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Retrofitting of Confined Brick Masonry with FRP

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Abstract: ***Brick masonry structures are commonly used in world because of its simplicity and economy. However, it is susceptible to failure in earthquakes because of the bricks weak interlocking bonds and brick masonry structures designed mainly against gravity load demand. Therefore, in recent years research work has been conducted to confine the unreinforced brick masonry with reinforced concrete tie beams and column, to improve its seismic performance. This enhances both the lateral resistance and stability of the entire structure, to perform as one mass unit against the lateral forces. However, the effect of confining brick masonry through reinforced concrete member has been evaluated in the past only on testing single cantilever walls or single room. Therefore, this research work aims to evaluate its influence on large structures i.e., highlight its limitation and afterward mitigate the damages by introducing external FRP strengthening techniques. The structures configuration is based on the observation made in Pakistan's rural areas where mostly brick masonry structure. Confined brick masonry walls are subjected to quasi static lateral loading, afterwards retrofitted with FRP and tested again. The test result discussion includes load response behavior, stiffness degradation, energy dissipation and damage indices.***

Keywords: Confined brick masonry, RC tie beam column, FRP, Retrofitting, Seismic analysis, Quasi Static

I. INTRODUCTION

Over the past 100 years, a number of earthquakes have struck Pakistan and its surrounding regions. Amongst these, three of magnitude greater than 8.0 has struck in the last 50 years. The combined casualty rates are more than 100,000 individual persons, and infrastructure damage is in billions. About 4 million plus building has been collapse in the Kashmir earthquake alone, among which majority of the building were of unreinforced brick masonry [1]. Major URM failures occur because of the weak interlocking bonds between the out-of-plane and in-plane and walls. Therefore, in case of the strong connections between the orthogonal walls of the masonry structure, the dominant failure mode is always in-plane failure mode. Confined masonry on the other hand having strong connection because of the introduction of stiffer line and economical.

[2] developed an effective strengthening technique using CFRP to enhance the seismic performance of in plane aligned masonry panels. The strength of the specimens was enormously increased in comparison to reference specimens. There was no significant difference between the specimens of different adopted configuration. The effect of FRP laminates on changing the failure mode and deformation and strength characteristics of small specimens subjected to diagonal stress and joint shear was analysed by [3]. It was found that the load carrying capacity of the masonry specimens suffering shear failures along the mortar joints was greatly enhanced by laminates. [4] worked using grid and diagonal configuration on confined masonry walls retrofitted with CFRP strips. It was reported that CFRP strips improved the seismic behavior of confined masonry walls under in plane cyclic loading. CFRP grid and diagonal layout increased the capacity by approximately 36% and 16% respectively. [5] studied the effectiveness of one-sided retrofitted methodology of load bearing wall by FRP sheets and anchorages. He concluded that CFRP sheets proved to be an effective retrofit technique load bearing walls. Capacity of single layer of CFRP-retrofitted specimen, in each direction was 1.5 times the reference specimen without the retrofit. [6] experimentally studied the in-plane performance of damaged masonry walls retrofitted with FRP. The shear capacity and lateral displacement increased significantly and was same compared to strengthened specimen having the same amount of CFRP. Using GFRPs with various configurations, [7] analysed the in-plane static cyclic response of perforated unreinforced brick walls, before and after retrofitting. The results showed that the lateral strength, deformation capacity and energy dissipation ability of the masonry wall were improved by GFRPs and the improvement in performance was dependent on the configuration of the GFRP. [8] tested clay masonry panels under in plane compression and diagonal compression retrofitted with CFRP laminates. CFRP enhanced the capacity of masonry, improving ductility, stiffness and ultimate capacity in some cases by adopting effective retrofitting configuration. [9] assessed in-plane response of full-scale tuff masonry panels with various (FRP) strengthening layout under monotonic shear-compression loading. It was observed that for walls subjected to in-plane loads, the shear capacity of the walls was substantially improved when reinforced with FRP laminates.

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Moreover, the reinforced walls had a more ductile behaviour. Many authors have also investigated the seismic retrofitting of full-scale masonry walls consisting of hollow clay bricks with FRP. It was found that the retrofitting enhances lateral capacity of the walls, improves the shear capacity, the maximum displacement before failure. [9] retrofitted masonry walls on side with GFRP sheets. He adopted monotonic loading protocol to investigate the in-plane performance. He concluded that GPRF sheets enhanced the in-plane performance of masonry walls.

Experimental studies performed by various researchers to analyse the out-of-plane and in-plane performance of FRP-reinforced masonry panels made of clay bricks have shown that they offer a light and effective alternative to conventional materials and increase the performance of masonry elements under monotonic, seismic, and explosive loads. [11], [12], [13], [14] and [15] Retrofitting of confined masonry wall with GFRP enhanced the seismic capacity by 25% to 32% and ductility and energy absorption of the panel by 33% to 85%. Also, the collapse was considerably delayed by retaining the stability of the wall under significant lateral deformations.[16] In plane performance of full scaled URM walls retrofitted with CFRP and Hybrid Composites (GFRP plus AFRP) was assessed by [17]. It was concluded that both the composites performed well by increasing the lateral capacity by 4.3 and 6 times with respect to reference model.

II. TEST SPECIMENS

A typical confined brick masonry walls of single bay and two bays was fabricated which replicated the walls of room of a typical building in Pakistan. The walls' dimensions were 1/3rd scale down due to limitations of the working space available in the research laboratory i.e. (UET) Peshawar. Dimensions of the Single Bay and two bay confined masonry walls was 46”x47” and 89”x47” respectively. These walls were constructed over 6” reinforced concrete pad with pre holes provided for securing it to the floor of testing frame. The walls were built using brick masonry in an English bond pattern with a thickness of 3” (76.2mm) and a 1:6 cement-sand mortar, as is typical in the area. In order to eliminate any vertical joint in the masonry each layer of the bricks is laid in a staggered pattern 0.75” toothing was provided in every course of masonry. Walls was confined by tie column having a size of 3”x3”. 4 #1 longitudinal bars and #1 stirrups @ 6” c/c were used to for column reinforcing. Stirrups were made by combining three wires of 1mm diameter of binding wire. Tie beams were casted over the walls having a size of 3”x3” and reinforced with 4 #1 bars tied by #1 stirrups @ 6” c/c.

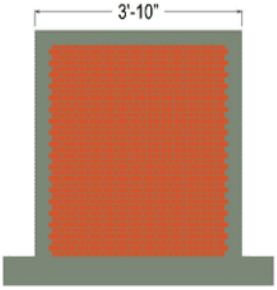


Figure 1. Confined Masonry Single Panel



Figure 2. Models construction phases

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III. MATERIAL PROPERTIES

1/3rd scale brick of first class was selected after performing different types of tests from a local vendor. The Scale down brick replicated actual bricks qualitatively and quantitatively. After collecting all the essentials materials for the construction of walls, the second stage of experimental study was the testing of constituent materials to determine the different material properties. Compressive strength of masonry unit was calculated according to ASTM C-67 specification. Compressive strength of masonry unit was calculated according to ASTM C-67 specification. In order to measure the initial rate of absorption of brick units, Section 10 of the ASTM C-67 test specification was used. In compliance with the ASTM C-109 specification, the compressive strength of mortar used in brick masonry walls was determined using 2-inch mould. For the preparation of concrete, a standard ratio of 1:2:4 (1-part cement, 2 parts sand and 4 parts coarse aggregate) with a water-cement ratio of 0.6 was used. ASTM C39 parameters were used to measure the compressive strength of the concrete cylinder sample. The masonry tensile strength ft was obtained by testing three masonry square prism of dimension 16"x16" under diagonal compression load as specified by ASTM 519 (ASTM C1391). All the results are shown in table 1.

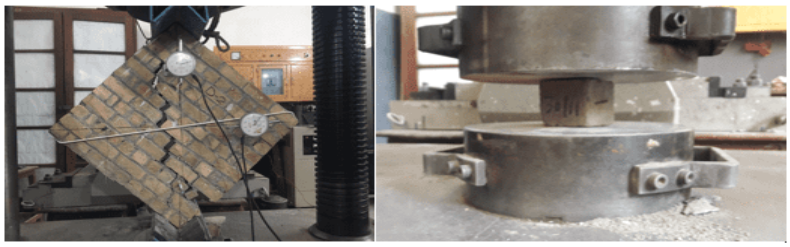


Figure 3. Diagonal Compression and Mortar Compressive Test

Table I. Material properties

Description	Symbols	Values	Units
Average Compressive strength concrete cylinders	fc'	2200	Psi
Average Compressive strength of bricks	Fb	2400	Psi
Initial rate of absorption	----	103	g/min/30 in^2
Water absorption of bricks	----	17.8	%
Average compressive strength of mortar	f_{mo},	650	Psi
Tensile strength of steel reinforcement	f_y	60,000	Psi

IV. EXPERIMENTAL SET UP

All the models were investigated in Structural Engineering laboratory. The bottom of specimen was fixed with stiff steel girder through bolts. Top of the specimens were kept free to allow free translation and rotation. This setup is used to simulate cantilever type setup. One actuator of 50-ton capacity was used to subject constant vertical compression load. Another actuator of same capacity was used to subject horizontal load. Vertical load was subjected on steel girder placed on 1.5" steel roller. The steel roller was roll ed on 1.5" inch thick steel plate placed on the top beam, which in turn distributed vertical load uniformly s shown in figure. Three LVDTs were connected to record horizontal displacement. LVDTs along the diagonals were also connected. Location of various LVDTs are shown in Figure 3.25. As illustrated in the figure, strain gauges were also utilized to record strain in the FRP strip at various points. As indicated in the diagram, all of these instruments were linked to a data logger machine (UCAM 70). All the LVDTs were calibrated in the UTM machine before test. Also, the load cells and data cable were checked and calibrated.



Figure 4. Load setup and instrumentation details

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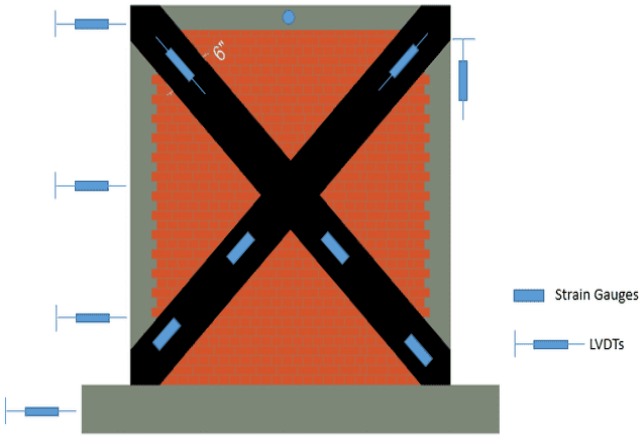


Figure 5. Instrumentation details

V. RETROFITTING TECHNIQUE

FRP strips were bonded to both surfaces of damaged walls as part of the retrofitting process. Before joining the FRP strips, the cracks were cleaned with a brush and a blower but not sealed. A typical hand-held grinding machine was used to polish the surfaces of the walls. In orders to achieve uniform and proper bonding between FRP and wall, surface along the diagonal strips were levelled with chemical mortar (Ultra Fairing Coat) as shown in figure. Diagonal configuration of FRP retrofitting was considered. Diagonal strips of width 6" were bonded in each direction on both sides of the wall as shown in figure. First, one coat of epoxy was applied to wall surface, then strip of FRP was bonded to pre-coated surface. Another coat of epoxy was applied over FRP strips with help of blade. In order to avoid detachment of FRP strips and to enhance the bond performance between the FRP and masonry substrate anchors were provided. Holes were driven at specific locations and then cleaned with pressurized air. Epoxy was injected in the hole through 100 ml syringe. Anchors made from FRP fiber were inserted in the holes and then fan out on FRP strips as shown in Figure 6.



Figure 6. FRP Retrofitting configuration

VI. TESTING PROCEDURE

All LVDTs and load cells were connected to the data logger machine once the instrumental setup was completed. All of the LVDTs and the load cell were set to zero. Then the vertical load was slowly increased to the desired magnitude. i.e., 1.15 Ton in case single panel wall and 2.31 Ton in case of double panel wall. After the vertical load was applied, the LVDTs were reset to zero. The first was started from 0.5mm horizontal displacement. Each cycle was run two times at the interval of 0.5mm displacement. LVDT 1 was used as controlled gauged. During and after each run cracks were investigated and marked with number showing the displacement in mm.

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VII. EXPERIMENTAL RESULTS AND DISCUSSION

A. Before Retrofitting

A quasi-static load was performed in the specimen. The damage pattern of the specimen is shown in Figure 7. The dominant failure pattern was step crack passing through mortar joints. First crack was noticed at 2mm displacement cycle at bottom left corner. Major crack along the diagonal was started at 2.5mm displacement cycle. The cracks were mostly concentrated along the both diagonals. Cracks in the tie column was observed after 3mm displacement cycle. Some minor cracks originating from top corners were also noticed. The test was stopped at the maximum displacement of 10mm at which damages were of moderate. Hysteresis Curves and Bilinear Curve is shown in Figure 8 and Figure 9 respectively.

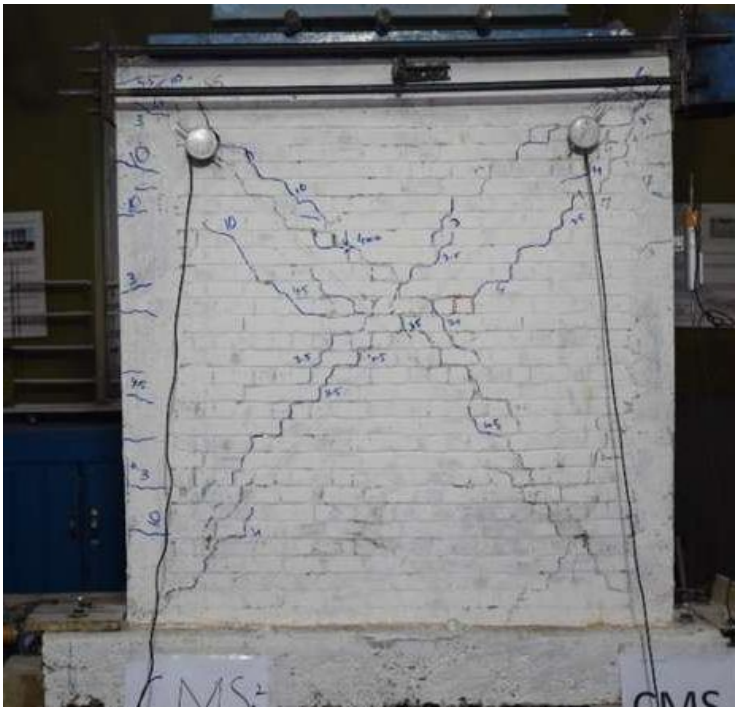


Figure 7: Damage pattern before retrofitting

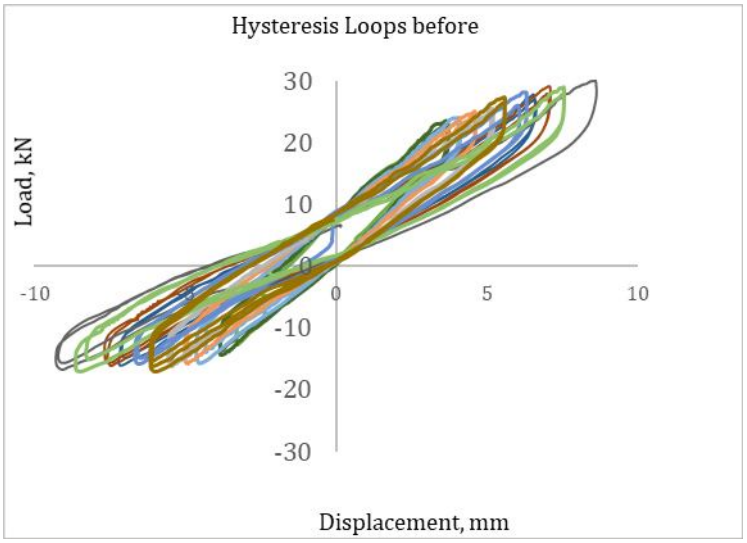


Figure 8: Hysteresis Curves before Retrofitting

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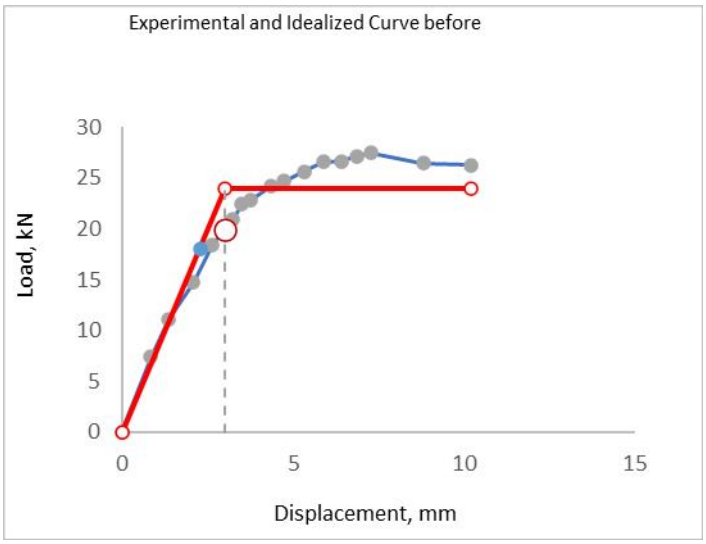


Figure 9: Bilinear Curve Before Retrofitting

B. After Retrofitting

The damage specimen and cracks pattern are shown in Figure 10. Formation of first crack occurred when the specimen was subjected to 2.5mm displacement. At 5mm displacement a horizontal crack at the interface of masonry and footing was observed which extend toward the tie columns in both directions. A diagonal shear crack appeared in the tie column which was wide enough to be visually seen during testing. Foundation pad become cracked at the top near the bottom of left tie column. This crack becomes wide and extended toward the bottom due to increase in lateral displacement. The test was then stopped. Hysteresis Curves and Bilinear Curve is shown in Figure 11 and Figure 12 respectively.



Figure 10. Crack pattern an d failure mode after Retrofitting

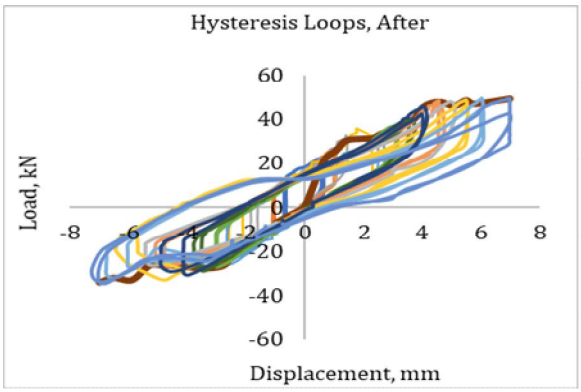


Figure 11. Hysteresis Curves after Retrofitting

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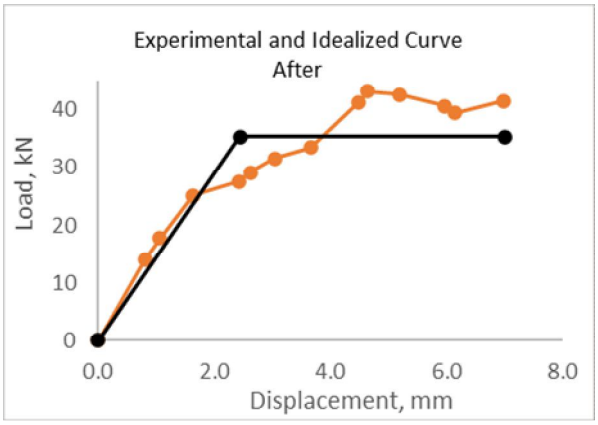


Figure 12: Bilinear Curve After Retrofitting

Table II Before and After retrofitting

#	Parameter	Before	After
1	Peak load V max (kN)	27.46	43.2
2	Peak displacement (mm)	7.29	4.65
3	Lateral Yield Strength, (kN)	25	35
4	Yield displacement (mm)	3	2.44
5	Ultimate Displacement (mm)	10.21	7
6	Lateral Stiffness, (kN/mm)	8.33	14.46
7	Yield Drift (%)	0.25	0.2
8	Ultimate Drift (%)	0.86	0.59

VIII. CONCLUSIONS

The following conclusion were derived regarding FRP retrofitting. It was concluded that the FRP significantly improved the lateral capacity of single panel by a factor of 1.4. The lateral yield strength was enhanced by a factor of 1.4. The stiffness was significantly increased by a factor of 1.6. Ductility ratio of both types of walls was almost same before and after retrofitting. Single panel showed high stiffness degradation and energy dissipation. Energy dissipated by retrofitted specimens was more than its reference specimens.

IX. RECOMMENDATIONS

It is recommended to study out of plane performance under same retrofitting configurations. Shake table testing on a scaled model is advised to fully investigate its seismic performance. It is recommended to study the in-plane performance of the same models using GFRP.

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REFERENCES

[1] Javed M., Khan A.N. and Magenes G. 2008. Performance of Masonry Structures During Earthquake -2005 in Kashmir, Mehran University Research Journal of Engineering and Technology , Vol. 27, No. 3, pp. 271-282.

[2] Can, Ö. (2018) 'Investigation of seismic performance of in-plane aligned masonry panels strengthened with Carbon Fiber Reinforced Polymer', Construction and Building Materials, 186, pp. 854–862. doi: 10.1016/j.conbuildmat.2018.08.028.

[3] El-Dakhakhni W, Hamid A, Hakam Z, Elgaaly M. Hazard mitigation and strengthening of unreinforced masonry walls using composites. Compos Struct 2005;73:458–77.

[4] Shakib et al., 2016 "Experimental and Analytical Evaluation of Confined Masonry Walls Retrofitted with CFRP Strips And," 1–11. https://doi.org/10.1061/(ASCE) CF. 1943-5509.0000885

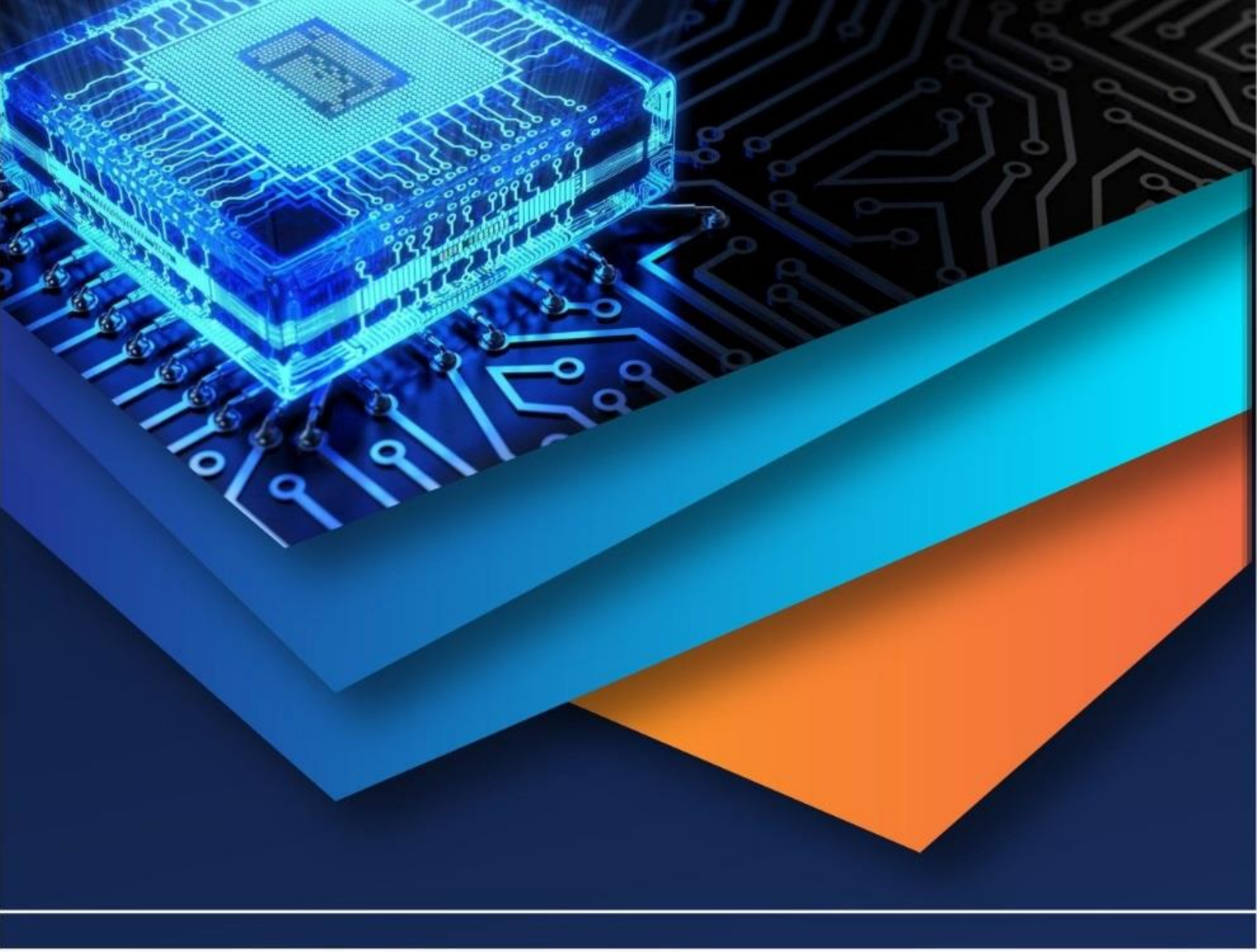
[5] Arifuzzaman, S. (2013) 'Seismic Retrofit of Load Bearing Masonry Walls by FRP Sheets and Anchors', 15th World Conference on Earthquake Engineering (15WCEE), (2002), p. 10.

[6] Santa-Maria, H. and Alcaino, P. (2011) 'Repair of in-plane shear damaged masonry walls with external FRP', Construction and Building Materials. Elsevier Ltd, 25(3), pp. 1172–1180. doi: 10.1016/j.conbuildmat.2010.09.030.

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[7] Kalali, A. and Kabir, M. Z. (2012) 'Cyclic behavior of perforated masonry walls strengthened with glass fiber reinforced polymers', Scientia Iranica. Elsevier B.V., 19(2), pp. 151–165. doi: 10.1016/j.scient.2012.02.011.
[8] Luccioni, B. and Rougier, V. C. (2011) 'In-plane retrofitting of masonry panels with fibre reinforced composite materials', Construction and Building Materials. Elsevier Ltd, 25(4), pp. 1772–1788. doi: 10.1016/j.conbuildmat.2010.11.088
[9] Marcari, G., Manfredi, G., Prota, A., and Pecce, M. (2007). "In-plane shear performance of masonry panels strengthened with FRP." Composites Part B: Engineering, 38(7-8), 887-901.
[10] Stratford, T. et al. (2004) 'Shear Strengthening Masonry Panels with Sheet Glass-Fiber Reinforced Polymer', (October), pp. 434–443.
[11] Willis CR, Seracino R, Griffith MC. Out-of-plane strength of brick masonry retrofitted with horizontal NSM CFRP. Eng Struct 2010;32:547–55
[12] Roca P, Araiza G. Shear response of brick masonry small assemblages strengthened with bonded FRP laminates for in-plane reinforcement. Constr Build Mater 2010;24:1372–84
[13] Willis CR, Yang Q, Seracino R, Griffith MC. Damaged masonry walls in two-way bending retrofitted with vertical FRP. Constr Build Mater 2009;23:1591–604
[14] Tan, K. H. and Patoary, M. K. H. (2004) 'Using Fiber-Reinforced Polymer Reinforcement', (February), pp. 79–87.
[15] Tumialan, J. G., Galati, N. and Nanni, A. (2003) 'Field Assessment of Unreinforced Masonry Walls trengthened with Fiber Reinforced Polymer Laminates', Journal of Structural Engineering, 129(8), pp. 1047–1056. doi: 10.1061/(asce)0733-9445(2003)129:8(1047).
[16] El-Diasity, M. et al. (2015) 'Structural performance of confined masonry walls retrofitted using ferrocement and GFRP under in-plane cyclic loading', Engineering Structures. Elsevier Ltd, 94, pp. 54–69. doi: 10.1016/j.engstruct.2015.03.035.
[17] Choi, Y. C. et al. (2015) 'Shear Strength of Unreinforced Masonry Wall Retrofitted with Fiber Reinforced Polymer and Hybrid Sheet', International Journal of Polymer Science, 2015. doi: 10.1155/2015/863057.
[18] ASTM C67, "Test Methods for Sampling and Testing Brick and Structural Clay Tiles", 4Th Ed., Philadelphia.
[19] ASTM C 109, "Standard Test Method for Compressive Strength ofHydraulic Cement Mortars (using 2-inch or 50 mm cube specimens)", 4Th Ed., Philadelphia.
[20] ASTM C1314, "Standard Test Method for Compressive Strength of Masonry Prisms", 4Th Ed, Philadelphia.

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