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CFRP Application in Retrofitting of Masonry Wall

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ABSTRACT

This study explores the result of an experimental investigation for enhancing shear strength of masonry wall, strengthened with Carbon Fiber Reinforced Polymer (CFRP) strips. Total 18 numbers of specimens were casted. Out of this 9 specimens were tested for standard condition and 9 were for deteriorated condition in that three were tested with CFRP wrapping respectively. The dimensions of all masonry wall panels are kept same throughout the experiment. Experiments are conducted to study the shear strength of masonry walls with and without FRP using local available materials. For the experiment shear compression test was conducted. Deterioration of the specimens is done by using solutions of calcium chloride ($CaCl_2$) with 3 molal ion concentrations. The experimental results demonstrated that the use of CFRP composite strips increases the shear strength of the masonry wall significantly by preventing the debonding of CFRP sheets, so that the full strength of the CFRP sheets get utilized.

Keywords: CFRP, $CaCl_2$, Shear Compression Test

I. INTRODUCTION

Deterioration in structures is a major issue faced by the infrastructures industries all over the world. Since complete replacement of these structures requires high investment, strengthening has become the suitable solution to modify and improve the performance of the structures. The strengthening using FRP composites has become a popular structural strengthening technique, due to the well-known advantages of FRP composites such as their high strength-to-weight ratio and excellent corrosion resistance. This civilization depends upon the continuing performance of its civil engineering structures ranging from residential & industrial buildings to power stations and bridges. Structure is normal or special these are precious part and are promptly associated with living as well as nonliving things. During its whole life span, nearly all engineering structures faces degradation or deteriorations. The main causes for those deteriorations are environmental effects including corrosion of steel, gradual loss of strength with ageing, variation in temperature, freeze-thaw cycles, repeated high intensity loading, contact with chemicals and saline water and exposure to ultra-violet radiations. This problem needs development of successful structural retrofit technologies.

To overcome this problem advanced composite materials such as carbon fiber reinforced polymer (CFRP) composites are used for retrofitting of structures. CFRP repair is a simple way to increase both the strength and design life of a structure. Because of its high strength to weight ratio and resistance to corrosion, these repair method is ideal for deteriorated concrete structure.

This work is focused on effects of CFRP wrapping for standard and deteriorated masonry wall panels with and without CFRP wrapping. The objective of study to carry out comparative study of the standard masonry wall with masonry wall wrapped with CFRP in terms of structural performance. To investigate the Failure Patterns for same specimens. The masonry wall panels are designed as per ASTM C1717-09. The shear compression test on wall is carried out as per guidelines from ASTM E574 (2000).

II. GEOMETRY OF MASONRY WALL PANELS

The geometry of all masonry wall panels is as per ASTM C1717-09. The sizes are 700 mm length, 700 mm width and 230 mm thickness. The bricks used are first class conventional bricks of size 230*110*70 mm. The dimensions of all masonry wall panels are kept same throughout the experiment. Experiments are conducted to study the shear strength of masonry walls with and without FRP using local available materials. All the masonry wall panels are gradually test loaded up to failure. Total 18 numbers of specimens were constructed. Out of this 9 specimens were tested for standard masonry walls and 9 were for deterioration in that three were tested with CFRP wrapping respectively.

A. Deterioration of specimens

The Specimens are deteriorated by using second class bricks instead of first class and also by using cement mortar grade 1:6 instead of 1:4. The specimens were exposed to weekly cycles of wetting and drying in water and in solutions of calcium chloride (CaCl2) with 3 molal ion concentrations, equivalent in ion concentration to a 7.5% solution $CaCl_2$. The specimens were cured in solution for 7 days. After 7 days, they were removed from the solution and dried in air. Cycles were repeated for 5weeks. Nine Specimens were used to deterioration.

B. Design of CFRP for masonry wall panels

TABLE I
CFRP PROPERTIES

Thickness per ply	t_f	1.02mm
Ultimate tensile strength	f^*_{fu}	621N/mm^2
Rupture Strain	ε^*_{fu}	0.015mm/mm
Modulus of elasticity of FRP laminates	E_f	37000N/mm^2
Environment factor	C_E	0.95

Number of Ply: 1
Type of Wrap: 150mm wide strips wrapped diagonally
The strengthened specimen is capable of sustaining the new required strength.

III. EXPERIMENTAL PROGRAMME

All the specimens are tested in loading frame of the Applied Mechanics Laboratory, Walchand College of Engineering, Sangli. After curing for 7 days and 28 days, standard specimens are tested one by one applying load slowly up to failure load. The shear-compression test was performed in two steps. The in-plane shear on a masonry wall can be directly simulated by subjecting a wall to a vertical load and then subsequently to a static or dynamic horizontal load at the top of the wall. Because of the horizontal force, shear is applied on the brick masonry wall panel. The horizontal and vertical loads lead to tension and shear combined with compression in the masonry wall. The masonry was loaded by a combination of normal compression and shear as per ASTM E 574 [2000].

A. Loading Pattern

The Fig.1 given below shows the typical test arrangement under multiple concentrated loads applied vertically and horizontally in the structural laboratory.

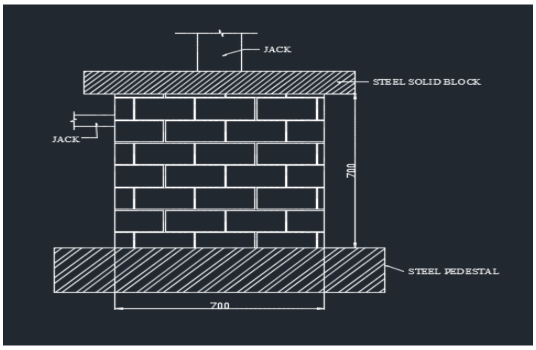

Figure 1: Test Setup

IV. Test Results and Discussions

This chapter interprets the results obtained from the experimental investigation which comprises of testing of eighteen masonry wall panels. The behaviour of the masonry walls with respect to shear strength, crack pattern and deflection is studied throughout the test and their failure modes are described.

A. Test Results for Standard Specimens

The standard specimen is not strengthened with CFRP composites and not deteriorated. To study the behaviour of the failure without strengthening. It is tested under the vertical and horizontal static loading system by applying the loads gradually. The experimental setup is shown in previous chapter. The average load at failure for 7 days specimen is 13 kN and the shear strength is calculated as 0.082 MPa, failure pattern is observed as diagonal shear failure. For 28 days test the average load at failure is 25 kN and the shear strength is calculated as 0.1532 MPa.

TABLE II
TEST RESULTS OF STANDARD SPECIMENS FOR 7 DAYS

Specimen	**Failure Load (kN)**	**Maximum Displacement (mm)**	**Average Shear Strength (MPa)**
Wall 1	12	4.3	0.082
Wall 2	15	5.4	
Wall 3	13	4.7	

TABLE III
TEST RESULTS OF STANDARD SPECIMENS FOR 28 DAYS

Specimen	**Failure Load (kN)**	**Maximum Displacement (mm)**	**Average Shear Strength (MPa)**
Wall 4	24	6.4	0.153
Wall 5	25	6.3	
Wall 6	25	6.7	

B. Test Results for Deteriorated Specimens

The deteriorated specimen is not strengthened with CFRP composites. It is deteriorated by using second class bricks instead of first class and also by using cement mortar 1:6 instead of 1:4. To study the behaviour of the failure without strengthening. It is tested under the vertical and horizontal static loading system by applying the loads gradually. The average load at failure for 7 days specimen is 12 kN and the shear strength is calculated as 0.0766 MPa, failure pattern is observed as diagonal shear failure. For 28 days test the average load at failure is 22 kN and the shear strength is calculated as 0.138 MPa.

TABLE IV
TEST RESULTS OF DETERIORATED SPECIMENS FOR 7 DAYS

Specimen	Failure Load (kN)	Maximum Displacement (mm)	Average Flexure Strength (MPa)
Wall 1	12	4.6	0.0766
Wall 2	12	4.4	
Wall 3	13	5.3	

TABLE V
TEST RESULTS OF DETERIORATED SPECIMENS FOR 28 DAYS

Specimen	Failure Load (kN)	Maximum Displacement (mm)	Average Flexure Strength (MPa)
Wall 4	22	5.8	0.138
Wall 5	23	6.2	
Wall 6	22	5.9	

C. **Load Vs Displacement Graph for Specimens without Strengthening**

Specimens are tested after 7 days and 28 days curing in loading frame. The masonry wall panels are tested one by one by applying load slowly up to the failure load and deflection is measured by using gauge located at the top of a wall specimen.

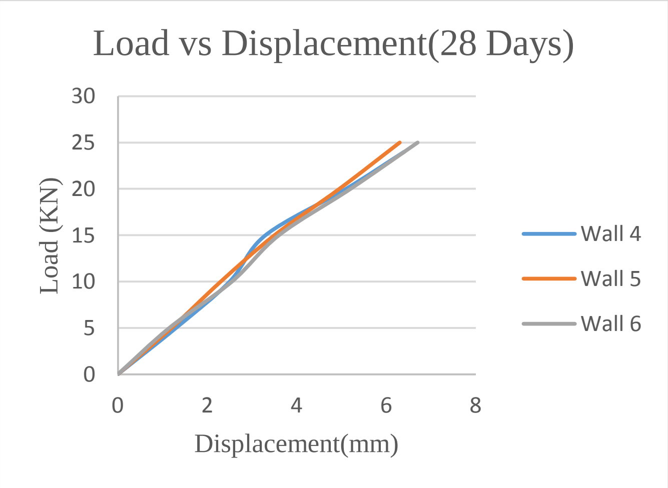

Figure 2: Load Vs Displacement Graph of Standard Specimen

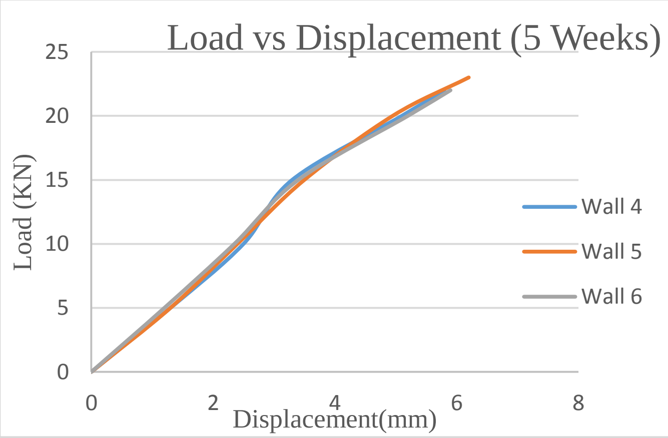

Figure 3: Load Vs Displacement Graph of Deteriorated Specimen

D. **Test Results for CFRP Wrapped Specimens**

The specimens are strengthened with bidirectional woven CFRP strips of 1 layer bonded to the specimen diagonally with 2 strips of equal width of 150 mm. The testing of specimens is same as above. . The average load at failure for standard specimen is 36 kN and the shear strength is calculated as 0.2215 MPa. For deteriorated specimens the average load at failure is 32 kN and the shear strength is found as 0.201 MPa. The sliding failure is observed in the masonry wall with diagonal shear failure.

TABLE VI
TEST RESULTS OF STANDARD SPECIMENS WRAPPED WITH CFRP

Specimen	Failure Load (kN)	Maximum Displacement (mm)	Average Shear Strength (MPa)
Wall 1	37	5.9	0.2215
Wall 2	35	5.3	
Wall 3	35	5.7	

TABLE VII

TEST RESULTS OF DETERIORATED SPECIMENS WRAPPED WITH CFRP

Specimen	Failure Load (kN)	Maximum Displacement (mm)	Average Shear Strength (MPa)
Wall 4	32	5.2	0.201
Wall 5	32	4.9	
Wall 6	33	5.5	

E. **Load Vs Displacement Graph for Strengthened Specimens**

The masonry wall panels are tested one by one by applying load slowly up to the failure load and deflection is measured by using gauge located at the top of a wall specimen.

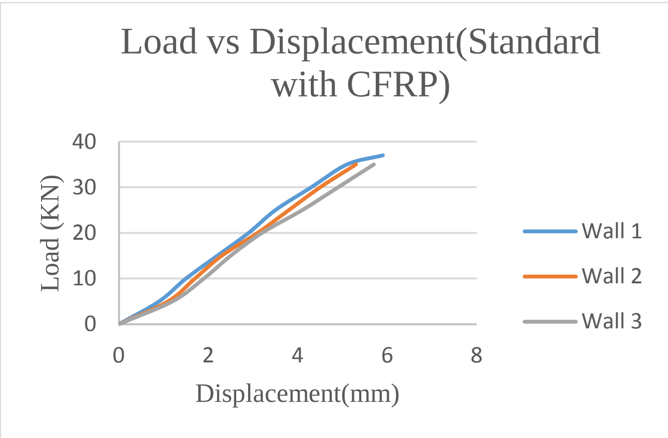

Figure 4: Load Vs Displacement for standard specimen wrapped with CFRP

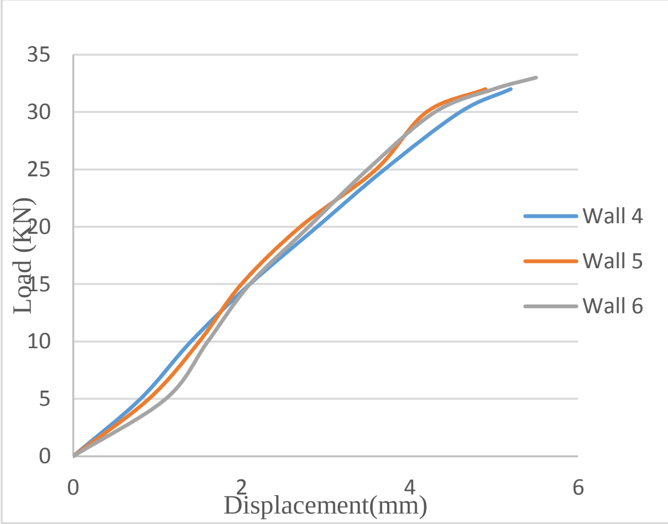

Figure 5: Load Vs Displacement for deteriorated specimen wrapped with CFRP

F. **Comparison of Load for Standard Wall Specimen with CFRP Wrapped Specimen**

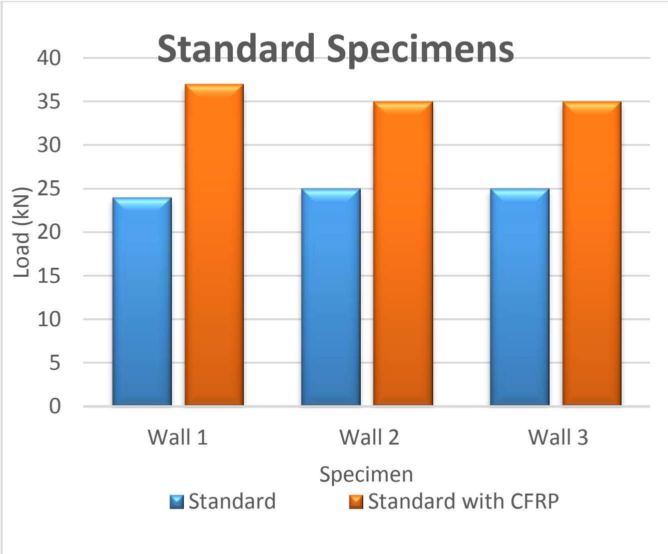

Figure 6: Comparison of Load

Graph shows that strength of standard specimen is enhanced by 44.77% due to CFRP wrapping.

G. **Comparison Load for Deteriorated Specimen with CFRP Wrapped Deteriorated Specimen**

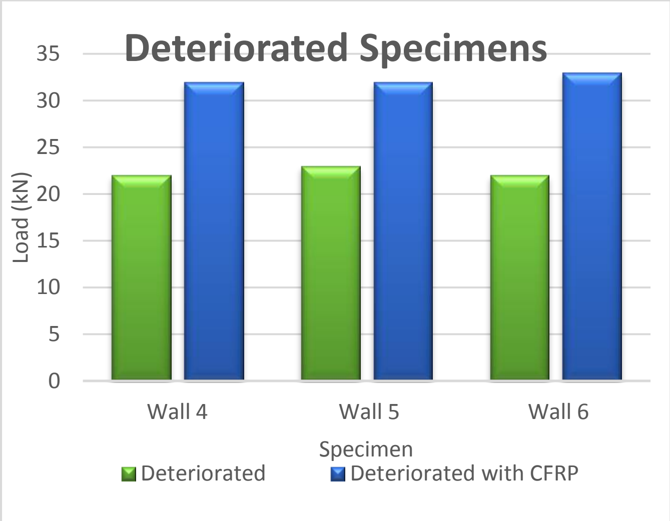

Figure 7: Comparison of Load

Graph shows that strength of deteriorated specimen is enhanced by 45.65% due to CFRP wrapping.

H. **Failure Patterns of Masonry Wall Specimens**

Diagonal shear crack appeared from top left corner to the bottom right corner.

Due to wrapping the failure pattern changed from diagonal shear crack to sliding failure.

V. Conclusions

- The shear strength of deteriorated specimen decreased by 9.8% as compared to standard specimen.
- After application of CFRP the shear strength of standard specimen is approximately increased by 44.77%.
- After application of CFRP the shear strength of deteriorated specimen is approximately increased by 45.65%.
- The initial cracks in strengthened specimens are formed at higher load as compared to the standard specimens.
- Diagonal shear failure pattern is observed for standard specimens.
- The diagonal crack & sliding failure patterns are observed for strengthened specimens.

VI. REFERENCES

1. Hasim Ali Khan, Radhikesh Prasad Nanda, Diptesh Das. “In-plane strength of masonry panel strengthened with geosynthetic”, ELSEVEIR, Construction and Building Materials 156, 351-361, 2017.
2. Mohammad Z. Kabir et al., “Experimental investigation on out-of-plane behavior of GFRP retrofitted masonry panels”, Construction and Building Materials, Vol. 131, pp. 630-640, 2017.
3. C Mazzotti et al., “Diagonal compression tests on masonry panels strengthened by FRP and FRCM”, Structural Analysis of Historical Constructions, ISBN 978-1-138-02951-4, 2016.
4. M Jarc Simonic et al., “In-situ and laboratory tests of old brick masonry strengthened with FRP in innovative configurations and design

considerations", Springer Science Business Media Dordrecht, Vol. 13, pp. 257-278, 2015.
5. Saghafi M. H. et al., "In-Plane Shear Behavior of FRP Strengthened Masonry Walls", Selection and peer review under responsibility of Asia-Pacific Chemical, Biological & Environmental Engineering Society, Vol. 9, pp. 264-268, 2014.
6. S Arifuzzaman and M. Saatcioglu, "Seismic Retrofit of Load Bearing Masonry Walls by FRP sheets and Anchors", World conferences on Earthquake Engineering, 2012.
7. N Torunbalci et al., "An experimental study on alternative CFRP retrofitting applications of heritage structures", International Journal of Sustainable Development and Planning, Vol. 6, pp. 152-165, 2011.
8. Saghafi M. H., "Seismic performance of URM panels reinforced by FRP", Department of Civil Engineering, University of Semnan, 2009.