AN EXPERIMENTAL STUDY OF TILE BOND BEHAVIOUR OVER STRUCTURAL CONCRETE MASONRY WALLS

MEDEIROS, JONAS SILVESTRE; MELLO, MURILO BLANCO; ASAMURA, RENAN EIJI

INOVATEC CONSULTORES ASSOCIADOS

ABSTRACT

The present study aims to determine the influence of vertical deformation under compression of concrete block of a masonry structural wall on the bond behavior of the ceramic wall tile covering directly adhered with adhesive mortar. The results show that displacements caused by the design axial load are not enough to cause tile debonding, although they were fully transferred from the wall surface to the tiles. Loadings beyond this point, however, can introduce stresses that may impair ceramic tile bond resistance.

1. INTRODUCTION

The present study aims to determine the influence of concrete masonry wall deformation due to compression loading on the adherence of ceramic tiling. It was motivated by several ceramic tile debonding cases that have occurred recently, particularly in indoor building where tiles were installed directly over concrete block.

The behavior of ceramic tiling installed over a ceramic block masonry was also studied by Camacho et al. (2015) [1]. Three ceramic block walls were tested with a cement plaster layer before tile installation and another three walls where tiles were directly adhered over the blocks. All tested tiled walls showed no sign of debonding under loads until very close to ultimate load.

The bond strength of tiles, however, is not only a characteristic of the adhesive mortar, but it is determined by the whole system, including the block wall surface, tile surface and installation method, as explained by Guan (1997) [2] in his study of the impact of workmanship. That is why laboratory tests were planned to reproduce the whole tiling system, constructed as it was in the field, including installation techniques.

2. METHODOLOGY

Concrete block wall masonry specimens were built and tested according to Brazilian standards NBR 13279:2005 [3], NBR 15961-2:2011 [4] and NBR 16522: 2016 [5]. All three walls were built with the same kind of block manufactured under the same factory conditions. The only difference between them were the compressive strengths. The walls were tiled on both sides with the same adhesive mortar (AC II), ceramic tile (30 x 46 cm, BIIb absorption class) and installation technique (horizontal single troweling respecting open time of less than 3 minutes). Figure 1 shows the final configuration of the walls.

Thirty days after the tiling installation, each wall was subjected to a compressive loading cycle. The loading cycle was calculated according the actual structural design of a 19-storey structural block wall actual masonry building where debonding defects had occurred.

Figure 1 *– Wall specimens built in the laboratory for the experimental study.*

Tiling bond direct tensile strength was determined through tensile pull-out tests, before and after the wall compression cycles. Pull-out tests were done according to Brazilian standard NBR 13754:1996 [6], which establishes a minimal tensile adherence strength of 0.3 MPa. At least four of six values should be equal to or higher than 0.3 MPa after 28 days of adhesive mortar curing.

The batch of adhesion tests consisted of 24 specimens in each wall, 12 on each face. The wall compression tests were performed at the Structural Laboratory of the School of Engineering of São Carlos at University of São Paulo (EESC/USP). The general data for each wall tested is summarized in Table 1 where Nd is the design axial load resistance.

	WALL 1	WALL 2	WALL 3
STRENGTH OF BLOCK	8 MPa	8 MPa	16 MPa
LOAD % Nd	120 % Nd	200 % Nd	120 % Nd
MAXIMUM LOAD	420 kN	680 kN	593 kN
VELOCITY	35 kN / 3 minutes	50 kN / 3 minutes	50 kN / 3 minutes

Table 1 *– General characteristics of structural masonry concrete block wall specimens.*

During the loading application, the deformations were monitored by vertical transducers (T3 and T4) installed on each wall face and side (T1 and T2), as shown in Figure 2. A horizontal transducer was installed on the third row of ceramic tiles to monitor the horizontal displacement of the wall (T_{hor} - Figure 3).

Eight electric strain gauges (E1, E2, E3, E4, E5, E6, E7 and E8) were also installed, divided into two points (A and B) of each wall in the central row as shown in Figure 4, Figure 5 and Figure 6, to monitor masonry and tiling deformation.

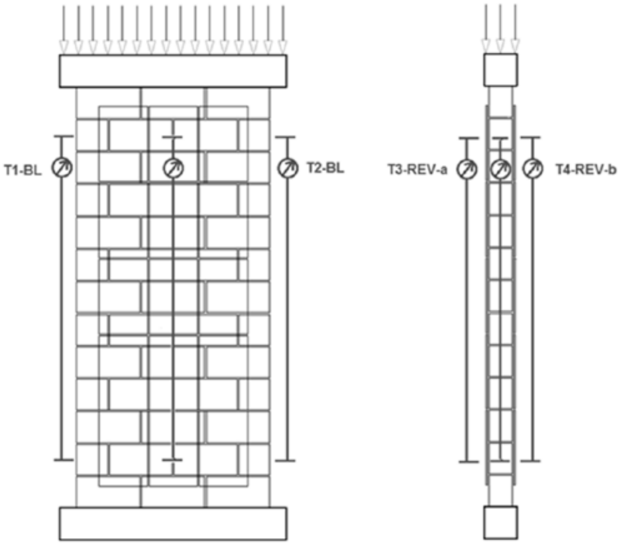

Figure 2 *– Positions of vertical transducers.*
Source: Report EESC/USP (not published)

Figure 3 *– Horizontal transducer as installed.*

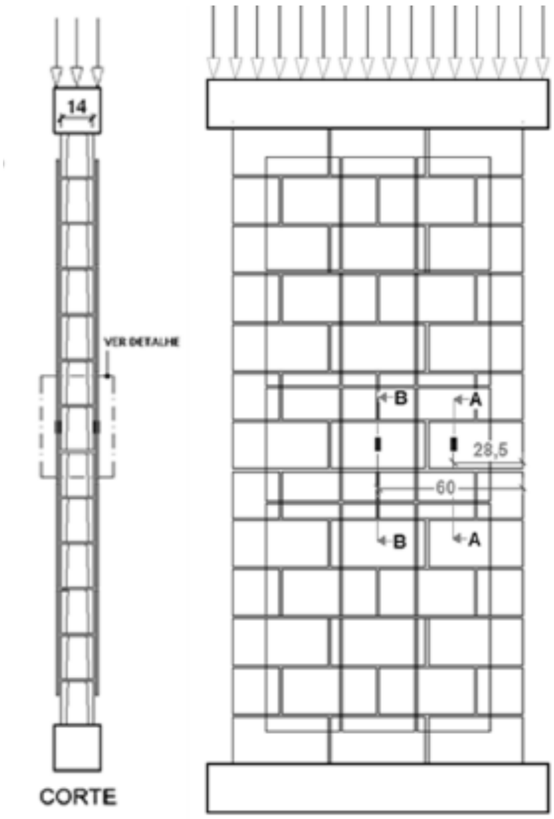

Figure 4 *– Positioning of the strain gauges*
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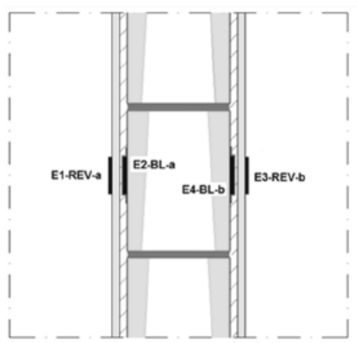

Figure 5 *– Section A-A*
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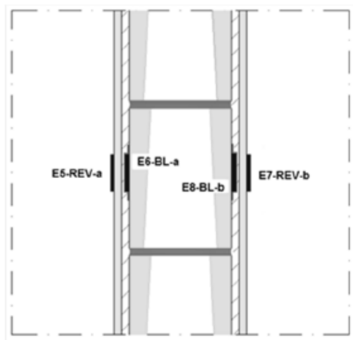

Figure 6 *– Section B-B*
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3. RESULTS

Table 2 shows the maximum deformations observed for each wall. For all walls, T1 and T2 presented similar deformations, indicating symmetrical behavior in their main faces.

Wall 1 presented a slight flexion during compression, which was detected by the horizontal displacement determined by T_{hor} (2.42 mm) and by the variation of the deformation of the transducers and strain gauges positioned on the faces of the wall. This explains why T3 on Side B deformed much less than T4 on Side A, indicating that the wall flexed toward side B. This behavior undermines the deformation analysis, since the wall flexion results have different deformations for each side. Because of this, the results obtained for Wall 1 are shown separately in Table 3.

Maximum deformation (mm/mm)	E1	E2	E3	E4	E5	E6	E7	E8	T1	T2	T3	T4	T_{hor} (mm)
WALL 1	2.0 E-4	2.0 E-4	3.0 E-4	2.6 E-4	1.4 E-4	1.5 E-4	2.4 E-4	2.0 E-4	3.3 E-4	3.0 E-4	8.2 E-5	2.8 E-4	2.42
WALL 2	3.2 E-4	3.7 E-4	3.3 E-4	2.9 E-4	3.2 E-4	3.1 E-4	3.4 E-4	3.4 E-4	4.0 E-4	3.7 E-4	2.7 E-4	3.2 E-4	0.29
WALL 3	2.4 E-4	2.3 E-4	2.0 E-4	3.2 E-4	2.8 E-4	2.8 E-4	2.4 E-4	2.4 E-4	3.4 E-4	3.8 E-4	3.0 E-4	3.7 E-4	0.31

***Table 2** – Deformations during wall compression cycle.*

Walls 2 and 3 presented better behavior for the axial compression test than Wall 1. Both horizontal displacements were only about 0.3 mm and can be considered ideal for the analysis of the studied phenomenon which is the aim of this research.

Table 4 shows that the load–deformation curves of the strain gauges are much closer to each other on these two walls and it allows good comparison of the results. This also indicates that most of the deformation that occurred on the concrete block surface was transmitted to the tile surface. This also means that the adhesive mortar used on the specimen construction was not able to accommodate the deformation originated on the surface of wall, transferring the related stresses straight to the tiles.

Figure 7 shows the average adherence obtained in the tests performed before and after wall compression.

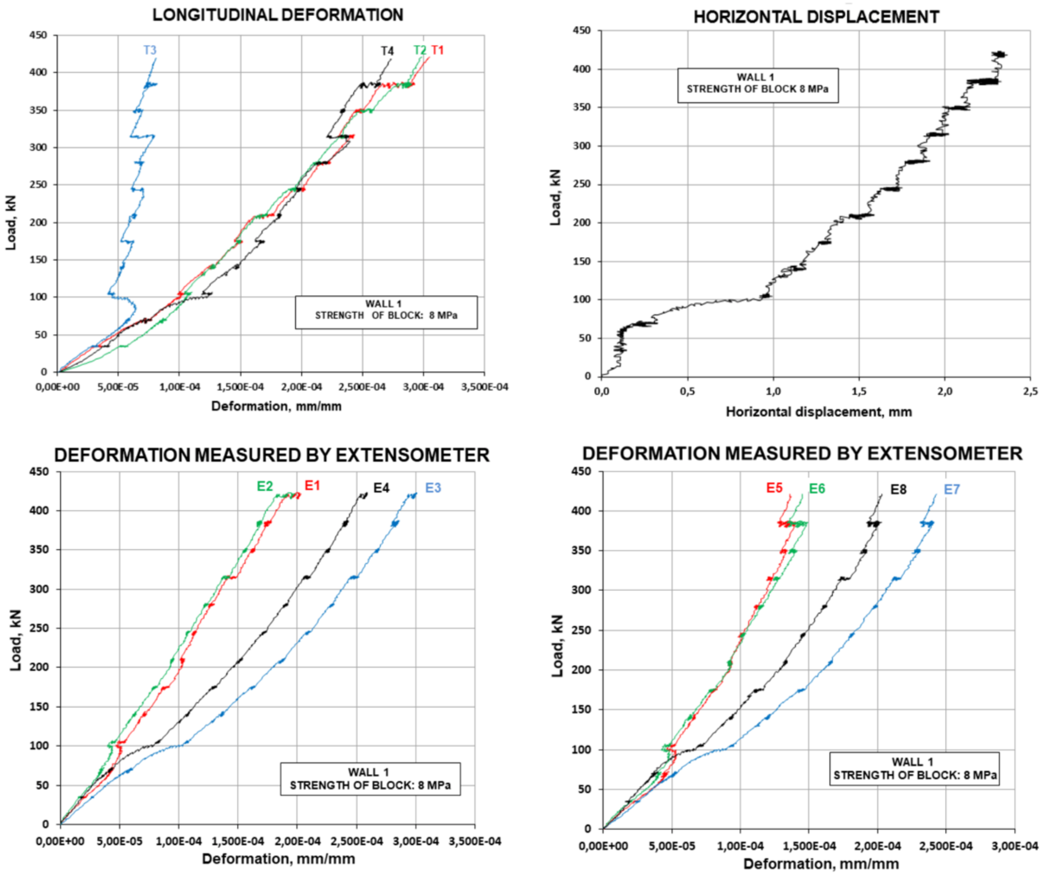

Table 3 *– Wall 1 load–deformation behavior under compression.*

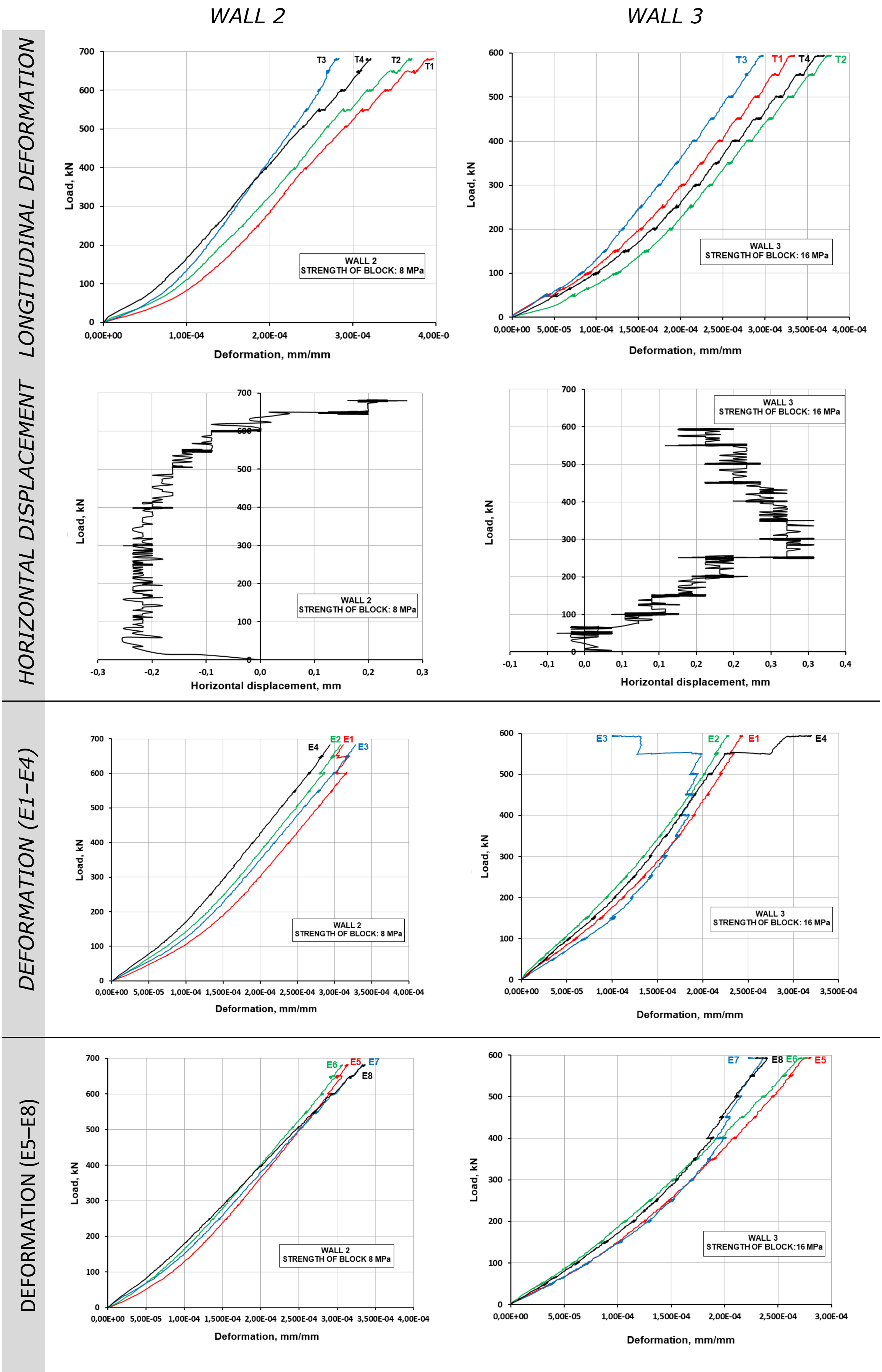

Table 4 *– Wall 2 and Wall 3 load–deformation behavior under axial compression*

The results for Wall 1 show a slight reduction in bond strength after compression. However, as these reduction values in bond results are higher than the coefficient of variation obtained in tests, it is not possible to draw any conclusions regarding the tile bonding tendency.

Wall 2 was loaded close to the ultimate compressive strength (200 % Nd) and showed a clearer tile debonding tendency – this time with much lower results than the statistical variation of results - indicating that tile bonding may have been affected, but just when the load cycle was close to the ultimate load.

Wall 3, which was loaded to 120 % of the design load (Nd), did not show any tendency in tile bonding loss. The pull-out test results were slightly higher after the compression cycle probably due to the high coefficient of variation of the tests.

Figure 8 shows the positioning of each specimen of the compression adhesion tests.

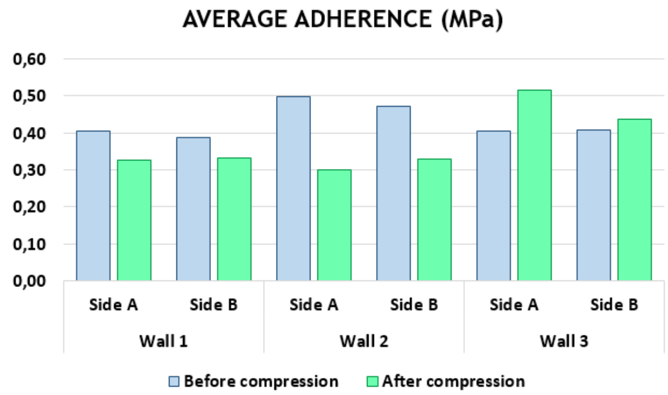

Figure 7 *– Average tile bond strength before and after wall compression tests.*

Figure 8 *– Wall specimen after the compression test procedure.*

4. CONCLUSION

Wall 1 bent slightly, and its center point was displaced about 2.4 mm after compression. This behavior was detrimental to the analysis of the influence of base deformation on tiling adhesion.

Walls 2 and 3 showed a more characteristic behavior during the axial compression test. However, only Wall 2 tiling showed adhesion strength results with a downward trend. This occurred when loading was far above service loads. This wall was the only one subjected to a load of 200% of Nd which represents about four times the service load in actual building design.

On the other hand, all results showed that the adhesive mortar did not have the capacity to accommodate deformations from the background wall, since equivalent deformations were observed both on the concrete block wall surface and on the ceramic tile outer surface.

Overall, the study results indicate that the usual deformations of structural masonry walls subjected to typical service loads do not contribute directly to bonding loss of the ceramic tiling installed over it. These results confirm theoretical analyses (7) (8), another experimental study (9) and literature available on the subject (10).

It may be noted that, in this study, tile bond strength was tested 28 days after installation over 28-day-old walls. Therefore, any eventual contributions from concrete masonry shrinkage was not considered, as suggested by Henrich et al. (11).

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