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Numerical Simulation on Retrofitting in Roof Corner Joint Strengthened With FRP Using FEM Method

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Abstract: ***Repair and strengthening of damaged or vulnerable reinforced concrete structures is important in order to guarantee the safety of residents or users. Beams are important structural elements for withstanding loads, so finding the efficient repair and strengthening methods are necessary in terms of maintaining the safety of the structures. This research study investigated various repair, retrofit, and strengthening techniques for reinforced concrete beams. The comparison and summary of each repair and strengthening method are provided in this thesis. The thesis involves the literature review of current experimental test of repair and strengthening techniques for reinforced concrete beams. Comparing the numerical investigation we can confirm that the deflection in the strengthened specimen is comparatively lesser than that of the un-strengthened specimen. It is observed that the stress in the specimen is better in the retrofitted with CFRP specimen when compared with the normal specimen without CFRP wrapping. 3. From the overall study, it can be concluded that the strengthening with CFRP structure will increase the serviceability of the structure. CFRP laminates reduces the deformation and stress 59% and 15.79% respectively With the help of this Simulative results we conclude that CFRP laminates provide more strength to the structure .***
Keywords: - frp, fem, ansys, cfrp, roof joint, rc structure,

I. INTRODUCTION

The maintenance, rehabilitation and upgrading of structural members, is perhaps one of the most crucial problems in civil engineering applications. Structures constructed in the past using the older design codes in different parts of the world are structurally unsafe according to the new design codes. Since replacement of such deficient elements of structures incurs a huge amount of public money and time, strengthening has become the acceptable way of improving their load carrying capacity and extending their service lives. Infrastructure decay caused by premature deterioration of buildings and structures has lead to the investigation of several processes for repairing or strengthening purposes. Additional strength may be needed to allow for higher loads to be placed on the structure. This is often required when the use of the structure
changes and a higher load- carrying capacity is needed. This can also occur if additional mechanical equipment, filing systems, planters, or other items are being added to a structure. Strengthening may be needed to allow the structure to resist loads that were not anticipated in the original design. This may be encountered when structural strengthening is required for loads resulting from wind and seismic forces or to improve resistance to blast loading. Additional strength may be needed due to a deficiency in the structure's ability to carry the original design loads. Deficiencies may be the result of deterioration (e.g., corrosion of steel reinforcement and loss of concrete section), structural damage (e.g., vehicular impact, excessive wear, excessive loading, and fire), or errors in the original design or construction.

A. Fibre reinforced polymer (frp)

High strength non-metallic fibres, such as carbon, glass and agamid fibres, encapsulated in a polymer matrix in the form of wires, bars, strands or grids have shown great potentials as reinforcement for concrete, particularly where durability is of main concern. It is commonly known as fibre reinforced polymer or, in short, FRP. Despite being a recent development, numerous investigations have already been reported in the literature on various aspects of its structural use. Fibre-reinforced polymers (FRP) have been used for structural reinforcement materials and also for bridge construction materials such as bridge decks and materials. One area where FRP can play a major role is in strengthening and retrofitting of degraded or strength deficient structures already in existence. By virtue of its light-weight, extraordinarily high strength and high corrosion resistance, FRP presents an attractive material for structural rehabilitation. Moreover, being available in the form of thin sheets, such a system makes very little change to the

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dimension of the existing member. Similar to the flexure and shear strengthening, the FRP fabric is bonded to the tension surface of the RC members for torsion strengthening. In the case of torsion, all sides of the member are subjected to diagonal tension and therefore the FRP sheets should be applied to all the faces of the member cross section. However, it is not always possible to provide external reinforcement for all the surfaces of the member cross section. In cases of inaccessible sides of the cross section, additional means of strengthening has to be provided to establish the adequate mechanism required to resist the torsion. The effectiveness of various wrapping configurations indicated that the fully wrapped beams performed better than using FRP in strips.

B. Advantages

Fiber composite strengthening materials have higher ultimate strength and lower density than steel. When taken together these two properties lead to fiber composites having a strength weight ratio higher than steel plate in some cases (though it is often not possible to use this fully). The lower weight makes handling and installation significantly easier than steel. This is particularly important when installing material in cramped locations. Work on soffits of bridges and building floor slabs can often be carried out from man-access platforms rather than full scaffolding. Steel plate requires heavy lifting gear and must be held in place while the adhesive gains strength. Bolts must be fitted through the steel plate into the parent concrete to support the plate while the adhesive cures and to reduce the effects of peeling at the ends. On the other hand, the application of FRP plate or sheet material has been likened to applying wallpaper; once it has been rolled on carefully to remove entrapped air and excess adhesive it may be left unsupported. In general, no bolts are required; in fact, the use of bolts would seriously weaken the material unless additional cover plates are bonded on. Furthermore, because there is no need to drill into the structure to fix bolts or other mechanical anchors there is no risk of damaging the existing reinforcement. Fibre composite materials are available in very long lengths while steel plate is generally limited to 6 m. The availability of long lengths and the flexibility of the material also simplify installation. **Disadvantages** The main disadvantage of externally strengthening structures with fibre composite materials is the risk of fire, vandalism or accidental damage, unless the strengthening is protected. A particular concern for bridges over roads is the risk of soffit reinforcement being hit by over-height vehicles. However, strengthening using plates is generally provided to carry additional live load and the ability of the un-strengthened structure to carry its own self-weight is unimpaired. Damage to the plate strengthening material only reduces the overall factor of safety and is unlikely to lead to collapse. Experience of the long-term durability of fibre composites is not yet available. This may be a disadvantage for structures for which a very long design life is required but can be overcome by appropriate monitoring. A perceived disadvantage of using FRP for strengthening is the relatively high cost of the materials. In reinforced concrete frames, T connections (exterior beam column joint) have recognised as a weaker components when subjected to cyclic lateral loads. Several damages of connection in general and of a T connection in a particular section may cause deterioration of whole performance of frame. Many RC frames are originally designed to carry only gravity loads. They lack the ductility and strength to present a global failure mechanism caused by cyclic loading conditions. These structures typically have a non-ductile reinforcement at the beam column joint areas in terms of inadequate transverse reinforcement and strong column weak beam design. Strengthening of existing reinforced concrete structures is now a major part of construction activity all over the world. The RCC structures constructed across the world are often found to exhibit distress and suffer damage, even before service life is over due to several causes and earthquakes, corrosion, overloading, change of code provisions, improper design, faulty construction explosions and fire. For all framed structures the most important is beam column joint, and the structural design of joint is neglected during the design stage, attention is only resisted to provision of sufficient anchorage for the beam. Unsafe design and detailing within the joint is dangerous for the entire structure, even though the structural members themselves may confirm to the design requirements. It is well known that joint region in reinforced concrete framed structures are recognized as very critical as it transfer the forces and bending moments between the beams and columns. In most cases during extreme loading, the beam column joints, if not designed properly are the most vulnerable component. With the advent of revised design and detailing codes and detailing codes and increase in the earthquake vulnerability level of many regions, the existing structures needs retrofitting and strengthening.

C. Types of beam column joints

Beam column joints are generally classified with respect to geometrical Configuration and identified as interior, exterior and corner joints. The fundamental differences in mechanism the shear requirements, two types of joints such as interior joint and exterior joint are considered. With respect to the plane of loading, an interior beam-column joint consists of two beam on either side 5 of the column and an exterior beam-column joint has a beam terminating on one face of the column.

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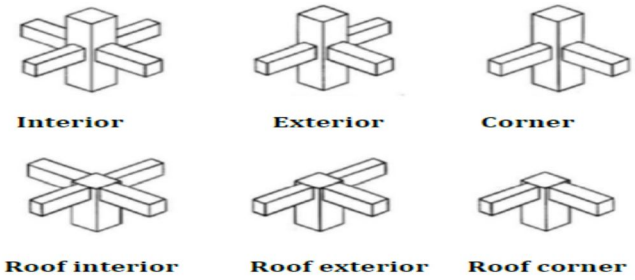

Figure 1. Different type of joints

II. LITERATURE REVIEW

A review of some significant experimental investigations conducted using steel plates is presented to demonstrate some of the structural implications of external plating. Research work into the performance of members strengthened with steel plates was pioneered simultaneously in South Africa and France in the 1960s (L'Hermite and Bresson, 1967; Fleming and King,1967; Lerchenthal,1967; Gilibert et al., 1976). Continued development of suitable adhesives and the increased use of the technique in practice stimulated further research work. Eberline et al. (1988) present a literature review on research and applications related to steel plate bonding..naveeena, m.ranjitham (2016) in reinforced concrete structures, beam column joint are considered as most damageable structural element subjected to lateral loads. In the paper a finite element model for exterior beam column joints is presented to stimulate the seismic behavior of RC existing structure with design criteria. The Retrofitting of existing structure is one of the major challenges in the modern civil engineering structures. This paper presents the jacketing method for strengthening or retrofitting of exterior beam column joint, to enhance their strength and stiffness. An analytical model is proposed to predict the shear capacity strengthened with carbon fibre reinforced polymer (CFRP).The axial load were applied at the column top of the surface and held constant during the test. The free end of the beam subjected to cyclic loading Two specimen one is un-strengthened and another is strengthened specimen with CFRP were modeled and analyzed. An effective re-habitation strategy is in order to increase the ductility of the beam column joint and transfer the failure mode to beam or delay the shear failure mode. The specimens are then loaded with step by step load increment procedure to stimulate the cyclic loading in testing. The stress and deformation results were evaluated and compared their results with strengthened and un-strengthened specimen. The numerical result shows that the beam column joint strengthened with CFRP can increase their structural stiffness, strength and energy dissipation capacity. 2. Jong-Wha Bai(2003) Many existing structures located in seismic re gions are inadequate based on current seismic design codes. In addition, a number of major earthquakes during recent years have underscored the importance of mitigation to reduce seismic risk. Seismic retrofitting of existing structures is one of the most effective methods of reducing this risk. In recent years, a significant amount of research has been devoted to the study of various strengthening techniques to enhance the seismic performance of RC structures. However, the seismic performance of the structure may not be improved by retrofitting or rehabilitation unless the engineer selects an appropriate intervention technique based on seismic evaluation of the structure. Therefore, the basic requirements of rehabilitation and investigations of various retrofit techniques should be considered before selecting retrofit schemes. In this report, the characteristics of various intervention techniques are discussed and the relationship between retrofit and structural characteristics is also described. In addition, several case study structures for which retrofit techniques have been applied are presented. 3.R.K.L. Su and Y. Zhu (2005) This paper aims to develop a new method for strengthening reinforced concrete coupling beams. Experiments were conducted to test three full-scale RC coupling beams, of which two were strengthened by bolted external steel plates on the side faces of the beams and the other one acted as a control specimen without strengthening. The improvements to strength, deformation and energy dissipation of the external plate strengthened RC coupling beams were observed from the experimental results. Nonlinear finite element analysis was carried out to model the strengthened and non-strengthened coupling beams. The material properties used for concrete and reinforcement in the numerical analysis were validated by the laboratory tests. As experimental study showed that there was a small slip between the bolted connection and the concrete wall pier, a bilinear model was used to simulate the load-slip behaviour of the bolt connections. The model was calibrated by the experimental results from the plate strengthened coupling beams. Numerical parametric study found that the small slip (>3mm) between the bolt connection and the concrete wall could significantly affect the load carrying capacity of the bolt connections as well as the structural performance of the strengthened coupling beams. The numerical model developed is very useful for investigating strengthened beams with other configurations and other reinforcement details. 4.F. Nateghi-Elahi and A. Dehghani (2008) It is obvious from

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experience that structures which had not been designed and constructed according to standard codes, and therefore do not have enough lateral stiffness, will undergo sever damages during intense earthquakes. As an effective rehabilitation technique, strengthening unreinforced masonry (URM) infills with fiber reinforced polymer (FRP) can improve their contribution in load-bearing action and in doing so, they can be considered as a structural element. In this article, the method of Equivalent Strut for modeling infill walls is analyzed with the aid of finite element (FE) procedure, and then by defining the compressive and tensile strut behavior, URM infill's are modeled both in un-retrofitted and retrofitted states. The results of nonlinear push-over analysis show that the proposed model can give the behavior close to the experimental specimens. 5. G. Genesio, R. Eligehausen, A. Sharma & S. Pampanin(2010) In reinforced concrete framed structures under seismic excitations the beam-column joint cores are arguably one of the most vulnerable zone. Experimental tests have shown that the structural behavior of poorly detailed joints is decisive for the structural response of older frame buildings. Due to inadequate shear reinforcement in the joint, poor bond properties of longitudinal reinforcement and deficiencies in the anchorage of reinforcement, a brittle failure mechanism can be expected. In the numerical analysis of r.c. moment resisting frames the joint core is usually considered as rigid and all the plastic rotations are assumed to take place in the beams and/or columns. Although this assumption is reasonable for structures subjected mainly to gravity loads, it may be highly misleading for structures subjected to seismic loads. In the literature several methods to assess the shear resistance of beam-column connections were proposed, but the deformation capacity of joints was not deeply investigated yet. In this study exterior beam-column joints designed for gravity only (or mainly) loads as typical of old code provisions are considered. Experimental investigations were conducted in the laboratory of the Bhabha Atomic Research Centre (BARC) in Mumbai. Three exterior beam column joints characterized by lack of shear reinforcement in the joint panel and by different anchorage solutions commonly used in the construction practice until the beginning of the 1970s were tested. Numerical analyses were carried out with the finite element (FE) Code MASA, developed at the University of Stuttgart and capable of three-dimensional (3D) nonlinear analysis of quasi-brittle materials, like concrete, based on the micro plane material model. In both experimental and numerical investigations particular attention was given to the evaluation of the deformation capacity of the joint. The capability to numerically reproduce the joint behavior was discussed and the influence of several parameters such as bond of longitudinal reinforcement of beam and column and shape of the anchored bars were investigated. The results were compared with the available data described in the literature and found in the tests. 6. Suat Yildirim, Goktug Asik, Baris Erkus, Yuce Yetimoglu, Yuksel Tonguc, Imad Mualla (2014) This paper presents retrofit project of a reinforced concrete building using friction dampers. The building is an 8-story government office building, where disturbance of the operations cannot be allowed. Preliminary studies shows that this building, which was designed and built using earlier Turkish seismic codes, do not satisfy the current Turkish seismic and structural code requirements. The lateral system of the building is interacting shear walls and moment frames. However, shear walls are not significant, and the structure is quite flexible. A study based on conventional retrofit approaches is conducted, where some of the moment frames are converted to shear walls and jacketing or CFRF wrapping of columns are used. Conventional retrofit method requires vacating the building for the construction, which is estimated to be costly, considered to be problematic and which will disturb the operations of the office significantly. In overall, the owner decided that conventional method is not feasible and requested an alternate approach for retrofit. Preliminary studies showed that use of energy dissipation devices can be a feasible solution for this specific building. It is required by the owner that retrofitted building has immediate occupancy performance under design basis earthquake level hazard and collapse prevention under maximum considered earthquake hazard. Upon receiving approval for proceeding with the detailed retrofit project, response spectrum analyses are conducted to estimate the number of dampers, damper capacities and locations. In this study, the building is modeled as linear and dampers are modeled as equivalent linear springs, where spring stiffness is estimated after an iterative study. Supplemental damping is reflected to the design response spectrum curve. Performance evaluation based on internationally accepted standards are used. Also, damper to structure connections are checked for feasibility and possible details are developed. In this part, both of the clients requested performance criteria are satisfied. In the next part of study, time-history analysis are conducted, where the structure is modeled linearly and dampers are modeled nonlinearly and performance of the building is evaluated for seven set of earthquakes and the second performance criteria is evaluated and is shown to be satisfied. After these studies, which confirms that proposed retrofit method satisfies the required performance objectives, details of the connections, foundations and detailed calculations are prepared. Proposed retrofit scheme and conventional retrofit scheme are compared. It is shown that there are numerous advantages of retrofitting with dampers compared to conventional approaches

III. OBJECTIVE OF THE STUDY

The purpose of this study is to highlight the methods of repair and rehabilitation to be undertaken for structures with defects and

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deficiencies that necessitate rehabilitation. Repair and Rehabilitation methods currently used are reviewed on the basis of present knowledge and the merit of a holistic system approach. This study focuses on visible symptoms of the problem rather than on visible and invisible problems as well as the possible causes behind them. This thesis focuses about the repair materials and the techniques are essential for the satisfactory performance of the repaired structure.

IV. PRONLEM FORMULATION

The main objective of this thesis is to study about the strength and serviceability of the CFRP retrofitted beam column joint. Also • To develop an effective rehabilitation in order to strengthen the beam column joints to avoid or delay their shear failure. • To increase the shear capacity of beam column joint using carbon fiber reinforced plastic materials. • To improve the seismic performance of damaged building in terms of lateral strength and serviceability. • To determine the load deflection behaviour of damaged beam column joint strengthened with CFRP when it is subjected to cyclic loading • To compare the behaviour of un-strengthened and strengthened specimen.

A. Structure dimension

Size of the column 150 x 200 mm
Size of the beam 150 x 200 mm
Height of column 800 mm
Length of the beam 600 mm

B. Steel reinforcement details

column: 4 no's of 12 mm diameter longitudinal reinforcement. 8mm diameter bars @ 150mm C/C distance.
beam: 4 no's of 12 mm diameter bars 8mm diameter bars @ 100 mm C/C distance
Steel reinforcement To model concrete reinforcing, discrete modelling is used by assuming that bond between steel and concrete is 100 percent. Beam column has six degree of freedom at each node. These include translations in the x, y, z directions and rotations about the x, y, z directions. This element is well-suited for linear, large rotation, and large strain nonlinear applications.

C. Laminates

To model laminated composites SHELL 91 is used. It may be used for layered applications of a structural shell model or for modelling thick sandwich structures. Up to 100 different layers are permitted for applications with the sandwich option turned off. When building a model using an element with fewer than three layers SHELL91 is more efficient than SHELL 99.

V. METHODOLOFY AND RESULTS

A. Cad model

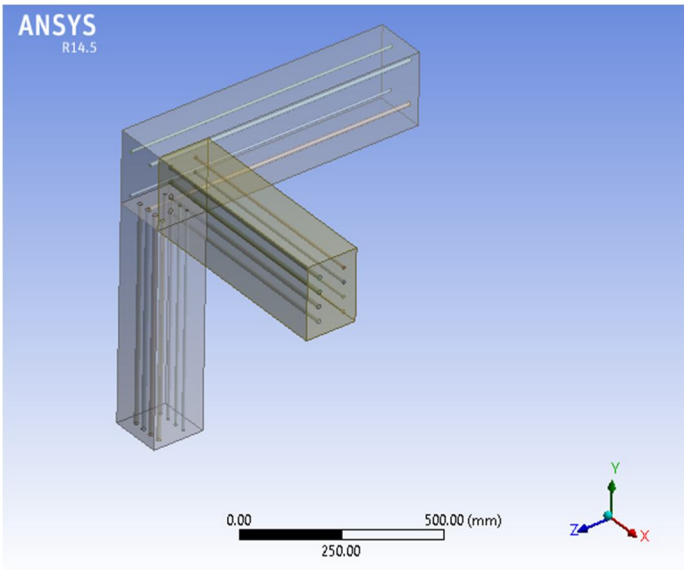

Figure 5.1. Cad model of steel reinforced roof joint

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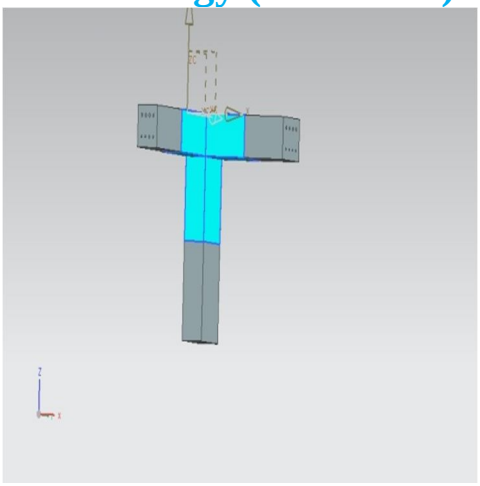

Figure 5. 2. Cad model of CFRP reinforced roof joint

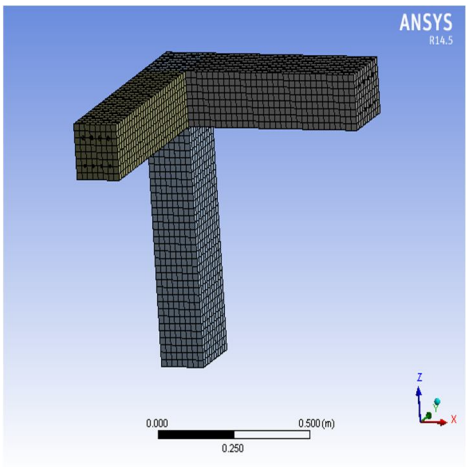

Figure 5.3. Mesh model of steel reinforced roof joint

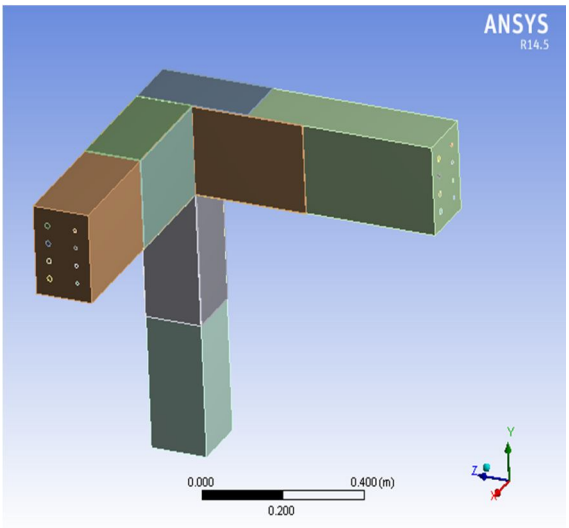

Figure 5.4. Cad model of CFRP reinforced roof joint

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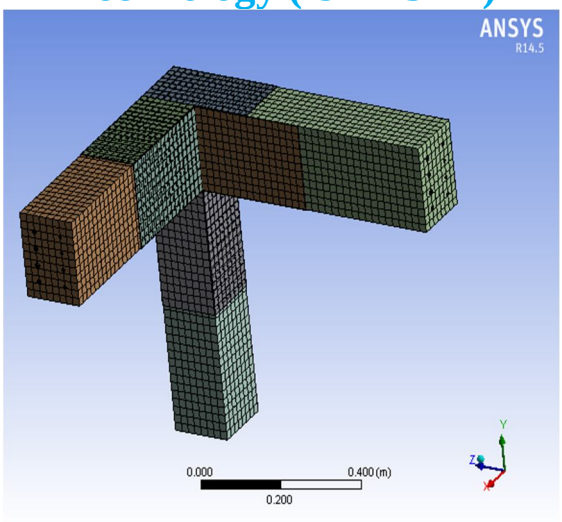

Figure 5.5. Mesh model of CFRP reinforced roof joint

Table 5.1 material properties

Material used	Modulus of Elasticity (E)	Poisson's Ratio (μ)
Unreinforced concrete	E= 22.36×10^{9}N/m^2	μ=0.23
CFRP Sheet	E=181×10^{9} N/m^2	μ=0.24
Steel	E=2x10^{11} N/mm^2	μ=0.3

B. Roof joint without cfrp wrapping

The structural geometry of exterior beam column joint has been modelled for the mentioned dimension and analysed using ANSYS. The exterior beam column joint has been analysed without CFRP wrapping. The bottom of the column is constrained in all degree of freedom. The load of 30KN is applied on the beam.

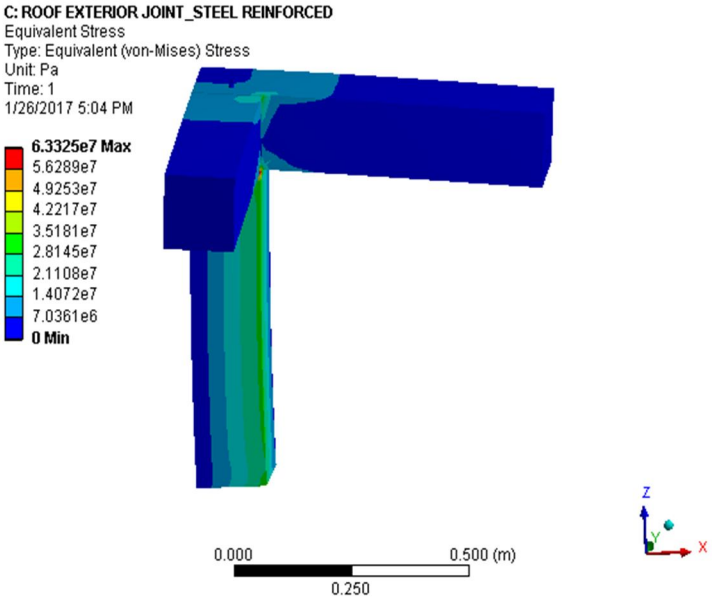

Figure 5.6. Stress in steel reinforced roof joint

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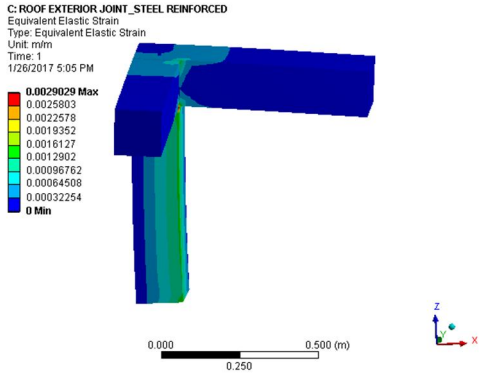

Figure 5.7. Strain in steel reinforced roof joint

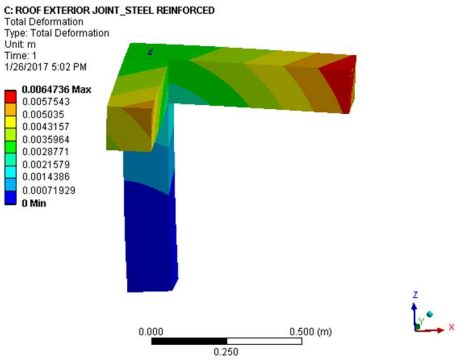

Figure 5.8. Deformation in steel reinforced roof joint

C. Roof- column-beam joint with cfrp wrapping

The structural geometry of Roof–column-beam joint has been modelled for the mentioned dimension and analysed using ANSYS. The roof joint has been analysed with CFRP wrapping. The bottom of the column is constrained in all degree of freedom. The cyclic load of up to 30KN is applied on the beam. The thickness of wrapping of CFRP is 2 mm. Poison ratio is 0.24young modulus $181x10^9$ N/mm^2 And it is wrapped on 300mm length on all sides.

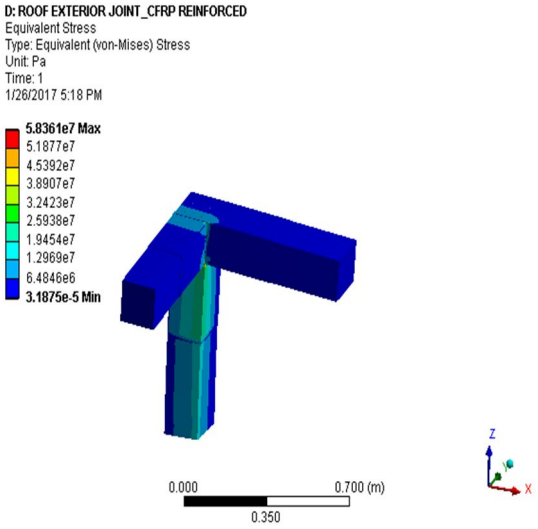

Figure 5.9. Stress in CFRP reinforced roof joint

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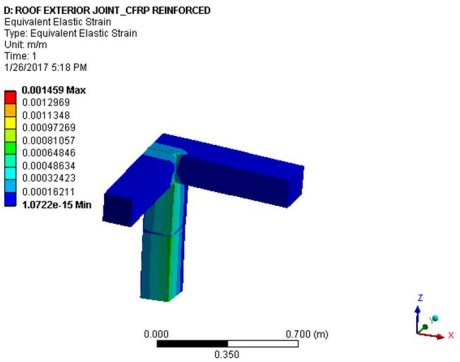

Figure 5.10. Strain in CFRP reinforced roof joint

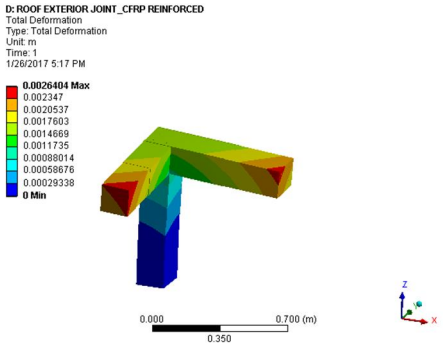

Figure 5.11. Deformation in CFRP reinforced roof joint

RESULTS TABLE 5.2

MATERIAL	STRESS (N/M2)	DFORAMATION (mm)	STRAIN
STEEL REINFORCED	6.33e7	6.47	0.0029029
CFRP LAMINATES	5.83e7	2.64	0.001459

VI. CONCLUSION AND FUTURE SCOPE

In this chapter the numerical results of both with CFRP wrapping and without CFRP wrapping are Analyzed. Their behaviour throughout the analysis is studied from the recorded data obtained from the deflection behaviour and load carrying capacity using ANSYS. The strengthened and un-strengthened beam column joints are tested for their ultimate strength.

1**.** The load deformation characteristic is improves to the large extent in case of retrofitted specimen over un-strengthened specimen. 59% Reduction of deformation is carried out in CFRP laminates as compare to the Steel reinforced structure.

2. 15.79% reduction in stress value in CFRP laminates stricture as compare to the STEEL reinforced structure.

3. The ductility of the retrofitted specimen will be more when compared with the normal specimen 4. CFRP retrofitting specimen of the beam column joint shifted the failure of the joint from column portion to the beam portion of joint which will prevent progressive collapse.

The following observations and conclusions can be drawn based on the analytical results of the study. 1. Comparing the numerical investigation we can confirm that the deflection in the strengthened specimen is comparatively lesser than that of the un-strengthened specimen. 2. It is observed that the stress in the specimen is better in the retrofitted with CFRP specimen when compared with the normal specimen without CFRP wrapping. 3. From the overall study, it can be concluded that the strengthening with CFRP structure will increase the serviceability of the structure.

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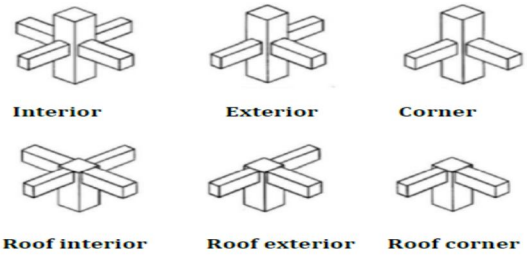
A. Future scope

Current Study can be extended with both geometrical and material aspects:

Different RC Structure can be taken like



Different wrapping length of CFRP can be Taken.

Various thicknesses of CFRP Sheets can be apply.

Different FRP'S like Carbon fiber-reinforced polymer, carbon fiber reinforced plastic or carbon fiber-reinforced thermoplastic (CFRP, CRP, CFRTP) or often simply carbon fiber, or even carbon) can be apply as a reinforced material for better strengthened.

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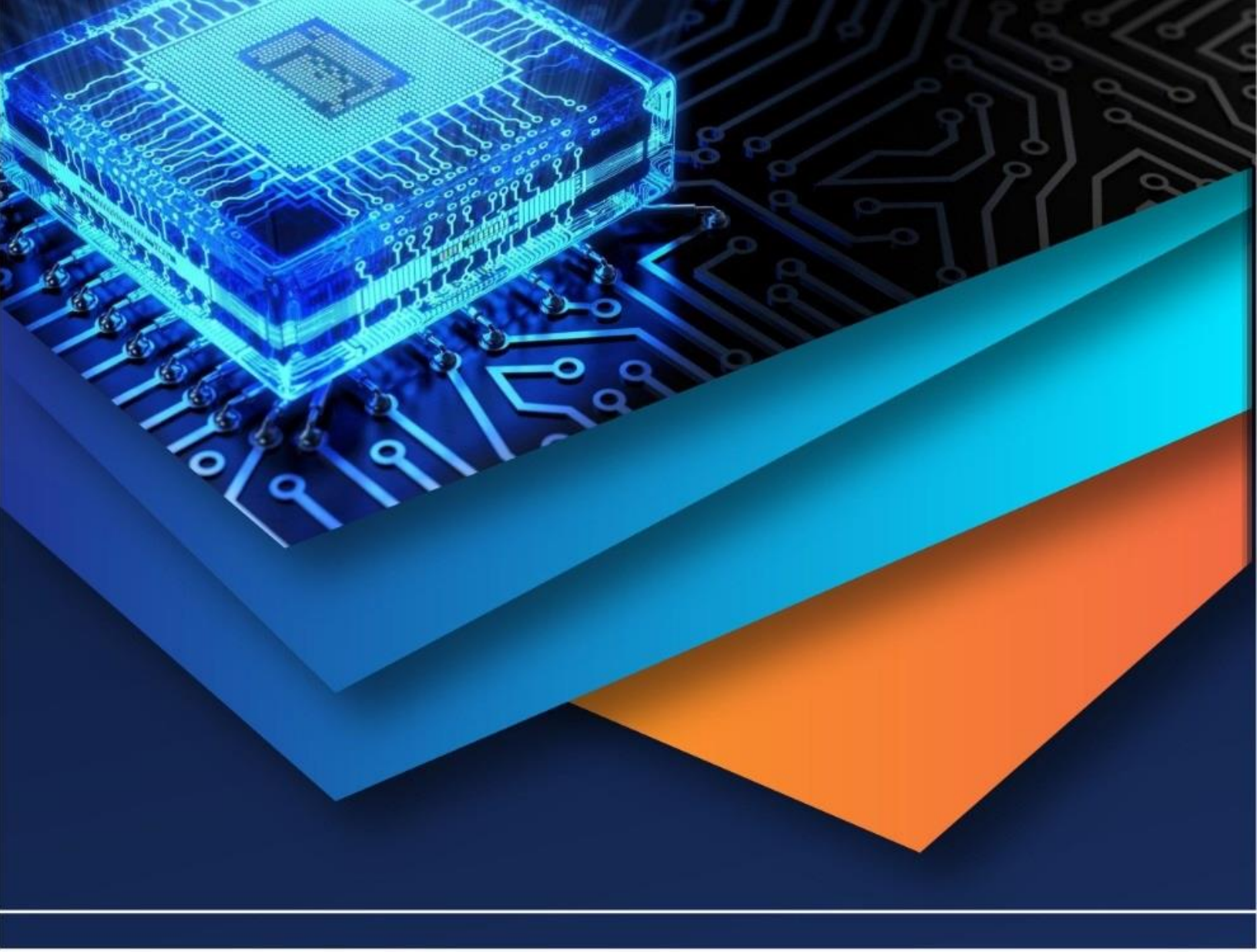

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