/m^3}{7} = 96.6kg/m^3$ - water density in each proposed block

Therefore weight of water in block = $96.6kg/m^3 \times 0.017m^3$ = 1.64kg

Mix design for mortar paste (using water-cement ratios of 0.5, 0.6 AND 0.7)
A mortar joint thickness of 20mm was used.
Volume of the mortar joint = 0.02m × 0.15m × 0.45m = $0.00135m^3$.
Increasing volume by 10% to compensate for material losses;
Hence volume of mortar region per couplet sample = $1.1 \times 0.00135m^3$ = $\underline{0.0015m^3}$.
Weight of each material in each mortar sample;
Using block density as density of mortar joint,

Cement: $\frac{1\ x\ 1353kg/m^3}{7}$ = $\underline{193.28kg/m^3}$ – Density of cement in mortar
Therefore cement weight = $193.28kg/m^3 \times 0.0015m^3$ = 0.29kg

Fine Aggregate: $\frac{5.5\ \ 1353kg/m^3}{7}$ = $1063.07kg/m^3$ – Density of fine aggregate in mortar. Therefore fine aggregate weight = $1063.07kg/m^3 \times 0.0015m^3$ = 1.59kg
Water: *For a 0.5 water-cement ratio;* Weight of water = 0.5 × 0.29kg = 0.15kg_ *For a 0.6 water-cement ratio;* Weight of water = 0.6 × 0.29kg = 0.17kg *For a 0.7 water-cement ratio;* Weight of water = 0.7 × 0.29kg = 0.2kg

Preparation of Samples

On determining the mass of each material component in each block-mortar sample from the mix design, sandcrete block samples were prepared using a six inches block mould. Blocks were prepared and left to harden for a day, the mortar paste with varying water-cement ratios of 0.5, 0.6, 0.7 was prepared and placed on a sandcrete block and laying another block on them to form block couplets as shown below;

RESULTS AND DISCUSSION

The results from the experimental programme show the trend of average compressive strength in each group of samples (samples with same water-cement ratio), obtained after crushing test was carried out. The comparison of average compressive stress against age of sample is as shown in table 1.

Table 1: Average stresses obtained for samples with different water-cement ratio at different crushing days

Crushing days	Mortar joint with 0.5w/c ratio	Mortar joint with 0.6w/c ratio	Mortar joint with 0.7w/c ratio
	Average stress (N/mm^2)	Average stress (N/mm^2)	Average stress (N/mm^2)
7	4.79	4.25	3.09
14	5.78	5.58	3.61
28	7.31	6.47	4.87

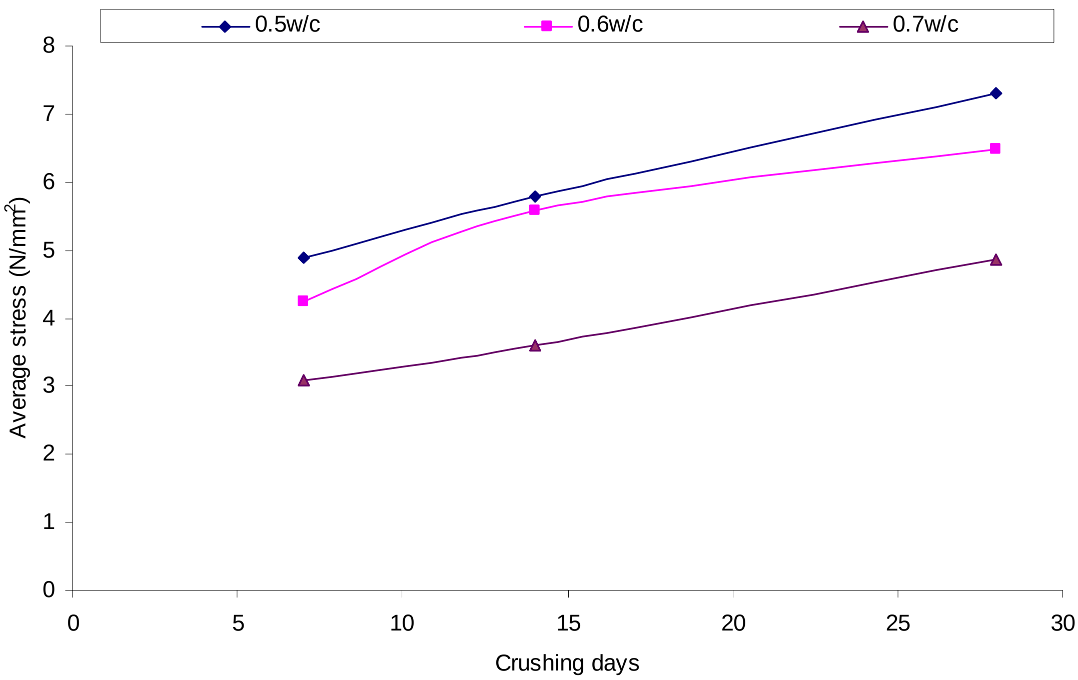

Figure 2: Graph of average stress against crushing days for varying water-cement ratio of mortar joint

From the graph plotted above, it is clearly seen that for each water-cement ratio, there was no irregular trend in strength rise, as the age of samples increased with decreased water/cement ratio of the mortar joint as seen in the graph plotted in figure 2. It was also observed that, block-mortar couplet with mortar region having a water-cement ratio of 0.5, had high value of strenght. This therefore suggests that to achieve a high compressive strength of masonry block wall unit, the water-cement ratio of mortar to be used should be kept at a minimum acceptable level (0.5 water-cement ratio for this research work). However, the sample with a 0.7 water-cement ratio mortar region also has its 28day strength not far off from strength of samples with 0.5 and 0.6 water-cement ratio, making the sample also useful especially in large masonry projects were material conservation will be significant.

CONCLUSION

The tests therefore, has shown that there is variation in compressive strengths when water-cement ratio used in the mortar region of block-mortar couplets is varied hence the following deductions can therefore be stated from this research;

- Compressive strengths of block-mortar couplets with mortar regions having water-cement ratio of 0.5, yielded the highest 28day compressive strength.
- Compressive strength of block mortar couplet with 0.7 water-cement ratio mortar region is found to be useful when executing large projects where material conservation is important.
- Couplet strength reduced as the water-cement ratio in the mortar region was increased, hence mortar with a very high water-cement ratio would have a very low compressive strength.
- Comparison between experimental results and theoretical values shows that tests carried out to determine compressive strength of block-mortar couplets yielded results that conform to real life theories.

From the experimental programme, a water cement ratio of 0.5 and 0.6 is therefore recommended for preparing mortar that would be used in binding masonry on site. Water-cement ratio of 0.7 can however be considered when financial availability and conservation is a critical criteria in executing a given job as this would save cost on materials purchase though this will only be significant in large projects.

Increasing the number of water-cement ratios to vary would have yielded a wider range of results which would have proven very useful hence extensive studies on wider range of water-cement ratios should also be investigated. Also studies using other mortar types should be carried out and compressive strain and other properties of the block-mortar couplet should also be investigated.

REFERENCES

[1] Standard Specification for Mortar for Unit Masonry, (**1951**), ASTM C270-51T.
[2] Lawrence S.J., and Cao H.T. (**1987**) An experimental study of the interface between brick and mortar, *proc. 4th North American Masonry conference.,* University of California, Los Angeles, USA, TMS, pp 48-1, 48-14.
[3] Orubide T., (**2010**) Determining of Optimum Mortar Joint Thickness of Brick-Mortar Complexes That Will Produce Maximum Compressive Strength, B.Eng thesis, University of Port-Harcourt, Port-Harcourt Rivers State, Nigeria, pp 4-5.
[4] Groot Casper J.W.S, (**1993**) Effect of Water on Mortar-Brick Bond, Ph.D thesis, University of Delft, Delft, The Netherlands, pp 28.
[5] Held L. and Anderson C, (**1983**), The Effect of Sand Grading on Mortar Properties and Tensile Bond, Ph.D thesis, South Bank University, London, England.
[6] Cheema T.S. and Kligner R.E., (**1986**), Compressive Strength of Concrete Masonry Prisms. American Concrete Institute ACI, vol.83(1), 88-97.
[7] Guirguis, S. Lawrence S.J. and Samarasinghe, W. (**2003**), Durability of Masonry Mortar, *Proceedings 6th CANMET/ACI Conf.* on Durability of Concrete, pp.837-852, Thessaloniki, Greece.
[8] Lawrence S.J. and Samarasinghe, W. (**1998**), A new method for Assessing the service life of masonry mortars. Rehabilitation of structures, *Proceedings of the 2nd International RILEM/CSIRO/ACRA Confernece*, pp.481-488.
[9] Testone, T. Sugo, H.O.; Page, A.W. and Lawrence, S.J. (**2006**), *Investigation of Factors Affecting Durability of Masonry Mortar:* University of Newcastle and SPL Consulting.
[10] Bond Strength in Masonry Construction, Technical Note 65, Cement and Concrete Association of Australia (**2001**).
[11] Cleaning Clay Masonry Clay Technical Guide, Brick and Paver institute of Australia (CBPI) website.