

## Seismic Retrofitting Of RCC Structure by FRP Jacketing

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**Abstract** -Seismic Retrofitting for reduction of vulnerability of a structure is a relatively new concept in India. India was not considered to be a seismically active country unless recently some earthquakes like one in Latur (93) and Bhuj Earthquake (2001) among the major ones has happened. In the recent past, India has seen mass destruction due to failure of structures hit by earthquakes and consequently, lost a lot of lives. Hence, it is of utmost importance that attention be given to the evaluation of the adequacy of strength in framed RC structures to resist strong ground motions. In this project, four storey reinforced concrete structure without seismic loading has been considered, which lies in zone III according to IS 1893:2000 classification of seismic zones in India. FRP jacketing is the most appropriate method of retrofitting the failing members in the given 4-storey RC structure. The norms stated in ACI 440-2R.02 have been followed to calculate and suggest the method and scheme of application of FRPs to the member and covering by frp to be used.

**Key Words:**Equivalent Static Method, Demand Capacity Ratio, Flexural Capacity, Shear Capacity, Reinforced Concrete Structure, FRP Strengthening.

### 1.INTRODUCTION

The 4-storey RC Structure being analysed in this particular project is considered without seismic loading which is located in zone 3 (Mumbai). hence, some of the RC members may fail due to the earthquake because they not able to resist against seismic activity. studying the performance of the structure without earthquake loading and compares the same with the application of the earthquake load suggesting suitable retrofit measures for failing members in the structure. A Fiber Reinforced Polymer (FRP) composite is defined as a polymer (plastic) matrix, either thermo set or thermoplastic, that is reinforced (combined) with a fibre or other reinforcing material with a sufficient aspect ratio (length to thickness) to provide a discernable forcing function in one or more directions. FRP composites are different from traditional construction materials such as steel or aluminium. FRP composites are anisotropic (properties apparent in the direction of the applied load) whereas steel or aluminium is isotropic (uniform properties in all directions, independent of applied load). Therefore, FRP composite properties are directional, meaning that the best mechanical properties are in the direction of the fiber placement. According to the Seismic Zoning Map of IS 1893:2002, India is divided into five seismic zones, in ascending order of a certain zone factor which is assigned to them on the basis of their seismic intensity.

**FRP's are increasingly use for jacketing because of :-**

High Strength to weight ratio, Immunity to corrosion, Easy handling & applications, No effect on external aesthetics of structure, High tensile strength, Flexible, Less labour & equipment cost.

### Drawbacks of FRP-

Sensitive to fire & temperature, Expensive, Difficult in near MEP Services & openings.

**Types of Fibers:-**The fiber reinforced polymers used for strengthening civil engineering structures are made of Carbon:-Stable under high temperature. Resistant to acidic/alkali/organic environments. High stiffness and tensile strength. More expensive.

**Glass:-**E-glass (less expensive), AR-glass (alkali-resistant), S-glass (stronger and stiffer)

**Aramid:-**Polymeric fibers appropriately processed to achieve high tensile strength-to-density ratio. Aramid fibers share some general characteristics that distinguish them from other synthetic fibers: High strength, Good resistance to abrasion, Good resistance to organic solvents, Non-conductive, No melting point, Low flammability, Good fabric integrity at elevated temperatures

**FRP's can be used in the concrete structures in following forms.**

**1.Plates-**at the face to improve the tension capacity.

**2.Laminates-**below beams & slabs to improve load taking capacity.

**3.Bars-** as reinforcements in beams & slabs replacing the steel bars.

**4.Cables-** can be used as tendons and post-tension members in suspension and bridge girders.

**5.Wraps-** around concrete members i.e. columns, beams, slabs etc for confinement

### Theory & Formulation

**Demand Capacity Ratio:-**The calculation of Demand Capacity Ratio to identify the failing members, is the part of Equivalent Static Analysis.

**Demand:** -It is amount of force or deformation imposed on an element or component (in this case, with respect to earthquake loading).

**Capacity:** -It is the strength or deformation of a structural member or system (Without Earthquake Loading).

### DCR= DEMAND/CAPACITY

If DCR is lesser than 1, the member passes, else it passes. It is an important tool used to determine whether a certain member of the structure is passing or failing due to moment and/or shear. The check for DCR exceeding 1 was performed for both flexural and shear capacities of the beams of the structure.

**To avoid failure, the following methods can be adopted-**

Reducing the loads acting on the member, Increasing the area of the section ,Replacing with a material of higher strength

If **DCR <1**, the member is labelled PASS i.e. it can take the moment induced by the seismic loading.

If **DCR >1**, the member is labelled FAIL i.e. it cannot take the moment induced by the seismic loading.

### Steps of FRP Jacketing

#### Design Of Beam FRP Jacketing As Per ACI 440-2R

Step 1:- Calculate the FRP system design material properties

Step 2:-Preliminary calculation

Step 3:-Determine the existing state of strain on the soffit:

Step 4:-Determine the design strain of the FRP system:

Step 5:-Estimate c, the depth to the neutral axis

Step 6:- Determine the effective level of strain in the FRP reinforcement

Step 7:-Calculate the strain in the existing reinforcing steel:

Step 8:-Calculate the stress level in the reinforcing steel and FRP

Step 9:- Calculate internal forces resultant and check equilibrium

Step 10:- Calculate flexural strength components

Step 11:- Calculate design flexural strength of the section

### Design Of Shear Reinforcement

#### As Per ACI 440-2R

Step 1:- Cal the FRP system design material properties.

Step 2:-Cal. the effective strain level in the FRP shear reinforcement

Step 3:-Cal. Contribution of the FRP r/f to the shear strength.

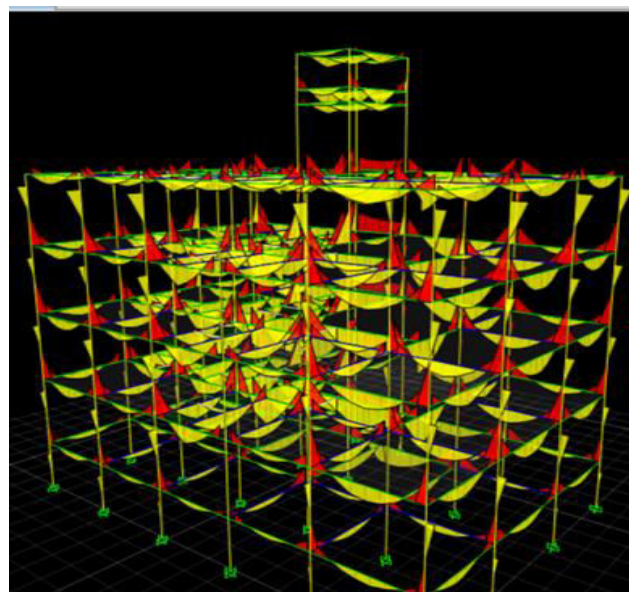
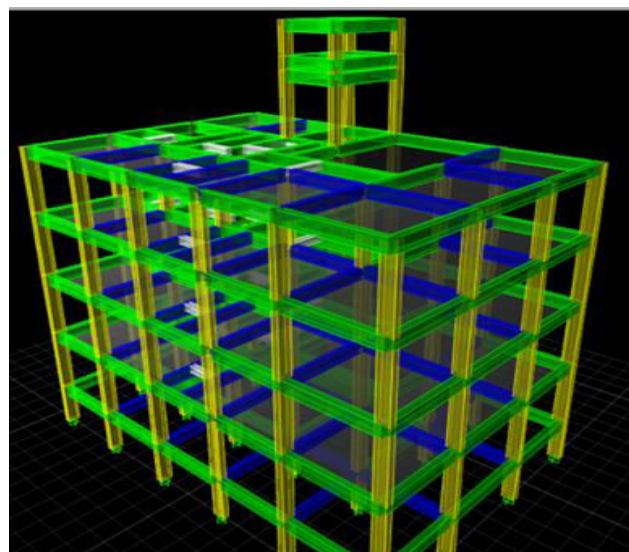
Step 4:-Total Shear Strength of Section.

### Structural Data

The structural system for the proposed residential building. It consists of R.C.C. framed structure with columns, beams, slabs and staircases etc. The floor slabs are mainly R.C.C. slab system. The report outlines the key structural design criteria/assumptions. The design has been done in accordance with the provision given in the architectural/services drawings as well as IS standards.

The Number of floors which has to be Design is given below  
Ground +4 Floors +Terrace + OHT/LMR

#### 3D View

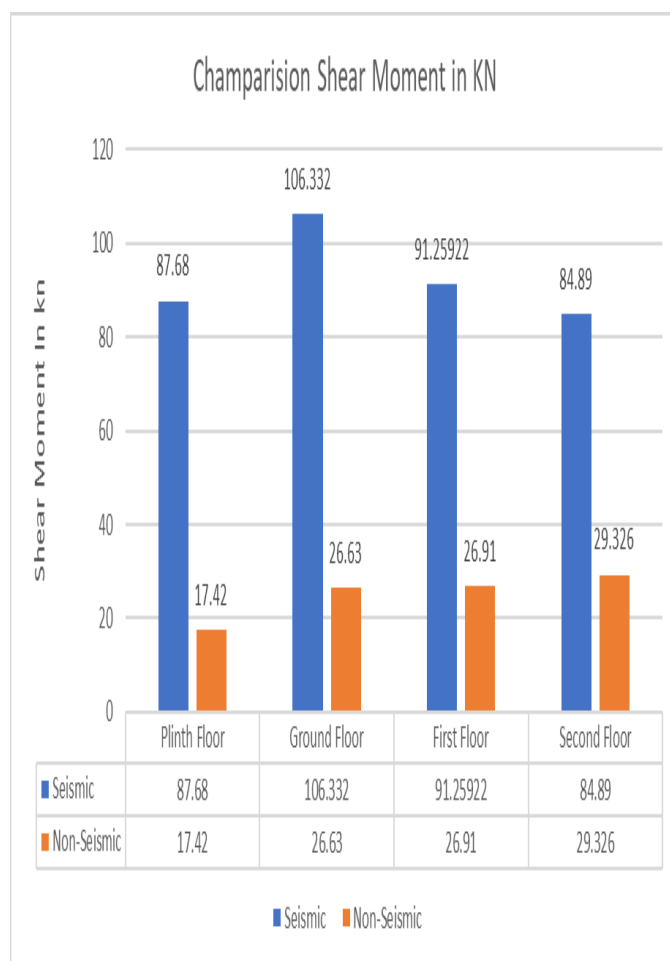
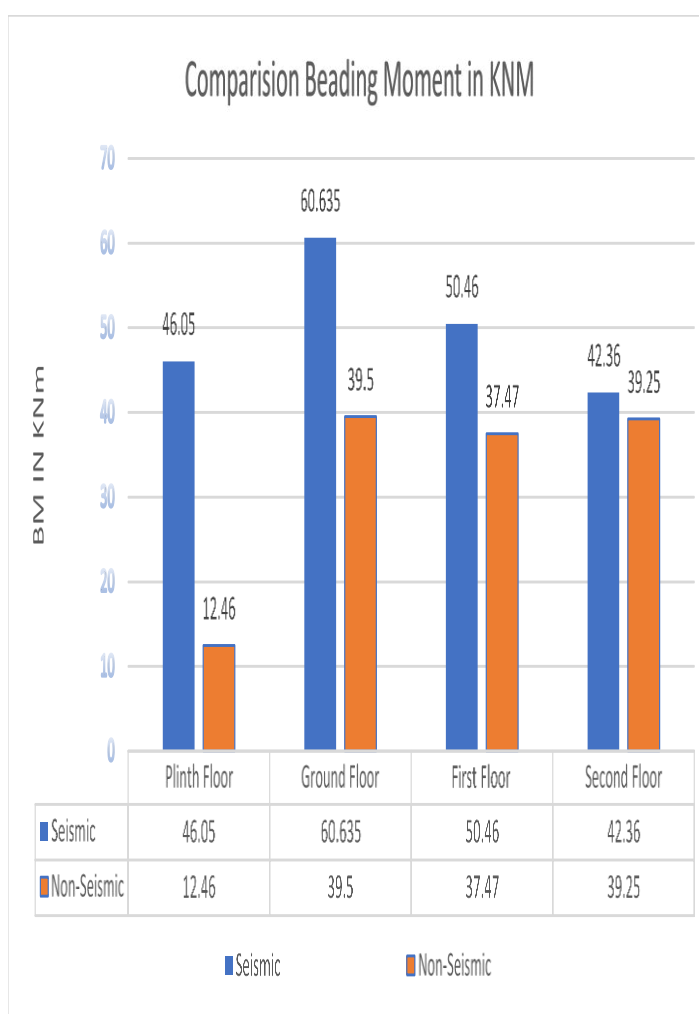


#### DCR CALCULATIONS FOR BEAMS

#### MOMENT CAPACITY OF BEAM

MOMENT CAPACITY OF BEAM						
BEAM NO	FLOOR	BEAM SIZE	DEMAND MOMENT KN.M	CAPACITY MOMENT KN.M	DCR	RESULT
B104	FIRST FLOOR	B230X450	52.7901	49.3298	1.07	FAIL
B105	FIRST FLOOR	B230X450	11.0068	18.2166	0.604	PASS
<b>B108</b>	<b>FIRST FLOOR</b>	<b>B230X500</b>	<b>71.0323</b>	<b>59.1628</b>	<b>1.201</b>	<b>FAIL</b>
B109	FIRST FLOOR	B230X500	53.6015	28.3926	1.888	FAIL
B111	FIRST FLOOR	B230X450	15.4848	29.7119	0.521	PASS

SHEAR CAPACITY OF BEAM						
BEAM NO	FLOOR	BEAM SIZE	MAX SHEAR (kN)	SHEAR RESISTED (kN)	DCR	RESULT
B104	FIRST FLOOR	B230X 450	120.9181	28.9452	4.1775	FAIL
B105	FIRST FLOOR	B230X 450	80.8993	31.5879	2.5611	FAIL
<b>B108</b>	<b>FIRST FLOOR</b>	<b>B230X 500</b>	<b>128.3821</b>	<b>58.2992</b>	<b>2.202</b>	<b>FAIL</b>
B109	FIRST FLOOR	B230X 500	85.1682	18.1266	4.6985	FAIL
B111	FIRST FLOOR	B230X 450	102.1277	15.788	6.4687	FAIL



## SHEAR CAPACITY OF BEAM

## DCR CACLCLATIONS FOR COLUMNS

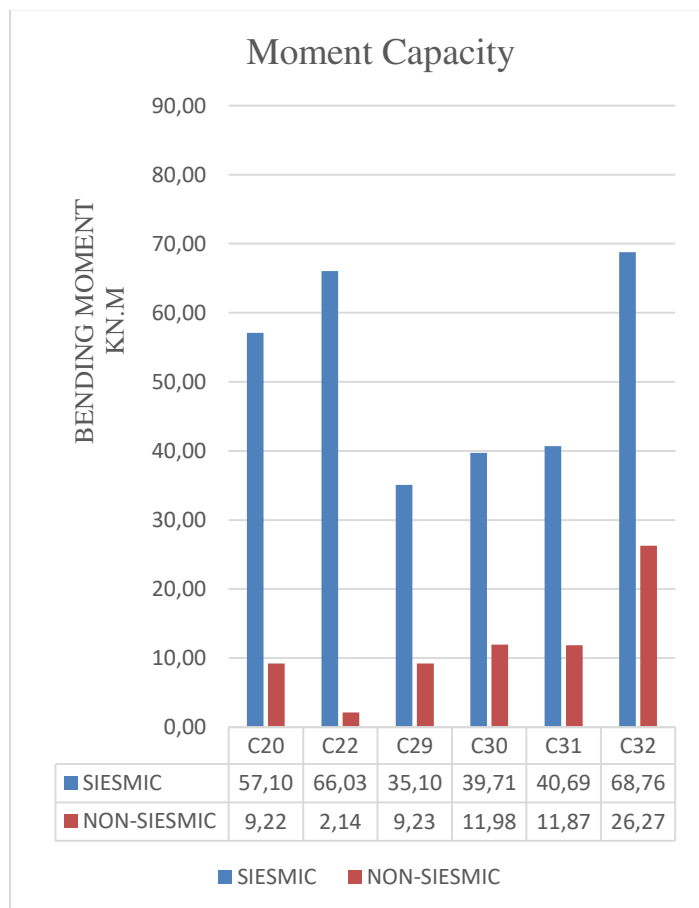
## MOMENTCAPACITY

MOMENT CAPACITY OF COLUMN						
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COLU MN NO	FLOOR	BEAM SIZE	DEMA ND MOMEN T KN.M	CAPACI TY MOMEN T KN.M	DCR	RESU LT
C20	SECOND FLOOR	C230X500	41.9741	18.565	2.261	FAIL
C22	SECOND FLOOR	C230X500	57.6612	10.6293	5.425	FAIL
C29	SECOND FLOOR	C230X500	51.0627	18.2641	2.796	FAIL
C30	SECOND FLOOR	C230X500	55.9574	25.7539	2.173	FAIL
C31	SECOND FLOOR	C230X500	58.3926	25.3687	2.302	FAIL
C32	SECOND FLOOR	C230X500	80.7717	47.4405	1.703	FAIL

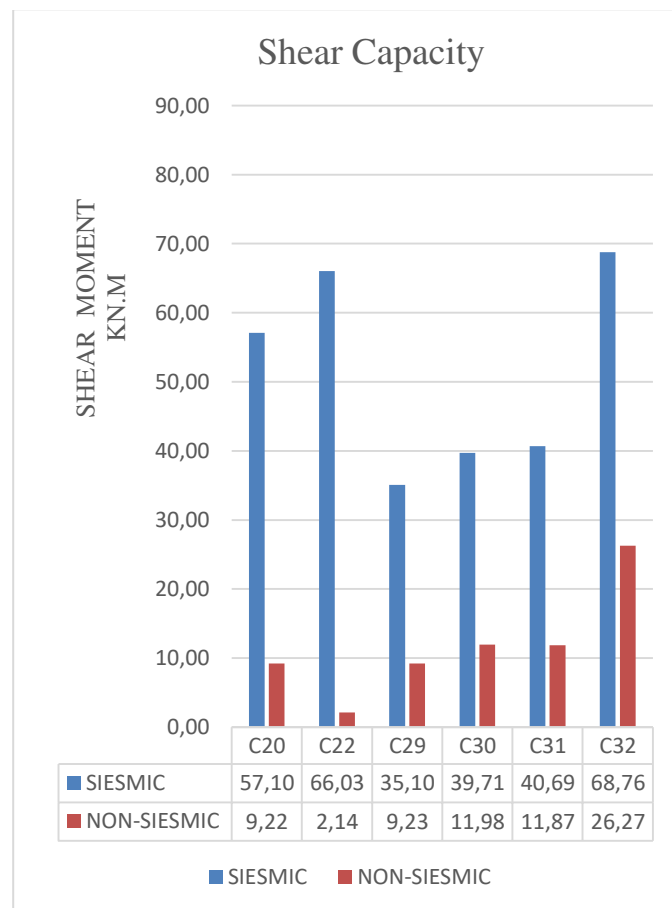
## SHEARCAPACITY

SHEAR CAPACITY OF COLUMN						
SHEAR CAPACITY						
COLU MN NO	FLOOR	BEAM SIZE	DEMA ND MOMEN T KN.M	CAPACI TY MOMEN T KN.M	DCR	RESU LT
C20	SECOND FLOOR	C230X500	57.099	9.2152	6.196	FAIL
C22	SECOND FLOOR	C230X500	66.0286	2.1365	30.90	FAIL
C29	SECOND FLOOR	C230X500	35.1021	9.2275	3.804	FAIL
C30	SECOND FLOOR	C230X500	39.7105	11.9758	3.315	FAIL
C31	SECOND FLOOR	C230X500	40.6891	11.8651	3.429	FAIL
C32	SECOND FLOOR	C230X500	68.759	26.2715	2.617	FAIL

## BAR CHART



## BAR CHART



## RESULTS & CONCLUSION

DESIGN FLEXURAL STRENGTH OF THE SECTION  
( $\phi M_n$ ) = 71.6 kN-m

$\phi M_n = 71.6 \text{ kN-m} > M_u 71.03 \text{ kN-m} \dots \text{SAFE}$

"HENCE PROVIDE 1 LAYER OF CFRP JACKET."  
NOMINAL SHEAR STRENGTH PROVIDED BY FRP  
 $V_f = 126.51 \text{ kN}$   
TOTAL SHEAR STRENGTH OF SECTION  
 $\Phi V_n = 185.49 \text{ kN}$   
 $\Phi V_n = 185.49 \text{ kN} > V_f 128.38 \text{ kN} \dots \text{SAFE}$

"HENCE PROVIDE 2 LAYER OF CFRP JACKET."

The analysis of beams by Equivalent Static Method revealed that most of the beams failed in flexural as well shear capacity. Based on the above observations, the deficiency in flexural & shear capacity was identified and the FRP jacketing scheme was suggested only for beams, failing in flexure & shear. Due to the high tensile strength and stiffness, stability under high temperatures and resistance to acidic/alkali/organic environments, carbon fiber was chosen as the FRP material to be used.

FRP strips that are commercially available are not made to a universal standard but a localized standard as set by the manufacturing company. Thus, the dimensions considered for the strips were strictly as per a design example in ACI 440.2R-02. FRP wrapping scheme would have increased the strength of member.

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