LOAD BEARING CAPACITY OF UNREINFORCED MASONRY WALL AND STRENGTHENED BY UHPC

A. F. Mazumder*

Department of Civil Engineering, Presidency University, Dhaka, Bangladesh
**Corresponding Author: mazumder_buet@yahoo.com*

ABSTRACT

The majority of existing masonry buildings using unreinforced masonry walls (URM) has been constructed for low service loads. These buildings consequently do not have enough capacity to dissipate the energy resulting from high service loads, the excitation action during event like earthquake. As a result, there is an urgent need to strengthen these walls in order to improve their ability to withstand to higher service loads. Several strategies for strengthening of masonry structures have been proposed and applied to increase the axial strength of masonry. The new generation of advanced concrete technology, ultra-high performance concrete (UHPC), has created enormous possibilities for innovative construction utilization. This work addresses the behavior of strengthening concrete block masonry walls subjected to axial compression loading and retrofitted by UHPC plastering on both sides of the wall, with mortar having microsilica as strength modifier and steel fibers as reinforcing additive.

Keywords: URM; UHPC; strengthening

INTRODUCTION

Masonry wall is one of the most popular and common type of structural component in the world which has a long history and is beautiful in appearance, low cost and ease of construction. Masonry wall is the component of structures made from individual units laid in and bonded together by using mortar. The key advantages of masonry wall are the thermal mass of a building and protection of the building from fire has been increased, there is no requirement of painting and resulting reduced life-cycle costs and useful life cycle is 30 to 100 times higher than structural steel. Most common uses of masonry wall are for partition walls, structural wall, and retaining wall and even in heritage structures. It is well-known that those structural elements are constructed mainly of unreinforced masonry wall (URM). These URM walls are subjected axial load, earthquake load etc. URM walls can be used as load-bearing wall, if proper strengthening material is used. Some researchers had used CFRP, GFRP sheet and bars, testile reinforced mortar (Basaran et al, 2013; Vasconcelos et al, 2012; Mahmood et al, 2008; ElGawady et al, 2006; Zhao et al, 2003 for strengthening. URM wall can be more useful for load-bearing type of wall with proper strengthening techniques and cementitious material could be one of the possible solutions. Ultra-High Performance Concrete (UHPC), also referred as Ultra-High Performance Fiber Reinforced Concrete (UHPFRC), is a new generation of cement-based materials that was developed in France in the 1990s. UHPC is relatively a new generation of concrete optimized at the micro and nano-scale to provide superior durability and mechanical properties compared with conventional and high performance concretes. Improvements in UHPC are achieved through limiting the water-cementitious materials ratio (w/cm < 0.2), optimizing particle packing, eliminating coarse aggregate, using specialized materials and implementing high temperature and high pressure curing regimes. In addition, randomly dispersed and short fibers are typically added to enhance the material's tensile and flexural strength, ductility and toughness. Some researcher studied the physical and mechanical properties of UHPC (Hakeem, 2012; Wang and Lee, 2007). The improved mechanical properties of UHPC give the indication to be used as strengthening material.

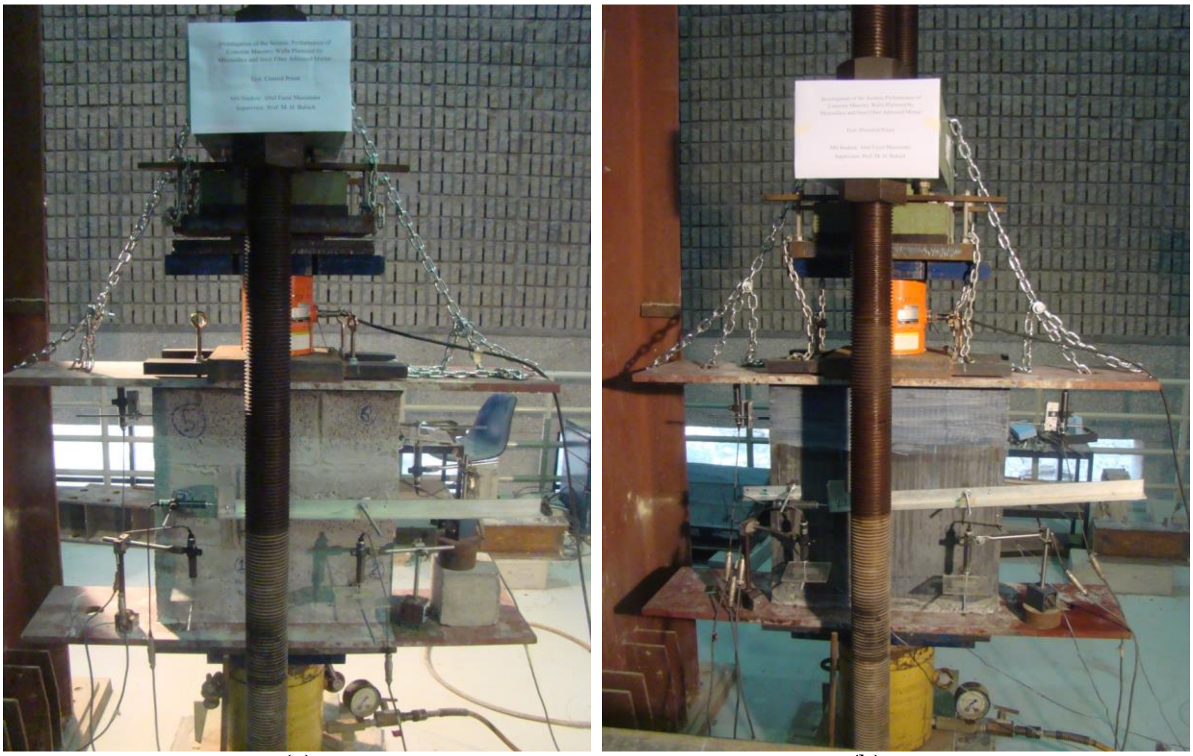
The main objectives of this study are a) to investigate the mechanical properties of block, mortar, and UHPC b) to investigate the axial capacity of Unreinforced Concrete Masonry Prism (NCMP) and c) to investigate the axial capacity of Unreinforced Concrete Masonry Prism Retrofit (NCMPR), which is UHPC plastered NCMP.

METHODOLOGY

The load bearing capacity of unreinforced concrete masonry prisms were evaluated on the basis of axial load tests. In this test incrementally increased vertical load was applied to the prism. Experimental program included two tests conducted on two prisms. The first one was unreinforced masonry prism (NCMP), second one was unreinforced masonry wall but plastered by 12.5 mm thickness of UHPC on both sides of the wall (NCMPR).

Construction of Test Specimen

In this study, two unreinforced concrete masonry prism were used under axial loading test. One of the prisms was made of concrete masonry blocks (400×200×100 mm) and Portland cement mortar. Another NCMP prism was plastered with UHPC by 12.5 mm thickness (NCMPR). The aspect ratio for all walls was kept to be 1. Height to thickness of the wall ratio was 60.
The key ingredients of UHPC include micro silica and steel fiber. There were two types of steel fibers used in the same mix. One of these steel fibers was straight and other one was hooked end. Hooked end steel fibers were used for better gripping and anchorage. The developed UHPC mix was utilized for strengthening. The UHPC was mixed in a horizontal pan mixer. After casting specimens were cured for 28 days under water curing process. After curing period was completed, the specimens were tested.



(a) (b)

Fig. 1: Experimental Setup, (a) NCMP and (b) NCMPR

Experimental Setup, Instrumentation and Procedure

According to ASTM C 1314 and European Standard EN1052-1(1999), masonry prisms (NCMP and NCMPR) were tested under uniaxial compressive load. To conduct the test, the prisms were placed in the proper position within a steel frame fabricated for purpose of testing under compressive load. Placing of the prism was critical issue, which the prism has to be perfectly aligned vertically and horizontally so that the application of vertical load using the hydraulic jack actuator will not result eccentricity when applying load. Laser leveler was used so that perfect alignment could be achieved. The axial compression forces were exerted on the prism through a steel plate attached to the top and bottom of the wall. High strength mortar (BASF EMACO S88C) was placed in top surface of the prism to ensure uniform distribution of the axial force on the prism without any stress localization. The wall deformations, vertical as well as horizontal, were captured and recorded using four vertical CDP-25 LVDTs and one horizontal CDP-25 LVDTs attached to the prisms at different positions [Figure 1].

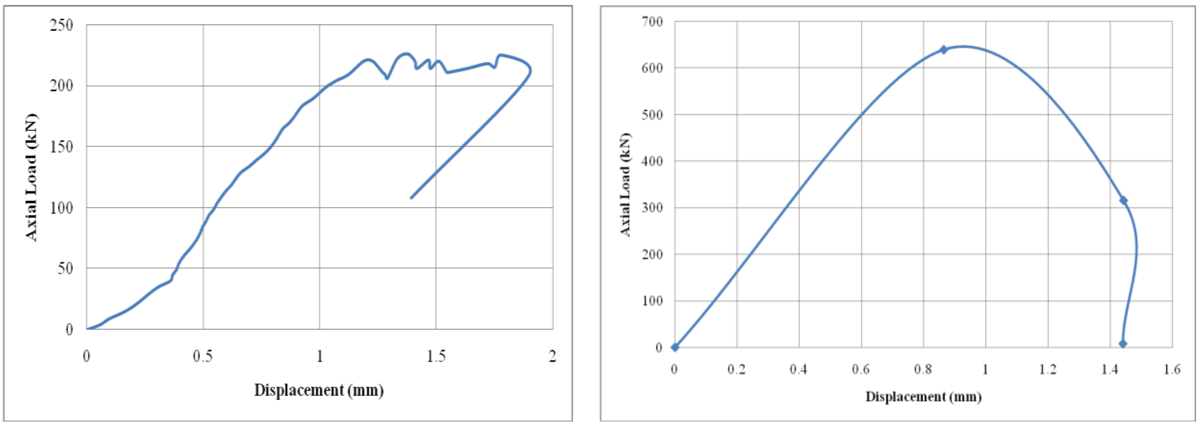
Material Properties

Mechanical properties of various wall components, like concrete masonry block unit, mortar, UHPC were found out by experimental tests. According to EN 772-1 European Standard 2000, compressive strength of concrete masonry blocks was obtained and average value was 9.46 MPa. Modulus of elasticity and Poisson ratio of concrete masonry blocks was 4 GPa and 0.15, respectively.

Blocks were attached in the walls by mortar. The water/cement and cement/sand ratio was kept to be 0.6 and 1/3 respectively. Compressive and flexural strength of mortar was 30 MPa and 2 MPa respectively. Specimens were tested after same age curing of walls. The modulus of elasticity was recorded to be 20.5GPa and Poisson ratio to be 0.18. In case of UHPC, average compressive strength found to be 128 MPa (150×150×150 mm specimens) in compression test and 11.5 MPa was found in direct tension test (Dog-Bone Test). The modulus of elasticity was obtained 45 GPa and Poisson ratio was 0.26.

RESULTS AND DISCUSSIONS

The experimental work was carried out in two specimens. The maximum compressive strength was recorded to be 5.28 and 11.13 MPa for NCMP and NCMPR prisms, respectively. So, the axial strength was increased by 111% approximately for NCMPR, comparing with NCMP. The maximum displacement captured in case of NCMPR was 1.44mm, which was lower than the NCMP. So, the plaster made the NCMPR prism stiffer than NCMP. Axial load Vs vertical displacement diagram is shown in Figure 2.



(a) (b)

Fig. 2: Axial Load Vs Displacement Diagram, (a) NCMP and (b) NCMPR

CONCLUSIONS

An innovative system for strengthening concrete masonry walls using UHPC plaster has been investigated. As a retrofit measure, UHPC plaster is congruous and compatible with the existing NCMP in contrast to other retrofitting techniques including use of CFRP and other non-cementitous materials. Following conclusions can be drawn from this study:

- UHPC plaster of plaster thickness to wall thickness ratio of 0.25 was able to increase the strength of the URM wall by an order of 111%.
- Use of UHPC plaster resulted in increase of overall stiffness of the URM wall.

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