Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 7, No. 1, July : 2023

RESTORATION & REHABILITATION OF HSC RCC BEAM STUDIED UNDER CYCLIC LOADING

Mr J.Ansari Research Scholar, Dept. of Civil Engineering, SGSITS Indore.
Er V. Tiwari. , Assistant Professor, Civil Engineering and Applied Mechanics Department, SGSITS Indore.

Abstract
Present work involves restoration and rehabilitation of high strength concrete RCC beams studied under cyclic loading repair and strengthening measures to improve the distressed structures condition as compared to its original condition. The need for sustainable construction material has made use of glass fiber wrap. The glass fiber wraps concrete restoration and rehabilitation of the concrete structure strength. Application of glass fiber wrap and epoxy like material are used to the exterior of a concrete column, beam or slab, adding significant strength without giving additional weight on foundations and other structural members. Fiber wrapping concrete members improve strength and durability. There are many existing concrete structures in India that do not meet current design standards due to poor design. FRP reinforcement is a method of increasing the load capacity of older structures that were designed to withstand lower service loads than they are experiencing today. Many different situations may necessitate structural reinforcement.to support heavier loads on the structure. Allow the structure to withstand additional floor loads and other loads. Due to the structure's inability to carry the original design loads, this was required. In this work, we discovered that strengthened beams carry 12–25% more loads and have less deflection than reference beams, implying that GFRP strengthening increases beam stiffness. The mode of failure varies for different configuration systems of GFRP, and the failure that occurs in these beams is a brittle failure as opposed to REF beams, and it gives a physical warning such as GFRP peeling before failure. Reinforced beams carry 15–20% more load than unreinforced beams, indicating that these two strengthening systems are more effective. Because wrapped FRP material is less commonly used, this is the best suitable strengthening system in terms of both economy and strength.

Keywords: Concrete Beam, Cyclic loading FRP Laminates, Glass Fiber, Rehabilitation, Strengthening.

I. Introduction

Repair and strengthening measures to upgrade the distressed structure for an improved performance as compared to its original condition. The main purpose is to carry out structural repairs to load bearing components to restore its original strength. Injecting rich mortar, epoxy like material which is strong in tension, into the cracks in walls, columns, beams etc. FRPC based strengthening strategy could be an attractive option in order to restore the joints. In addition to being lighter, thinner and easier to implement, FRPC reinforced joints have the virtue of making the joints more ductile. The study shows that GFRP wraps were quite capable of restoring the flexural strength of heat damaged beams. Removal of portions of cracked masonry walls & pier and rebuilding them in richer mortar will be preferable. To improve the durability and extend the service life of a structure. To improve the appearance of a structure. To restore the heritage value of a structure. The damage column or beam, fix the reinforcing add reinforcing if needed and re - concreting. Benefits of rehabilitation saving in financial, natural, equipment and manpower resources. Saving in user cost like delay, extra fuel cost, wear and tear of vehicles, inconvenience, due to demolition of deteriorated structure and its reconstruction. Shear strengthening of reinforced beams using fiber reinforcement polymers (FRP) is one of the best methods of rehabilitation and retrofitting, and it has been extensively researched over the last decade all over the world, including India. This method of strengthening is not widely used in the Indian field, which is due to a lack of basic guidelines and provisional codes for using this material as a composite.

II. Literature

Uttamasha Gupta et. al. (2010) [21] The benefits and drawbacks of fiber reinforced polymer (FRP) as a construction material are discussed. FRP has a high strength-to-weight ratio, a high specific stiffness, and strong chemical adhesion. It allows for lower labour and equipment costs, shorter installation times, and less service disruption, resulting in less downtime. The structural properties of FRP allow it to act as a polymer damper at the flooring area and connection zone by absorbing seismic or blast energy. Its limitations include a lack of codes, standards, or guidelines, as well as a lack of a formal method for designing structural upgrades in many countries. The lack of knowledge about the long-term environmental effects of using large volumes of resin also limits its use, because the volume of FRP used in construction could far outnumber that used in the aeronautical/aerospace and automotive industries.

Abhijit Mukherjee et. al. (2005) [6] An analysis into those behavior strengthening material girder-pillar connections It has been reported that under fatigue stress. In the beam-column connection, joints with sufficient and poor adhesion of the reinforcement were poured. GRP panels and strips in different configurations were applied to the joints. An axial force is applied to the beams while they are subjected to cyclic loads with managed deformation. A stroke dynamic actuator increases the amplitude monotonically. The samples' oscillation curves were displayed. Different FRP configurations' energy dissipation capacity was compared. Furthermore, following testing, the control samples were reused as damaged samples for remediation. The rehabilitation had been done with Ferrocement, and the outcomes were contrasted to those of relatively intact ones.

Ashkan Saradar et al. (2018) [14] Cementitious deformation and quantity decrease as a result of moisture loss, which ultimately leads to breaking. leads to cracking or further displacement of the concrete. The early test of high-strength concrete mixtures was used to investigate its impact of thermoplastics, rebar, acrylic, volcanic rock, and polyvinyl acetate on suppressible or flexural energy, cleaning, or crack potential The ASTM C1581 restricted shrinkage test was conducted on cementitious circle specimens. This investigation. The addition of fibers increased compressive strength by 17%, 21%, and 4% at the ages of standard days, also increased the elastic modulus durability index by 8.0 instances. it showed better Modulus of elasticity, but only a marginal effect on the crack frequency and crack moment with constrained deformation. The polypropylene fiber showed an about 59% decrease in fracture toughness and an 84% enhancement in brittle fracture due to aging.

Eisenhauer Tanner et. al. (2015) [3] For the maintenance and reusability of structural materials, CFRP polymers are frequently used as external sealant encouragement. CFRP samples exposed to different external conditions were made subject to tests to determine their resistance to deterioration. Its analysis indicates that its interaction of hot air as well as humidity quickly weakened a adhesive intensity. The need to assess long-term performance remains as steel reinforcement is progressively enhanced with Externally bonded FRP systems.

SANDEEP G. SAWANT ET. AL. (2013) [13] In their research paper experimental work on R.C.C. beam reinforcement with various glass fibers. The application of fiber-reinforced polymer sleeves, fiber board, and panels to the restoration and reinforcement of reinforced concrete elements. In this research various types of materials are used in the restoration of old structure materials like fiber systems, Fiber roving and fiber mats etc. The capacity of the Inverted roll girder was enhanced. by about 40- 48 %as compared to all sides rolling girder. The expense of knotted covering was greater than that of the single sheet and double sheet enclose, but its load-bearing capacity was also higher than that of the parameter and double mat wrap.

III. Objective of Study

To study the properties of Restored and Rehabilitated concrete under cyclic loading and for the aspects of durability.
Study the effect of glass fiber, epoxy.
To check the behavior of Restored and Rehabilitated concrete designed using glass fiber and epoxy under cyclic loading.
To establish Plastic strain curves, common point curves, and stability point curves under cyclic loading.
To establish NDT results with rehabilitated concrete undergone under cyclic loading.

IV. Experimental Programme

Non-destructive method of assessing the endurance and energy of existing concrete buildings. Researchers could also quantify concrete using the resilience non-destructive testing procedure without putting the sample to the test.

4.1 Basic Method of NDT Tests

1. Rebound hammer method
2. Ultrasonic pulse velocity method

4.1.1 Rebound hammer method (RH) The rebound hammer test is a non-destructive concrete testing method that provides a convenient and quick indication of the compressive strength of the concrete. The rebound hammer, also known as the Schmidt hammer, is made up of a spring-controlled mass that slides on a plunger inside a tubular housing. The rebound hammer's operation When the plunger of a rebound hammer is pressed against the surface of concrete, a spring-controlled mass with constant energy strikes the surface and bounces back. On a graduated scale, the extent of rebound, which is a measure of surface hardness, is measured. This measured value is known as the rebound number (rebound index). Concrete with low strength and stiffness absorbs more energy, resulting in a lower rebound value.

4.1.2 Ultrasonic pulse velocity method (UPV) The speed and attenuation of an ultrasonic wave passing through the element being tested are measured to determine the integrity and quality of structural concrete or stone (up to 6 feet thick). Lower-velocity areas typically have lower density and strength than high-velocity areas. Tomographic images of defects can be created using data collected along multiple test paths.

4.2 Sample preparation This experimental work consists of 12 reinforced beams that were wrapped in GFRP in various configurations, such as u-shape wrapping, side wrapping, and side fully laminated, and then tested. All beams are reinforced with GFRP sheets.

Experimental Testing of samples are carried out in monotonic, cyclic and stability loading for M40, M60 & M80 grades of concrete specimen.

4.3 GFRP and Adhesives Application

The adhesive used in all experiments is a compatible epoxy system suggested by the manufacturer. It is made up of two parts: resin and hardener. The component weight ratio is 100 parts of component A. Component B has 55 parts. For 10 minutes on low speed, thoroughly mix the ingredients. The components are evenly distributed. Beam strengthening begins after the beams have sufficiently cured and is carried out as follows: the manufacturer's instructions for FRP. The FRP was ready for application after the glass fiber was cut to the desired size and the concrete surface was prepared. Epoxy material was applied to the surface, and the fiber mat was then glued to it.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 7, No. 1, July : 2023

Adhesive with Cement

Retrofitting of fractured reinforced beam size 1800x200x230mm and grade of M40 is carried out with the help of cobalt-based epoxy resin and glass fiber in S.G.S.I.T.S structure lab as shown in above figure.

4.4 Test Procedure

The experimental programme includes static loading tests on un-strengthened and FRP-strengthened beams. Under two-point loading, test beam specimens were simply supported. Throughout the test, a continuous reading of load and deflection was obtained. Deflections were measured at 5-ton intervals using the load cell, a load meter, and a dial gauge.

V. Result and Discussion

We have done both destructive and non-destructive testing for M40, M60, and M80 grades of concrete for different sizes of specimens. We have Taken three Samples of each grade for the rebound hammer, ultrasonic pulse velocity test and performed monotonic, cyclic and stability for the same samples and compared both results.

5.1 Rebound Hammer Test Result

Table 5.1 Experimental results of reinforced beam specimen for M40 grade before two-point loading**.**

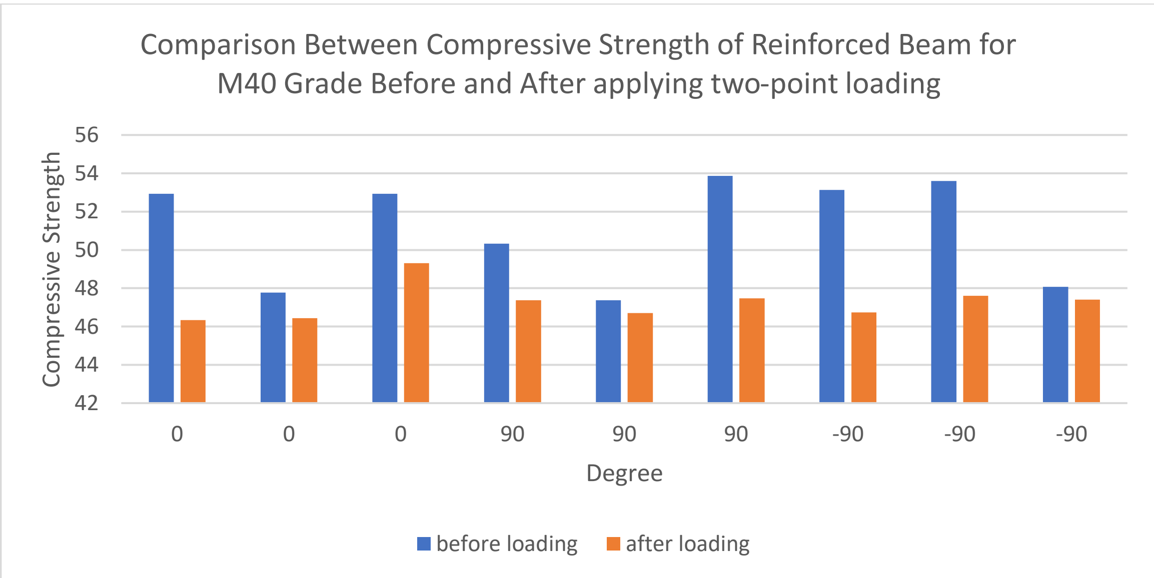
Angle of RH in Degree	Compressive Strength N/mm^2				Avg. Strength N/mm^2	Dispersion Factor	Max. strength	Min. strength	Range
0^0	Sample No.1	48.0	42.0	46.0	45.33	7.60	52.93	37.73	37-52
$+90^0$		44.0	42.0	44.0	43.33	7.00	50.33	36.33	36-50
-90^0		42.0	48.0	46.0	45.33	7.80	53.13	37.53	37-53
0^0	Sample No.2	38.0	40.0	44.0	40.67	7.10	47.77	33.57	33-47
$+90^0$		40.0	42.0	40.0	40.67	6.70	47.37	33.97	33-47
-90^0		44.0	48.0	46.0	46.00	7.60	53.60	38.40	38-53
0^0	Sample	48.0	44.0	44.0	45.33	7.60	52.93	37.73	37-52

$+90^0$	No.3	46.0	48.0	46.0	46.67	7.20	53.87	39.47	39-53
-90^0		38.0	42.0	42.0	40.67	7.40	48.07	33.27	33-48

Table 5.2 Experimental results of reinforced beam specimen for M40 grade after two-point loading

Angle of RH in Degree	Compressive Strength N/mm^2				Avg. Strength N/mm^2	Dispersion Factor	Max. strength	Min. strength	Range
0^0	Sample No.1	36.0	40.0	42.0	39.33	7.00	46.33	32.33	32-46
$+90^0$		40.0	42.0	40.0	40.67	6.70	47.37	33.97	33-47
-90^0		38.0	44.0	36.0	39.33	7.40	46.73	31.93	31-46
0^0	Sample No.2	36.0	40.0	42.0	39.33	7.10	46.43	32.23	32-46
$+90^0$		42.0	40.0	38.0	40.00	6.70	46.70	33.30	33-46
-90^0		38.0	42.0	40.0	40.00	7.60	47.60	32.40	32-47
0^0	Sample No.3	40.0	42.0	44.0	42.00	7.30	49.30	34.70	34-49
$+90^0$		44.0	40.0	38.0	40.67	6.80	47.47	33.87	33-47
-90^0		40.0	42.0	38.0	40.00	7.40	47.40	32.60	32-47

From the above two tables, table no 5.1 & 5.2 we can conclude that, after application of two-point loading average, maximum and minimum compressive strength of reinforced beam is decreased for M40 grade.



Comparison Between Compressive Strength of Reinforced Beam for M40 Grade Before and After applying two-point loading

5.1.1 Comparison in results for reinforced beam before and after retrofitting using FRP

Table 5.3 Experimental results of reinforced beam specimen for M40 grade before retrofitting.

Angle of Rebound Hammer in Degree	Compressive Strength N/mm^2				Avg. Strength N/mm^2	Dispersion Factor	Max. strength	Min. strength	Range
0^0	Sample No.1	36.0	40.0	42.0	39.33	7.00	46.33	32.33	32-46
$+90^0$		40.0	42.0	40.0	40.67	6.70	47.37	33.97	33-47
-90^0		38.0	44.0	36.0	39.33	7.40	46.73	31.93	31-46
0^0	Sample No.2	36.0	40.0	42.0	39.33	7.10	46.43	32.23	32-46
$+90^0$		42.0	40.0	38.0	40.00	6.70	46.70	33.30	33-46
-90^0		38.0	42.0	40.0	40.00	7.60	47.60	32.40	32-47
0^0	Sample No.3	40.0	42.0	44.0	42.00	7.30	49.30	34.70	34-49
$+90^0$		44.0	40.0	38.0	40.67	6.80	47.47	33.87	33-47
-90^0		40.0	42.0	38.0	40.00	7.40	47.40	32.60	32-47

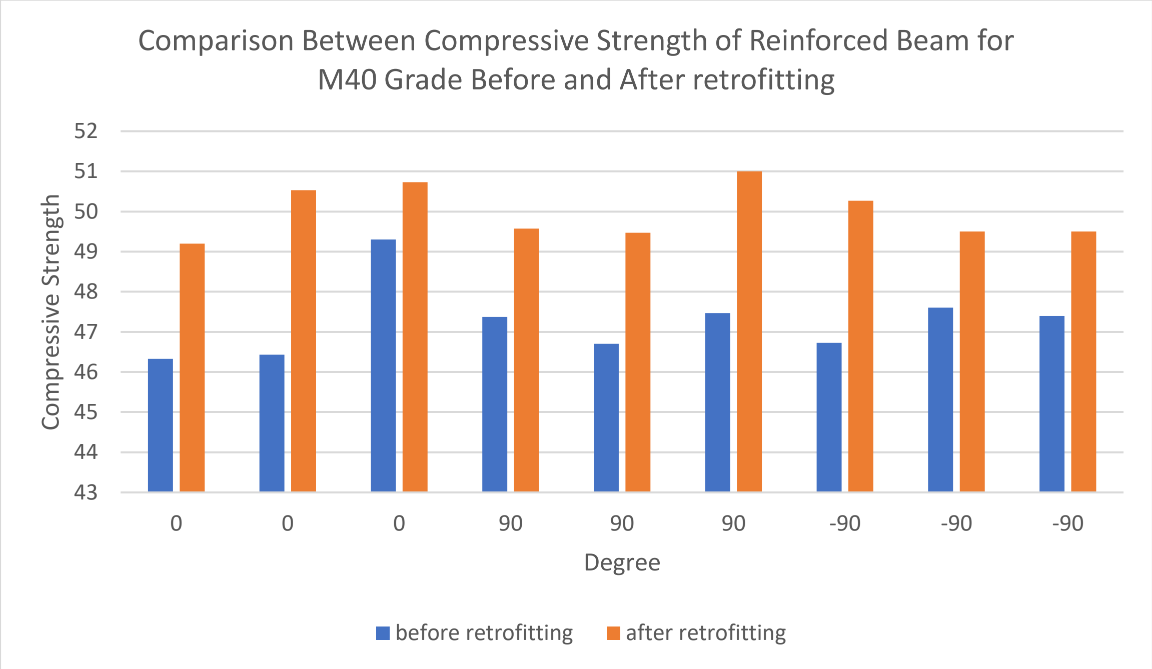
Table 5.4 Experimental results of reinforced beam for M40 grade after retrofitting using FRP.

Angle of Rebound Hammer in Degree	Compressive Strength N/mm^2				Avg. Strength N/mm^2	Dispersion Factor	Max. strength	Min. strength	Range
0^0	Sample No.1	40.0	42.0	44.0	42.00	7.20	49.20	34.80	34-49
$+90^0$		40.0	44.0	44.0	42.67	6.90	49.57	35.77	35-59
-90^0		42.0	44.0	42.0	42.67	7.60	50.27	35.07	35-50
0^0	Sample No.2	40.0	46.0	44.0	43.33	7.20	50.53	36.13	36-50
$+90^0$		44.0	40.0	44.0	42.67	6.80	49.47	35.87	35-49
-90^0		42.0	40.0	44.0	42.00	7.50	49.50	34.50	34-49

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 7, No. 1, July : 2023

0^0	Sample No.3	42.0	40.0	48.0	43.33	7.40	50.73	35.93	35-50
$+90^0$		46.0	44.0	42.0	44.00	7.00	51.00	37.00	37-51
-90^0		40.0	42.0	44.0	42.00	7.50	49.50	34.50	34-49

From the above two tables, table no.5.3 & 5.4 we can conclude that using FRP for retrofitting increases the average and maximum strength of reinforced beam by 5% to 10% for M40 grade.



Comparison of Compressive Strength of reinforced beam for M40 Grade before and after retrofitting

5.2 Ultrasonic pulse velocity Test Result

In this research, we found that most of the concrete samples show good, medium and excellent quality of concrete in direct, semi-direct and indirect methods.

Table 5.3 Experimental results of reinforced beam specimen for M40 grade.

Transmission Method	Specialization	Path Length(mm)	Traverse Time (micro-sec)	Ultrasonic Pulse Velocity (Km/sec)	Quality Concrete
Direct	Sample No.1	200	39	5.12	Excellent
Semi-Direct		-	50	4	Good
Indirect		-	48	4.16	Good
Direct	Sample No.2	150	45	3.33	Medium
Semi-Direct		-	48	3.12	Medium
Indirect		-	51	2.90	Doubtful
Direct	Sample No.3	100	19	5.26	Excellent
Semi-Direct		-	27	3.70	Good
Indirect		-	25.65	3.89	Good

Table 5.4 Experimental results of reinforced beam specimen for M60 grade.

Transmission Method	Specialization	Path Length(mm)	Traverse Time (micro-sec)	Ultrasonic Pulse Velocity (Km/sec)	Quality Concrete
Direct	Sample No.1	200	45	4.44	Good
Semi-Direct		-	54	3.70	Good
Indirect		-	49	4.08	Good
Direct	Sample No.2	150	46	3.20	Medium
Semi-Direct		-	47	3.19	Medium
Indirect		-	51	2.94	Doubtful
Direct	Sample No.3	100	26	3.80	Good
Semi-Direct		-	20	5	Excellent
Indirect		-	24	4.11	Good

Table 5.5 Experimental results for M80 grade loading concrete specimens

Transmission Method	Specialization	Path Length(mm)	Traverse Time (micro-sec)	Ultrasonic Pulse Velocity (Km/sec)	Quality Concrete
Direct	Sample No.1	200	47	4.25	Good
Semi-Direct		-	53.3	3.75	-
Indirect		-	51.10	3.92	-
Direct	Sample No.2	150	49	3.06	Medium
Semi-Direct		-	51	2.94	Doubtful
Indirect		-	50.4	2.97	Doubtful
Direct	Sample No.3	100	21.9	4.56	Excellent
Semi-Direct		-	30	3.33	Medium
Indirect		-	26.5	3.77	Good

VI. Conclusion

The result of the rebound hammer test shows that after the use of FRP the strength is increased up to 5 - 10%.The strengthened beams can carry 10–25% more loads before failure and have less deflection than the reference beam. In other words, GFRP reinforcement increases beam stiffness. The magnitude of the strength increase varies depending on the type of strengthening 75-85% configuration used. Peak stresses corresponding to the common point is more than 75-85% of the envelope curve for M40 grade concrete, 70-80% of envelope curve for M60 grade concrete and 67-75% of envelope curve for M80 grade concrete under cyclic loading. Peak stresses corresponding to the stability point is more than 70-75% of the envelope curve for M40 grade concrete and 60-70% of envelope curve for M60 grade concrete and 60-65% of envelope curve for M80 grade concrete under cyclic loading. Experimental studies also show the adequacy of NDT results are within the range as given by IS code. T he stress-strain envelope curve, common point curve, and stability point curve can be represented as mathematical using a polynomial and logarithmic function. The correlation regression index of this curve corresponds to 0.72-0.91 which is indicative of good test performance. Load cycles with peak stresses of the stability point curve clearly show accumulation of plastic strain below which strain stabilizes and hence below which model could not be failed.

References

[1]. Altoubat S, and Lange A.D, (2001). "Early Age Creep, Shrinkage, and Cracking of Restrained Concrete Measurement and Modeling of Concrete Creep and Shrinkage View the Fiber Reinforced Polymer project. View the project". https://www.researchgate.net/publication/237544826

[2]. Barros J. A. O, J. Cruz. M. S, R. M. Delgado, and A. G. Costa, "reinforced concrete under cyclic loading https://doi.org/10.1016/j.compositesb.2015.09.010

[3]. Deng J,, Eisenhauer J, Mukai D., Hamilton R. H., and Dolan W. C.(2015). "Durabili ty performance of carbon fiber-reinforced polymer in repair/strengthening of reinforced beams," *ACI Materials Journal*, vol.112,no.2,pp.247–257.https://www.researchgate.net/profile/Jennifer-Tanner-2/publication/249957197_Development_of_Accelerated_Aging_Test_Methodology_and_Specimen_for_Bonded_CFRP_Systems/links/5cffcc0b299bf13a384d66d0/Development-of-Accelerated-Aging-Test-Methodology-and-Specimen-for-Bonded-CFRP-Systems.pdf

[4]. Fukuyama K., Higashibata Y., and Miyauchi Y.,(2000). "Studies on repair and strengthening methods of damaged reinforced concrete columns." Cement & Concrete Composites 22. https://doi.org/10.1016/S0958-9465(99)00044-X

[5]. Modena C., Lourenço B.P., Roca P.,(2005). I. International Seminar on Structural Analysis of Historical Constructions 4th (2004 : Padova, *Structural analysis of historical constructions : possibilities of numerical and experimental techniques*. A.A. Balkema Publishers. https://doi.org/10.1201/9781482288377

[6]. Mukherjee A. and Joshi M. (2005). "FRPC reinforced reinforced beam-column joints under cyclic excitation," *Composite Structures*,vol.70,no.2,pp.185-199 https://doi.org/10.1016/j.compstruct.2004.08.022

[7]. Obaidat T. Y., Abu-Farsakh R.F.A.G., and Ashteyat M.A.(2019)."Retrofitting of partially damaged reinforced reinforced beam-column joints using various plate-configurations of CFRP under cyclic loading," *Construction and Building Materials*, vol. 198, pp. 313–322. https://doi.org/10.1016/j.conbuildmat.2018.11.267

[8]. Popovt P.E .and Berterot V.V, (1975). "repaired r/c members under cyclic loading" .earthquake engineering and structural dynamics, vol. 4, 129-144 (1975) https://doi.org/10.1002/eqe.4290040204

[9]. Rimshin V. and Truntov P. (2019). "Determination of carbonation degree of existing reinforced concrete structures and their restoration," in *E3S Web of Conferences*, vol. 135. https://www.e3sconferences.org/articles/e3sconf/pdf/2019/61/e3sconf_itese18_03015.pdf

[10]. Roy D.B.A, Sharma K.U., and Bhargava P.(2017). "Strengthening heat damaged reinforced reinforced beams using glass fiber-reinforced polymer (GFRP) laminates". https://www.researchgate.net/publication/291186500_

[11]. Saha P. and Meesaraganda P.V.L.(2019) "Experimental investigation of reinforced SCC beam-column joint with rectangular spiral reinforcement under cyclic loading," *Construction and Building Materials*, vol. 201, pp. 171–185 https://doi.org/10.1016/j.conbuildmat.2018.12.192

[12]. Sakar G., Hawileh R. A., Naser M. Z., Abdalla J.A, (2014) "Nonlinear behavior of shear deficient RC beams strengthened with near-surface mounted glass fiber reinforcement under cyclic loading," Materials and Design, vol. 61, https://doi.org/10.1016/j.matdes.2014.04.064

[13]. Sandeep G., Sawant B.A. and Kumthekar B.M,(2013). "Strengthening of R.C.C. Beam- Using Different".vol.1. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.684.4387&rep=rep1&type=pdf

[14]. Saradar A., Tahmouresi B., Mohseni E., and Shadmani A. (2018). "Restrained shrinkage cracking of fiber-reinforced high-strength concrete," *Fibers*, vol. 6, no. https://www.mdpi.com/264812

[15]. Senthil R., Kesavan K., and Ravisankar K.,(2013). "Experimental studies on performance of reinforced reinforced beam strengthened with CFRP under cyclic loading using FBG array" Scientist, CSIR-Structural Engineering Research Centre. https://doi.org/10.1016/j.measurement.2013.07.031

[16]. Shamseldein A., Elshafie H., Rashad A., and Kohail M. (2018). "Assessment and restoration of bond strength of heat-damaged reinforced concrete elements," *Construction and Building Materials*,vol.169,pp.425–435. https://doi.org/10.1016/j.conbuildmat.2018.03.008

[17]. Sharbatdar K. M., Kheyroddin A., and Emami E.(2012). "Cyclic performance of retrofitted reinforced beam-column joints using steel prop," *Construction and Building Materials*, vol. 36, pp. 287–294. https://doi.org/10.1016/j.conbuildmat.2012.04.115

[18]. Sotiropoulou B.A., Pandermarakis G.Z. and Passa S.D.(2012)."experimental study of fiber reinforced mortars that are used in the restoration of traditional buildings." vol.1. http://sdct-journal.com/images/Issues/2012/2.pdf

[19]. Tolstoy D.A., Lesovik S.V., Glagolev S.E., and Vodopyanov O.I.(2019). "Self-restoration hardening systems of high-strength concrete of a new generation," in https://iopscience.iop.org/article/10.1088/1757899X/560/1/012156

[20] IS 13311-1 (1992): Method of Non-destructive testing of concrete, Part 1: Ultrasonic pulse velocity

[21] Uttam Asha Gupta and U.B. Choubey (2010) FRP - A construction material: Advantages and limitations Indian Concrete Journal 84(8):37-39

[22] Yen R.Y.J. and Chien K.H.(2010). "Steel plates rehabilitated RC beam-column joints subjected to vertical cyclic loads," *Construction and Building Materials*, vol. 24, no. 3, pp. 332–339.

[23] Ravikant Shrivastava* Uttamasha Gupta** U B Choubey***, **E**FFECT OF CYCLIC LOADING ON FLEXURAL BEHAVIOR OF FRP STRENGTHENED RC BEAMS: A STABILITY POINT APPROACH, International Journal of Advanced Research in Engineering and Applied Sciences **ISSN: 2278-6252**

[24] IS 13311-1 (1992): Method of Non-destructive testing of concrete, Part 1: Ultrasonic pulse velocity [CED 2: Cement and Con]