EFFECTS OF AGE AND CURING TO THE BOND STRENGTH OF POLYMER CEMENT MORTARED THIN BED CONCRETE MASONRY

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ABSTRACT
Bond characteristics of masonry are partly affected by the type of mortar used, the techniques of dispersion of mortar and the surface texture of the concrete blocks. Additionally it is understood from the studies on conventional masonry, the bond characteristics are influenced by masonry age and curing methods as well as dryness/dampness at the time of testing. However, all these effects on bond for thin bed masonry containing polymer cement mortar are not well researched. Therefore, the effect of ageing and curing method on bond strength of masonry made with polymer cement mortar was experimentally investigated as part of an ongoing bond strength research program on thin bed concrete masonry at Queensland University of technology. This paper presents the experimental investigation of the flexural and shears bond characteristics of thin bed concrete masonry of varying age/ curing methods. Since, the polymer cement mortar is commonly used in thin bed masonry; bond development through two different curing conditions (dry/wet) was investigated in this research work. The results exhibit that the bond strength increases with the age under the wet and dry curing conditions; dry curing produce stronger bond and is considered as an advantage towards making this form of thin bed masonry better sustainable.

KEYWORDS: thin bed concrete masonry, flexural bond strength, shear bond strength, polymer mortar, age effect, dry curing, wet curing

1.0 Introduction

As one of the oldest construction methods aligned to human civilisation, masonry has remained as a major competitor in modern construction. Traditional masonry construction method is slow and labour intensive compared to present day's concrete and steel construction methods. The needs to minimise on the site labour influences and reduce construction time have led to the development of several new masonry construction systems; thin bed masonry is one such methods of masonry construction introduced to reduce the labour dependences onsite construction that does not require highly skilled mason. The construction of thin bed masonry is similar to conventional block work; however it is much simpler and can be learnt rapidly by labourers (Da Porto 2005, Nicholas et al., 2008). Thin bed concrete masonry is relatively new and not much research efforts have been made to study the structural benefits of this form of masonry. For a systematic development of the thin bed concrete masonry construction, a fundamental understanding of its basic bond characteristics is essential. As part of an ongoing research, the effect of age and methods of curing on bond strength with polymer cement mortar was investigated and reported in this paper.

2.0 Review of Masonry Bond

Masonry bond strength is important for dealing with the masonry subjected to in-plane and out-of-plane bending and shear. A number of investigations addressing various aspects of the bond development between the masonry unit and the mortar can be found in the literature ((Rao et al., 1996; ; Reddy et al., 2007; Walker 1999; Khalaf 2005; Lawrence et al., 2005). Most of these investigations are concerned with the parameters influencing the bond strength of different units (eg. clay, concrete, calcium silicate) using commonly used cement-lime mortars. The bond characteristics of 1mm- 4mm thick polymer cement mortar in thin bed concrete masonry is not yet well researched. The authors' previous studies on thin bed concrete masonry bond (Thamboo et al., 2012) have shown that the bond characteristic of polymer mortared thin bed concrete masonry is similar to that of the conventional masonry, but with higher strength.

The main factors influencing the bond between the mortar joints and masonry units are: (1) the type of mortars (mix design, workability. water retention. setting characteristics and air content), (2) the type of masonry unit (absorption characteristics and the surface texture/ roughness) and (3) workmanship (quality of filling the valleys of the unit surface, degree of pressure applied to masonry unit and the type of tooling used and productivity achieved). Additionally it is understood from few previous studies on conventional masonry (Sugo et al., 2007& Dhanasekar, 2011), the bond characteristics are influenced by masonry ageing and curing, as well as the dryness/wetness of the masonry.

The bond development takes place with the application of fresh mortar on to masonry units. The subsequent setting of the cement compounds is influenced by the absorption of mortar fluids into the masonry unit and the consequential transport of mortar fines into the mortar– unit interface. It could be expected that continued hydration over longer periods of time would further increase the bond strength. However, the previous research studies reported that a continuous increase in strength is not always observed, with the bond strength showing varying trends over time (Drysdale and Gazzola, 1985; De Vitis et al., 1998; Sugo et al., 2007). However, Dhanasekar (2011) has shown that well cured dry specimens (conventional masonry) exhibit higher bond strength compared to similarly cured wet specimens.

Additionally, the commonly used thin bed masonry mortars contain polymers; in addition to the cement hydration, polymer mortars undergo polymerisation in the presence of water depending on the proportion of polymers in the mortar, there by differing the process of gaining bond strength (Colville et al., 1997). An interesting finding was made on polymer cement mortar by Colville et al., (1997) where dry curing was shown to improve tensile bond strength of masonry than the wet curing. The influence of curing method to the bond strength gain of polymer-modified mortars could be inferred from this finding.

From the limited number of earlier studies, it is clear that the age effect on the bond characteristics of polymer mortared thin bed concrete masonry is not investigated well. Therefore in the present study, an attempt has been made to study the age effect to the bond characteristics of thin bed concrete masonry with polymer cement mortar; the influence of curing methods to the bond development in thin bed concrete masonry was also investigated.

3.0 Experimental Design

The main purpose of this investigation is to study the flexural and shear bond characteristics of thin bed concrete masonry with three different ages (14 days, 28 days and 56 days) and two different (Dry and wet) curing methods. The flexural characteristics was determined using four point bending (beam) test using the provisions for the conventional masonry in ASTM E513 (2003)and AS 3700 (2001). To study the shear response; the triplet test has been adopted as per BS EN 1052-3 provisions, because of its simplicity and wider acceptability amongst the masonry researchers.

Seven course flexural beams (figure 1(a)) and three course shear triplets (figure 1(b)) were built using one of the commonly used masonry concrete block dimension of 390mm×190mm×90mm with two symmetrically placed large holes. Allowing three specimens each combination, totally 18 beams and 18 triplets were built for testing. Due care was taken to ensure the mortar joint thickness was maintained uniform as 2mm by using spacers of the specified thickness.

The mortar used in this research study was a proprietary polymer cement mortar produced by one of the industry partners of this Australian Research Council sponsored project. The polymer cement mortar was delivered in a sealed bucket: preparation involved addition of water only. The polymer cement mortar contained of 4% polymer by weight. The mortar was mixed with a ratio of 250ml of water to 1kg of dry mortar mix. This amount of water was determined after several trials of mortar mixing.

(a) Beam specimens

(b) shear specimens

Figure 1: Constructed beam and triplet specimens

Moreover to avoid steel platen contact on to the masonry specimen, which can cause premature bearing failure, timber pieces were inserted between the specimen and the support/ loading steel plates. The specimens were fully covered with plastic sheets immediately after the construction to prevent moisture loss and cured. 7 days after construction, the covering of the dry curing specimens (beam and triplets) were removed and allowed for dry curing for the specified testing days.

The deformations of the specimens were monitored through digital imaging and linear variable differential transformer (LVDTs). The positions of LVDTs on the specimens are shown in Figure 2(a) and (b) for beam and triplet specimens respectively. A digital SLR camera (EOS 1000D) was used to take the deformation images (beam and triplet) for digital image analysis to study the deformation of specimens; the camera was attached to a tripod at a distance to provide clear coverage of the specimens especially the unit-mortar interface. The camera was connected to a computer that controlled the shutter through special purpose software specific to the camera. The digital images were taken at 5 seconds interval until the total failure of specimen.

(a) LVDT positions on beam

(b) LVDT positions on triplet

(c) Image acquiring of beam test

(d) Image acquiring of triplet test

Figure 2: Test set-ups

All the specimens (beam and triplet) were tested at the Queensland University of Technology Banyo structural testing laboratory. The tests were performed under displacement control in order to obtain the complete stress - strain curve of the specimens. The loading rate was kept constant as 0.01mm/s for both test types. A servo-hydraulic MTS controller with a double acting actuator of 300kN capacity was used. A 300kN load cell of precision of measurement of 0.001kN was used and the data recorded using the MTS controller software. The test set-up is shown in Figure 2(c) and (d).

4.0 Results and Discussion

4.1 Failure Modes

(a) Beam failure (bond failure)

(b) Triplet failure (bond Failure)

(c) Beam (partial block failure)

(d) Beam (block failure)

Figure 5: Typical failure patterns.

All of the beam and shear specimens in 14 days of testing failed through mortar/ interface as shown in Figure 5 (a) and (b). Since the mortar thickness is thin (2mm), it was difficult to ascertain whether the failures occurred through the mortar or the interface. All failures were sudden and brittle similar to the conventional masonry. Furthermore in 28 and 56 days of testing, a mixed of partial block and block failure were observed (see Figure 5(c) and (d)) with higher bond strength values in beam specimens. However the 28 and 56 days shear triplet specimens failed though interface/ mortar only.

4.2 Shear Bond strength

The age and curing effects to the initial shear bond strength in thin bed concrete masonry was studied through the triplet test for three different ages and two different curing methods. The average initial shear bond strengths and corresponding coefficient of variations are given in Table 1.

Table 1: Initial shear bond strength

Specimen	Average Initial shear bond strength /(MPa)	COV/ (%)
S-14-W	0.82	14.6
S-14-D	0.89	4.9
S-28-W	0.88	3.1
S-28-D	1.22	31.9
S-56-W	0.93	13.4
S-56-D	1.29	11.0

(Note: S- Shear strength; 14, 28 and 56- Age at test days; W-Wet cured, D-Dry cured).

The effect of age at testing and curing condition can be inferred from the average shear bond strength of the triplets that varied from0.82MPa to 1.29 MPa as shown in Table 1.It can be seem from the table the wet cured specimens consistently gave lower bond strength value than the dry cured specimens. This result is consistent with that of Colville (1997). For proper polymerisation process pore water should evaporate to form polymer films in the mortar; this action is retarded by the excess moisture in the wet curing process. Therefore the dry-curing tend to increase mortar setting and subsequently the bond strength than the wet-curing.

Another observation is about the increase in shear bond strength with the age of testing. It can be said nearly 65% -80% of the bond strength was reached in 14 days, thereafter the shear bond strength have a tendency to increase relatively more (20% -30%) up to 28 days that considered in this investigation. As the cement hydration and polymerisation (gaining strength in polymer cement) are continuous processed with the presences of moisture, therefore, it contributes to the bond strength gain in thin bed concrete masonry with polymer cement mortar.

4.3 Flexural Bond strength

The age and curing effects to flexural bond strength in thin bed concrete masonry was studied through the beam test for three different curing days and two different curing methods. The average flexural bond strengths and corresponding coefficient of variations are given in Table 2.

Similar to shear bond strength, the average flexural bond strength of the beams increased with age and curing method. Also analogous shear bond strength wet cured specimens consistently gave lower bond strength than the dry cured specimens. This change in strength in curing condition was due to the characteristics of polymer cement mortar as explained in previous section. Therefore, it confirms that the dry-curing enhances the mortar bond with the concrete block surface than wet-curing in thin bed concrete masonry; and subsequently the bond strength of masonry has been higher in dry cured specimens. Thin bed masonry containing polymer mortar can therefore be regarded better sustainable due to curing better with no requirement of water. Also it can be noticed, with aging duration considered in this investigation the flexural bond strength of thin bed concrete masonry increased noticeably. With wet curing flexural bond strength has increased from 0.77 MPa to 0.91 MPa and through dry curing the bond strength has increased from 0.87 MPa to 0.91 MPa.

Table 2: Flexural bond strength

Specimen	Average Flexural bond Strength/(MPa)	COV/(%)
F-14-W	0.77	10.7
F-14-D	0.87	11.6
F-28-W	0.87	11.0
F-28-D	0.95	7.0
F-56-W	0.91	2.1
F-56-D	0.98	5.3

(F- Flexural strength; 14, 28 and 56- Age at test in days; W-Wet cured, D-Dry cured).

5.0 CONCLUSIONS

In an attempt to study the bond strength characteristics with age of the bond and curing methods in thin bed concrete masonry, a total of 18 flexural and 18 shear specimens were tested at three different ages and with two different curing conditions. The flexural beams specimens were tested under four-point bending (per ASTM E513) and shear specimens (per BS EN 1052-3).

(1) Polymer cement mortars can be used in thin bed concrete masonry to improve the bond strength of thin bed concrete masonry.

(2) Both the shear and tensile bond strengths increase with the age.

(3) Dry cured specimens consistently provided higher bond strength than the wet cured specimens.

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