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Retrofitting Using FRP

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Abstract: *This research paper is focused on the structures which lack the required strength. The basic idea behind the strength enhancement of structure is based on the concept of improving the flexibility, stiffness, ductility and unity of the structure. The method of retrofitting improves the seismic force sustaining capacity of various components of building without stress concentration at critical points.*

***Index Terms* – Retrofitting, FRP, CPRF**

I. Introduction

Before the 1980s, the key issue for retrofitting of building structures was the assessment and strengthening of old houses. After the middle of the 1990s, however, structural assessment and strengthening for both old and new buildings is becoming more intensive due to the rapid development of the construction industry. Especially in the real estate market, privately owned houses have become a majority, and many disputes between house developer and house buyer have resulted. To solve these problems technically it is necessary to perform structural assessment and strengthening of building structures. In some cases, the result of inspection and assessment of building structures is becoming an increasingly important basis for government officials to mediate the disputes in the real estate market. Generally speaking, the following building structures need to be evaluated and retrofitted.

(1) The buildings whose serviceability or strength cannot meet the requirements of structural codes or regulations, due to misuse, irregular maintenance, aging of materials and structures.

(2) The buildings that have quality or safety problems due to design flaws or deficiency in construction quality. These problems are often met in new construction and existing buildings.

(3) The buildings in which structural damages are caused by disasters such as earthquakes, strong winds, fires, etc.

(4) Those historic buildings and memorial buildings that need to be rehabilitated and protected.

(5) The buildings that will be reconstructed, or have additional stories built.

(6) The buildings whose structural members may be changed during renovation, which may influence the performance of whole structural system.

(7) When the buildings are located close to the site of a deep pit foundation of a new construction, this deep excavation may cause unequal settlement of the surrounding soil and the surrounding buildings may consequently face potential damages or risks. The assessment and retrofitting of this kind of building is also an important safety measure for the construction of the deep foundation as well as the new structure.

II. Objective

1. Increasing the lateral strength and stiffness of the building.
2. Increasing the ductility and enhancing the energy dissipation capacity.
3. Giving unity to the structure.
4. Eliminating sources of weakness or those that produce concentration of stresses.
5. Enhancement of redundancy in the number of lateral load resisting elements.

III. Literature Review

The development of fiber-reinforced plastic for commercial use was being extensively researched in the 1930s. In the UK, considerable research was undertaken by pioneers. It was particularly of interest to the aviation industry. The study of following articles gives us bigger perspective of understanding

Retrofitting of reinforced concrete beams using composite laminates

Summary: This paper presents the results of an experimental study to investigate the behavior of structurally damaged full-scale reinforced concrete beams retrofitted with CFRP laminates in shear or in flexure. The main variables considered were the internal reinforcement ratio, position of retrofitting and the length of CFRP. The experimental results, generally, indicate that beams retrofitted in shear and flexure by using CFRP laminates are structurally efficient and are restored to stiffness and strength values nearly equal to or greater than those of the control beams. It was found that the efficiency of the strengthening technique by CFRP in flexure varied depending on the length. The main failure mode in the experimental work was plate deboning in retrofitted beams.

Strengthening Reinforced Beam Using Fibre Reinforced polymer (FRP) Laminates

Summary: This paper present in the various types of fibre reinforced polymer laminates are tested with the 14 simply supported cross section beams. In each beam was strengthened with FRP laminates of initially loaded above its cracking load and tested until failure. The carbon/ glass fibre reinforced polymer (CFRP/GFRP) of strengthening materials were used in externally bonded with beams. The different layers of frp sheet, types of epoxy and strengthening pattern which are examined and to calculate the absorbed energy to total energy, or energy ratio The proper combination of vertical and horizontal sheets are provided; proper epoxy can lead to a doubling of the ultimate load carrying of the beam. To conclude the behaviour of strengthening of beams are exhibits in higher factor of safety in design.

Retrofitting of RC beam and Column joints using FRP Laminates

Presented a procedure for analytical prediction of joint shear strength of interior beam-column joints, strengthened with externally bonded fibre-reinforced polymer sheets. To implement the available formulation for shear capacity prediction, a program was developed. Using this program, shear capacity of the joint and joint shear stress variation at various stages of loading were predicted and compared with experimental observations. It was observed that even a low quantity of FRP can enhance shear capacity of the joint significantly.

Strengthening of Rc Beam by using BFRP

Summary: The researched and find out the basalt fibre may use in concrete. After investigations, the basalt fibre used in concrete for the first time in world. And also, they are find out the beams reinforced with plain basalt bars failed in flexure due to inadequate bond between the steel and concrete. All the actual ultimate moments were much less than the calculated ultimate moments to the steel pull out failure. The beam with fibres exhibited a primary failure in flexure and shear followed by a secondary failure on splitting and also ductile, micro cracks resist bond between all the modified basalt rebar and concrete was extremely good. Ultimate moment good compare with normal concrete. In general, the basalt fibres are suitable for use in reinforced concrete section

Evaluation of Engineering Properties for Polypropylene Fibre Reinforced Concrete

Has studied on the performance of polypropylene fibre reinforced concrete. From the experimental studies properties such as compressive strength, flexural strength, split tensile strength and shear strength of polypropylene fibre reinforced concrete was studied. The fibre volume fraction of ranges from 0 to 2%. Conclusions drawn are like the failure modes when fibers are present in concrete are spelling of mortar or bulging in transverse direction.

IV. Methodology

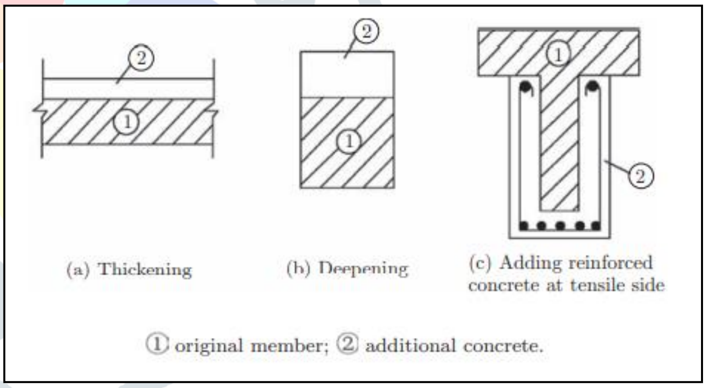
The retrofitting procedure of a building structure is as follows.

(1) Inspection of mechanical properties of structural materials

Generally, the material properties may be obtained from design documents and construction daily records, especially the checking and accepting record upon completion of the project. If there is doubt concerning material strength, testing of materials is necessary.

(2) Assessment of structural vulnerability and safety

Vulnerability assessment is to evaluate serviceability of a building structure by inspecting the appearance of members and structural system to provide a basis for maintenance and rehabilitation of the building.



3.1 Retrofitted Member

The safety assessment evaluates the strength of members and structural system by structural analysis and section checking according to related design code to provide a basis for structural retrofitting of the building

(3) Working out the retrofitting scheme

After completing the assessment of structural vulnerability and safety, a detailed retrofitting plan can be laid out by comprehensively considering the service requirements of the building, future life-cycle of the building, construction condition, cost issue, etc.

(4) Design of retrofitting construction drawings

Usually the construction drawings can be done according to the retrofitting scheme together with detailed attention paid to connections between new structure and existing structure, as well as the safety issue of existing structure during the retrofitting construction phase.

(5) Inspection during construction and acceptance checking after retrofitting

Designers and inspectors are required to go to the construction site to solve various problems that have occurred. Especially when the existing structure does not coincide with the construction drawings, the designers must go to site and modify their design drawings accordingly. The acceptance checking after retrofitting is as important as it is for new construction. In some cases, measurement after retrofitting is also necessary, especially for very important and large-scale construction.

3.2 Retrofitting of RC Beams and Slabs

1. Section Enlarging Method

The section enlarging method is effective when bearing capacity and member stiffness are far below the code-specified requirement. Furthermore, format of enlarging sections may be selected from one-side thickening, two-side thickening or three-side thickening in accordance with loading types, detail features and construction conditions. When additional concrete is cast above the original concrete surfaces of continuous beams, concrete added at mid-span of beams lies in compression zone, while the concrete is subjected to tensile force at supports. However, thickening underneath is the contrary case. The concrete added in the tension zone prevents additional reinforcement against erosion, whereas the concrete added in the compression zone enhances effective depth of the section, and increases stiffness and strength of the member. The retrofit strategy of adding concrete layer is 3.2 Retrofitting of beam using Reinforcement

definitely feasible.

Retrofitting by Adding Tensile Reinforcement

Retrofitting with tensile reinforcement is to add reinforcements on the tensile side of the beam to enhance its bearing capacity. The method is applicable where stiffness of the beam section and the shearing capacity are enough but the tensile strength of the bend region is insufficient and the adding reinforcement is not excessive. In this section, the procedure, characteristics and construction of retrofitting with adding tensile reinforcement, as well as the calculation method of the bearing capacity of the retrofitted members, will be introduced. The connection between additional reinforcements and existing beams involves three forms: full welding, semi-welding and bonding connections.

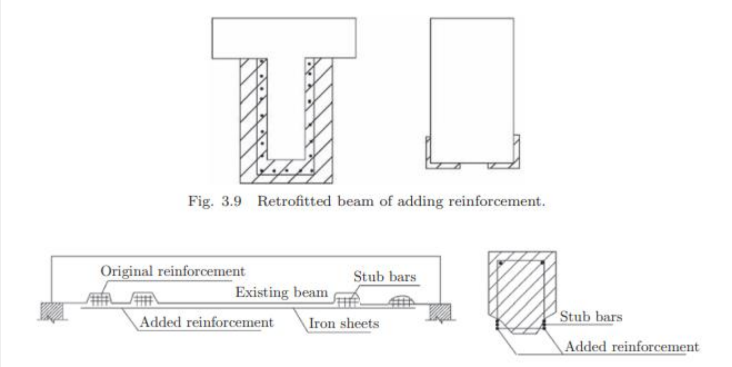


Fig. 3.9 Retrofitted beam of adding reinforcement.

(1) Full welding

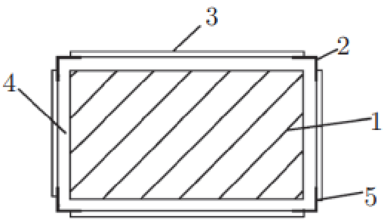
Regarding full welding, additional reinforcements are directly welded to original reinforcements, and additional concrete layers are

3.3 Encased steel method

not necessary. The additional reinforcements are exposed to natural

environment and participate in flexural resistance with original reinforcements by the action of weld.

In general, it is desirable to locate welding to the inflection points of existing beams where tensile stress of the original reinforcements is negligible. Therefore, concentrated load transmitted through weld from additional reinforcements may result in limited influence on original reinforcements that could be regarded as anchors for additional reinforcements.



Encased steel methods

1. original column; 2. rolled angle; 3. batten plate; 4. concrete or mortar; 5. agglomerate.

(2) Semi-welding casts fine-grained concrete layers after welding. Additional reinforcements definitely benefit from bonding with additional concrete as well as the anchor to original reinforcements. Therefore, mechanical behavior of the additional reinforcements is almost the same as that of original reinforcements and the reliability of retrofitted members has been improved further.

(3) Bonding concrete The bonding concrete technique denotes that additional reinforcements contribute to flexural capacity of retrofitted members based only on the bonding strength of concrete. Construction procedures are introduced herein.

a. Roughen the surfaces of existing members to ensure surface roughness more than 6 mm. b. Notch a groove for every 500 mm as a concrete shear stub and then weld U-shaped stirrups to original reinforcements or to anchor bolts for favourable mechanical behaviour.

c. Thread longitudinal reinforcements into U-shaped stirrups and then bind them together. Finally smear epoxy adhesive onto the interface before casting or ejecting additional concrete.

Concrete Column Retrofitting

1. Section-enlarging Method

Section-enlarging, also known as outsourcing concrete retrofitting, is a common method to retrofit columns. For enlarging section area and reinforcement of original columns, this method enhances column bearing capacity, and also reduces column slenderness ratio and improves column stiffness. Particularly in the seismic fortified areas, it could change the original strong beam-weak column structure into the strong column-weak beam structure, to enhance seismic resistance.

2. Encased Steel Method

Encased steel refers to retrofit the concrete column by wrapping four corners or two sides of the column with profiled steel. Its advantage is that concrete column capacity can be greatly increased along with a little increase of section size. For square or rectangle columns, rolled angles are generally wrapped on four corners and linked with horizontal batten plates to form a whole body. For circular members such as circular column and chimney, flat-rolled steel hoops with skeins are often used. Retrofitting by bonding steel and column together by filling latex cement or epoxy mortar or fine concrete in space between them is called wet-enclosing steel method. This method improves capacity of concrete columns and also improves ductility because of the restraints of profiled steel and batten plates.

V. RESULTS

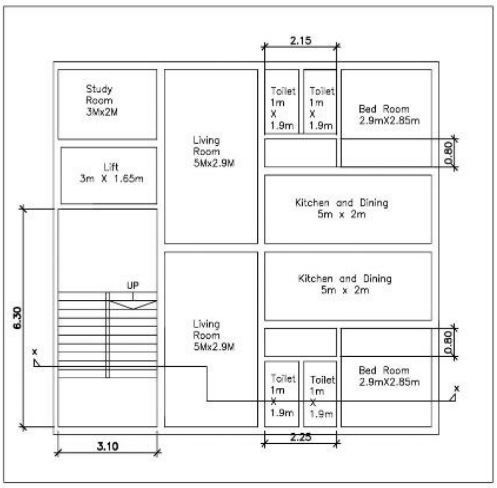
4.1 Implementation

1. The study can be extended to beams especially flanged reinforced concrete beams where ways and means are to be devised for complete wrapping of FRP composites for strengthening.

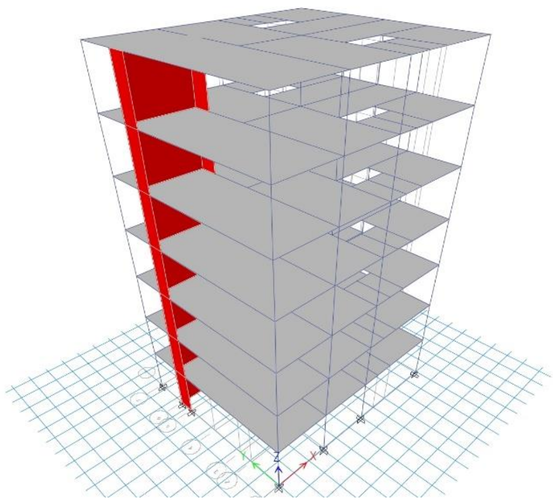
2. Select the different FRP materials like carbon fiber, basalt fibers etc for strengthening the concrete members to compare the results with GFRP
3. The fiber orientations of FRP laminates have significant effect on the ultimate strength of the members which were strengthened. Hence, the study can be extended for different fiber orientations apart from 0°/90° and +45°, to determine the appropriate fiber orientations of FRP laminates.
4. Studies can be taken up on prestressed concrete structural components strengthened with FRP composites.
5. Many environmental factors involved during the life span of a retrofitted structure need more attention. Thev include seasonal temperature variation, degradation of material properties, creep and so on.

4.2 Geometric and Retrofitting Details
G+6 Building

Unit = kilo newton and meter
Number lines along X direction = 6, Spacing in X direction= as per plan
Number of lines along Y direction= 7, Spacing in Y direction= as per plan
Story detail
Number of story= 6 Typical story height= 3, Bottom story height= 3
Steel frame and Concrete Frame design
Design codes= IS 456:2000
IS 800:2007
IS 875:1987
IS 1893:2016
Material Property
Compressive Strength= 30000, Yield strength= 6000000, Yield stress= 6000000
Beam size= 0.3m x 0.4m and 0.35m x 0.45m, Column Size=0.3m x 0.3m and 0.35m x0.35m
Bar size=16d, Corner Bar size= 16d
Slab thickness= 0.15m
Dead load of beam= 3, Dead load of column= 4, Dead load of slab= 3.125
Live Load= 3, Earthquake x= 1.5 of live load, Earthquake Y= 1.5 times of live load
Retrofitting detail
column size=0.35x0.35
Bar size=16d
Dead load=6.25, Live Load= 3,
Earthquake x= 1.5 of live load, Earthquake Y= 1.5 times of live load



Architectural Plan



4.3 Story Response value using E-Tabs Software

TABLE: Story Response Comparison (Displacement)						
Story	Normal Structure		Retrofitted Structure		Percentage %	
	X-Dir	Y-Dir	X-Dir	Y-Dir	X-Dir	Y-Dir
	m	mm	mm	mm		
Story7	30.363	15.42	15.295	6.496	49.60	57.87
Story6	26.841	13.429	13.586	5.839	49.38	56.52
Story5	22.484	11.258	11.366	5.016	49.45	55.44

Story4	17.582	8.82	8.834	4.008	49.75	54.56
Story3	12.439	6.202	6.148	2.868	50.57	53.76
Story2	7.409	4.061	3.512	1.672	52.60	58.83
Story1	2.843	1.92	1.223	0.572	56.98	70.20
Base	0	0	0	0	0	0

4.4 Story Drifts using E-Tabs Software

TABLE: Story Drifts Comparison

Description				Normal Structure	Retrofitted Structure	Percentage %
Story	Output Case	Case Type	Direction	Drift (mm)	Drift (mm)	
Story7	Siesmic	LinStatic	X	6.21×10^{-4}	3.74×10^{-4}	44.12
Story7	Siesmic	LinStatic	Y	4.2×10^{-4}	3.03×10^{-4}	27.86
Story6	Siesmic	LinStatic	X	8.15×10^{-4}	4.49×10^{-4}	44.91
Story6	Siesmic	LinStatic	Y	4.9×10^{-4}	3.87×10^{-4}	21.02
Story5	Siesmic	LinStatic	X	9.52×10^{-4}	5.23×10^{-4}	45.06
Story5	Siesmic	LinStatic	Y	6.02×10^{-4}	4.62×10^{-4}	23.26
Story4	Siesmic	LinStatic	X	10.22×10^{-4}	5.6×10^{-4}	45.21
Story4	Siesmic	LinStatic	Y	6.70×10^{-4}	5.05×10^{-4}	24.63
Story3	Siesmic	LinStatic	X	5.60×10^{-4}	5.54×10^{-4}	1.07
Story3	Siesmic	LinStatic	Y	6.92×10^{-4}	5.04×10^{-4}	27.17
Story2	Siesmic	LinStatic	X	9.49×10^{-4}	4.87×10^{-4}	48.68
Story2	Siesmic	LinStatic	Y	5.82×10^{-4}	4.33×10^{-4}	25.60
Story1	Siesmic	LinStatic	X	6.02×10^{-4}	2.59×10^{-4}	56.98
Story1	Siesmic	LinStatic	Y	4.74×10^{-4}	2.34×10^{-4}	50.63

VI. Conclusion

Fibre reinforced polymer (FRP) is widely accepted as materials for structural and non-structural application in the field. Interest in FRP for structural applications is due to specific modulus and strength of the reinforcing fibres. It is well suited for development of novel repair, retrofit and new construction solution that lead to economical and improved the structural performance. FRP as strengthening and retrofitting material has several advantages over conventional materials. Its thickness is small and hence its application does not add weight to existing structures. It helps to preserve the cultural heritage of monumental structures. GFRP, CFRP, BFRP, are most desirable in repair/retrofit if structural elements such as beam column and slabs, which requires a high increase in strength, toughness, energy absorption, fatigue and ductility ratio, etc

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