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Performance of Partially Bonded Engineered Cementitious Composites (ECC) In Concrete Block Masonry

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ABSTRACT. *The objective of this study is to examine the behavior and determine the potential implications of Engineered Cementitious Composites (ECC) to strengthen the concrete block masonry by using a unique method of partially bonding the tension face as tension strengthened beam under the out of plane loadings. The specimens under investigation were comprised of two categories i.e. un-strengthened concrete block masonry beams and tension strengthen beams with different thicknesses of ECC layers. All the specimens were experimented under the four point loadings to evaluate the flexural performance of fabricated beams. The current study reveals that the partially bonded ECC strengthening of concrete block masonry beams has significantly improved the strength and deformability.*

Keywords: Engineered cementitious composites, concrete block masonry, four-point loading.

1. INTRODUCTION

Concrete Block masonry walls are widely constructed for building structures, due to its high compressive strength, cost effectiveness, locally available material and time efficient technique for the construction across worldwide. However, the prevailing parameters under lateral loading i.e. out of plane efficiency and deformability of these masonry structures are sufficiently less that need to be enhanced with retrofitting techniques. It is therefore necessary to improvise the block masonry walls to enhance their capacity to embark the out of plane loads while maintaining the structure durability and safety [1, 2].

Owing to the safety concerns and low resistance against the out of plane loadings different techniques have been adopted to strengthen the masonry structures. The application of steel mesh with cement or concrete [3-7], usage of precast strips made of Fibre reinforced polymers (FRP) or in form of layers applied onto the masonry [8-10] and strengthening of concrete block masonry with CFRP composite to enhance the soundness and durability [11] are different methods that have been employed.

The use of different composite materials i.e. Engineered Cementitious Composites (ECC) onto the surface of walls has significantly enhanced the out of plane behavior in respect of deformability and strength as compared to the un-strengthened masonry walls. The application of ECC as partially bonding technique onto the brick masonry surface has enabled the structures to achieve maximum deformability before the structure fails [12].

Moreover, the ECC in the form of strips has been found to strengthen the masonry structures with enhanced deformability and strength and proved itself a reliable composite material to retrofit the masonry structures [13].

The aim of current study is to investigate flexural performance of externally strengthened concrete block masonry beams by using the partially bonding technique with different thicknesses of ECC layers on the tension face and to find out the most suitable thickness of ECC for tension strengthened beam.

2. EXPERIMENTAL PROCEDURE

The experimental investigation was performed in four stages. First, four block masonry beams were cast, with each beam consisting of eight concrete blocks and cement mortar of 1:3 was used between the blocks to constitute the block masonry beam. Secondly, Engineered Cementitious Composites (ECC) was prepared. Thirdly, partially bonded ECC layer was applied on the tension face of the beam (tension strengthened beam). Fourth, four-point bending tests were executed on Un-Strengthened Control beams (series-A) and partially bonded tension strengthened beams (series-B).

2.1. Detail of Experimented Beam

For experimentation 04 numbers block masonry beams were cast having length of 835 ± 25 mm, width of 300 mm and depth of 200mm. Each block masonry beam consists of 8 blocks with 7 joints in between the blocks. The thickness of each mortar joint is approximately 10mm. 01 beam (Series-A) act as a control beam that is unstrengthen beam without any application of ECC layer. 03 beams (Series-B) specimen were strengthened by applying different thicknesses of ECC layer (i.e. 10mm, 20mm and 30mm) partially on the tension face (bottom side) in a way that middle third portion was un-bonded by fitting duct tape on the face of blocks to avoid the interfacial bond of blocks and ECC. The detail of experimented block masonry beams is shown in the Table 1.

Table - 1: Summary of Flexural Tests Performed on Beams

Series	**Sr. No.**	**Specimens**	**Specimen ID**	**Thickness**
				Tension Face
A	01	Unstrengthen control block masonry beams (Non-retrofitted)	A-1	-
B	02	Partially bonded tension strengthened block masonry beams	B-1	10 mm
	03		B-2	20 mm
	04		B-3	30 mm

2.2. Constituents of ECC

In this research, ECC was prepared with 12mm long Polypropylene (PP) fibres (at a dosage of 2% by volume), cement, sand, fly ash and water. For enhanced workability and strength of ECC, high-range superplasticizer (SP) as Polycarboxylate at the dosage of 1% by weight of cement was used in the ECC mixture. Local fine sand was used as a filler for ECC and water cement ratio was used as 0.28 by volume. The fly ash / cement ratio (by mass) was retained at 1.8. Moreover, the sand/cement ratio (by mass) was used as 0.6. The ECC mixture was prepared by blending the cement and sand in the mortar mixer till the mix is homogenous then, fly ash was added and blended again along with the water. Hereafter, superplasticizer SP and Polypropylene fibre were added in the requisite amount accordingly.

3. RESEARCH METHODOLOGY

All the beams were cast with the cement mortar of 10mm thickness and each with 8 numbers of blocks. Then these block masonry beams were cured for 14 days by covering specimen with damp Hessian, thus the pre-strengthened fabrication process of beams was accomplished. Series-A specimen was kept as benchmark for the un-strengthened beam (see Fig.1a). Now, for strengthening with ECC the beams' surface was wetted, so that the absorption of water by the block surface could be minimized from the fresh ECC. For series-B i.e. tension strengthened beams the specimen were partially strengthened with ECC by placing the duct tape on the middle third length of beam to avoid the interfacial bond of block masonry and ECC layer, as shown in the Fig.1(b).

3.1. Instrumentation and Testing of Block Masonry Beams

All the concrete block masonry specimens were tested under the four-point loading. The load was applied monotonically till the failure of the beam. The deflection gauges were placed at the soffit of the beam to measure the vertical deflection. The schematic illustration of four-point bending setup is show in Fig. 1(c).

4. RESULTS ANALYSIS AND DISCUSSION

4.1. Un-strengthened Control Block Masonry Beams

The behavior of unstrengthen block masonry beam specimen (series-A) under four-point bending is illustrated in the Fig. 2(a). The beam specimen without any strengthening failed abruptly soon the crack occurred and did not exhibit substantial signs of cracking before failure commenced, thus brittle failure was observed at maximum load of 2.24 KN and the mid span deflection appeared as 0.11 mm.

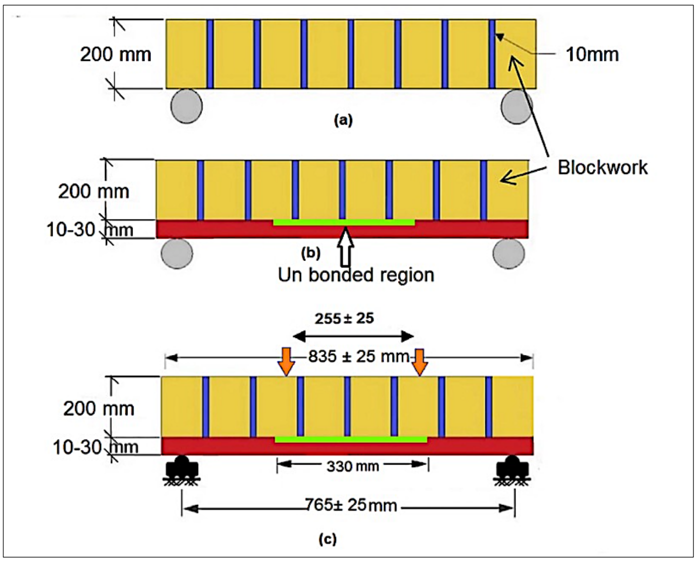


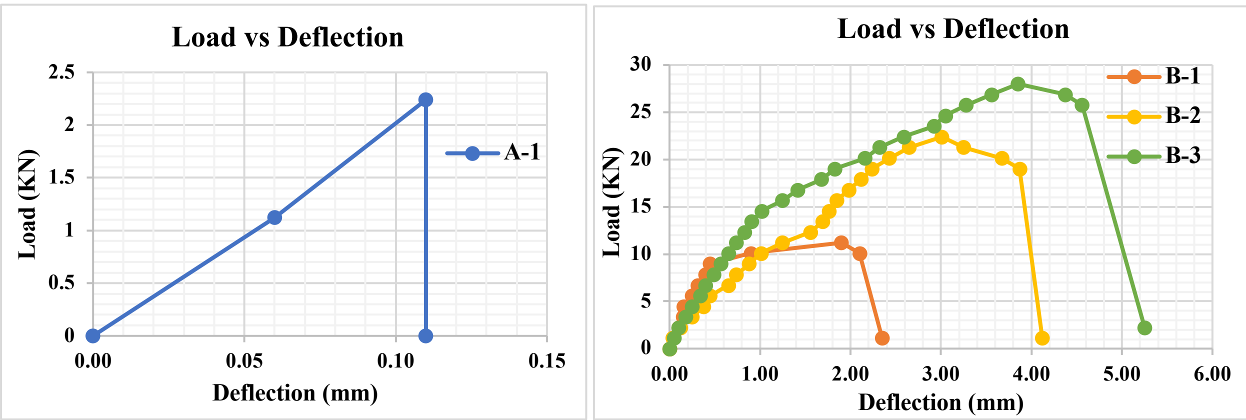
Fig - 1: Schematic diagrams of Block Masonry beams (a) Un-strengthened control block masonry beam (series-A), (b) Partially bonded tension strengthened concrete block masonry beams (series-B), (c) Four-Point Loading Setup of beams.

4.2. Un-strengthened Control Block Masonry Beams

The response of concrete block masonry beam specimen, partially bonded with the ECC layer of multiple thicknesses i.e. 10mm, 20mm and 30mm on tension face (series-B) under the four-point loading has been expressed as load-deflection curve in the Fig. 2(b). The maximum load and the respective deflections at mid span are shown in Table 2. It is observed that overall load carrying capacity and deformability increased after strengthening with partially bonded ECC layer of variable thicknesses as compared to the un-strengthened beam specimen.

Table - 2: Summary of four-Point Loading Results

Series	Sr. No.	Specimen ID	Peak Load (kN)	Mid Span Deflection (mm)
A	01	A-1	2.24	0.11
B	02	B-1	10.08	2.10
	03	B-2	22.40	3.01
	04	B-3	28.00	3.85



(a) (b)

Fig - 2: Load deflection response of four-point bending Test (a) Un-strengthened Control block masonry beam (series-A), (b) Partially bonded tension strengthened concrete block masonry beams (series-B)

The specimen showed linear behaviour before the substantial cracking initiated and then a deflection curve due to the tensile behaviour of ECC and un-bonded region at the middle third length which allowed the specimen to deform significantly as the load kept increasing on the specimen until rupture occurred. It is observed that, maximum load carrying capacity and maximum deformation was shown by the B-3 masonry specimen having

ECC thickness of 30mm. The maximum load and corresponding mid span deflection of B-3 is 12.5 times and 35 times higher than the un-strengthened specimen respectively, the failure of A-1 and B-3 is shown in the fig .3(a) and 3(b) respectively.

Fig - 3: Failure at four-point loading of (a) Un-strengthened Control block masonry beam (series-A), (b) Partially bonded tension strengthened concrete block masonry beams (series-B)

5. CONCLUSIONS

The study adopts the techniques of strengthening the block masonry with partially bonded ECC for better performance of masonry structures subjected to out of plane loadings. Consequently, the flexural response of partially bonded tension strengthen beams with different thickness of ECC layers was studied experimentally under the four-point bending tests.

1. The un-strengthened block masonry beam specimen could withstand the out of plane loading marginally and collapsed with brittle failure at an average load of 2.61 kN and deformation of 0.12 mm at mid span.
2. For the concrete block masonry beams partially strengthened with ECC on tension face (series-B), the deformability and maximum load carrying capacity increases with the increase in thickness. The maximum load carrying capacity and corresponding maximum deflection was achieved with 30 mm ECC thickness. The maximum load and corresponding mid span deflection for B-3 is 12.5 times and 35 times higher than the un-strengthened control concrete block masonry specimen respectively.

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