Construction and Building Materials 24 (2010) 2135–2144

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Masonry wallettes with damp-proof course membrane subjected to cyclic shear: An experimental study

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ARTICLE INFO

Article history:
Received 25 January 2010
Received in revised form 31 March 2010
Accepted 2 April 2010
Available online 4 May 2010

Keywords:
Clay brick
Cyclic shear
Damp-proof course
Embossed polythene membrane
Load tests
Shear behaviour
Shear wall
Unreinforced masonry (URM)

ABSTRACT

Cyclic load tests were performed on two series of unreinforced masonry wallettes with a damp-proof course placed either between the first two masonry courses or between the concrete base and the wallette. Two types of failure were observed, namely sliding and compression (toe crushing) failure. Wallettes that failed in compression exhibited limited energy dissipation. Wallettes which failed through sliding displayed considerable energy dissipation and behaved in a quasi ductile manner. Greater ductility was observed in the wallettes with the DPC in the bed joint rather than at the wallette–slab interface, indicating that the former detail would be more desirable for enhanced seismic performance. Simple analytical models for predictions of failure shear load are proposed and discussed.

1. Introduction

A joint research project by the University of Newcastle and the ETH Zurich on the structural behaviour of unreinforced masonry elements subjected to cyclic shear is underway at the University of Newcastle. The main goal of the research project is to investigate the influence of a damp-proof course (DPC) on the structural behaviour of masonry walls subjected to shear when the DPC is placed in the bed joint or at the interface of the masonry and its supporting concrete slab.

A damp-proof course (DPC) is often placed at the base of masonry walls as a moisture barrier and/or to act a slip joint to allow for differential movements (see Fig. 1). Although it is desirable for the DPC to be sandwiched in the mortar joint, in reality it is usually placed in the joint above or below the mortar. In some cases, the DPC alone is used, particularly if it is serving as a slip joint at the interface between a masonry wall and a concrete slab. Thus a DPC membrane in a joint has the potential to act as a plane of weakness due to the resulting lower shear and tensile capacities of the joint. From a structural design perspective it is therefore important to understand the influence of the DPC on the overall wall behaviour, particularly in relation to the in-plane behaviour of shear walls.

Cyclic load tests were performed on two series of masonry elements with a DPC placed into one of the bed joints. Each series consisted of nine 110 mm thick clay brick masonry wallettes with nominal dimensions of 1200×1200 mm. The DPC was placed either between the first two courses (Series A) or between the concrete base and first masonry course (Series B). In addition, three control specimens with the same dimensions and without a DPC were tested (Series C). The specimens were at first subjected to a vertical pre-compression load which was kept constant during the test and then subjected to a cyclic shear load applied in time steps with prescribed horizontal displacements. Three different levels of pre-compression were considered, see Table 1. For each level of pre-compression, three replicates were tested for Series A and B, resulting in a total of 21 tests being performed.

2. Previous investigation

The previous research activities related to the masonry behaviour under cyclic shear loading have been focused both on theoretical and experimental aspects. A substantial amount of theoretical work has been invested into modelling of structural masonry under cyclic shear. Both analytical and numerical solutions are reported in the literature, e.g. [1–12]. Regardless of the mechanical

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doi:10.1016/j.conbuildmat.2010.04.046

Fig. 1. Typical DPC practice and earthquake performance.

Table 1
Specimen designation for test programme.

Series	Pre-compression stress (MPa)		
	0.7	1.4	2.8
A	A3	A1	A2
B	B3	B1	B2
C	C3	C1	C2

model applied, in order to gain a deeper insight into the behaviour of structural masonry and due to its very complex modelling a verification of structural masonry behaviour which was gained theoretically or numerically is usually obtained from experiments. Furthermore, keeping in mind the composite nature of masonry and its anisotropic behaviour it is desirable to perform tests on a large scale, i.e. full scale. A large number of static, static-cyclic, dynamic and pseudo-dynamic tests on different set-ups and test programmes are reported in the literature, e.g. [9–14]. However, to the authors' knowledge there are almost no reports on (cyclic) shear tests on masonry walls with built-in DPC.

Previous investigation on damp-proof courses in masonry elements concentrated on the study of the behaviour of different damp-proof course membranes subjected to a static, static-cyclic and dynamic loading [15–20]. Griffith and Page [15] performed monotonic, static-cyclic and dynamic shear tests on small masonry elements (triplets) with different types of damp-proof course membranes: bitumen coated aluminium; polythene/bitumen coated aluminium and embossed polythene and reported corresponding friction coefficients. The DPC membranes were placed in both mortar joints of the brick triplet; in one series the middle brick was made of concrete in order to simulate the concrete slab. Test specimens were initially subjected to a certain level of pre-compression which was kept constant during the testing. The load was applied in the out-of-plane direction and the masonry materials used were typical extruded clay bricks with standard 1:1:6 (cement:lime:sand) mortar. These tests indicated that shear can be transmitted through a joint containing a DPC. Reasonable hysteretic behaviour was also observed. In addition, no degradation of the joint was noted even after fifty load cycles. Similar results were reported by Suter and Ibrahim [19] and Zhuge and Mills [20], latter also reported on tests on six unreinforced clay brick wallettes with built-in DPC.

3. Masonry materials and strength

A comprehensive overview of the results of different material tests performed on masonry and its components has been given in the research report [21]. In following, only the summary of these results is presented.

3.1. Masonry materials

Extruded clay bricks with nominal dimensions of 230 × 110 × 76 mm and void area of 25% were used for building the specimens, see Fig. 2. The compressive strength of brick was determined from 10 specimens in accordance with Australian/New Zealand Standard AS/NZS 4456.4:2003 [22]. The mean value obtained from the tests was 39.66 MPa and after applying the aspect ratio factor a mean brick compressive strength of 28.60 MPa was determined. The characteristic compressive strength obtained from the sample was 19.10 MPa.

A typical 1:1:6 mortar (cement:lime:sand) was used for building the wallettes. One batch of mortar was used for each wallette specimen and prepared in the laboratory by an experienced bricklayer. The mortar compressive strength was determined on six cube specimens with 100 mm sides. The cubes were cured in air in the laboratory and tested at 28 days. A mean compressive strength of 5.65 MPa was obtained.

After considering the results of the previous tests on masonry with damp-proof courses [15–18], an embossed polythene membrane was chosen as the damp-proof course for the current tests, see Fig. 2. The membrane was placed either between the first two courses (Series A) or between the concrete base and first masonry course (Series B). During the wallette construction the membrane was firstly placed either directly on the brick course (Series A) or on the concrete base (Series B). The bed joint mortar was then placed on top of the membrane and the bricks of the next course laid on the mortar bed.

3.2. Masonry strength

Masonry compressive strength was determined in accordance with the provisions of Australian Standard AS 3700:2001 [23]. Five tests on three-unit specimens were performed, see Fig. 2. The mean value obtained from the tests was 17.75 MPa (coefficient of variation 15.0%). After applying the aspect ratio factor, mean and characteristic masonry compressive strengths of 14.18 MPa and