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Retrofitting of Existing Structure with CFRP by using Pushover Analysis

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***Abstract*— The seismic evaluation of existing building is the strengthening of building for pre earthquake or post-earthquake. Strengthening is required to increase capacity of structure to resist specific demand of earthquake. Strengthening may be carried out in existing seismically deficient building or earthquake damaged building.Seismic evaluation and retrofitting are undertaken for the life -line building, such as hospital, police station, fire station, major administrative building, school, educational building, historical monument etc.. Mostly the strengthening of existing building carried by two ways i.e. jacketing and Carbon fiber reinforced polymer(CFRP).The aim of this paper to evaluate the response of existing building by using linear analysis and nonlinear analysis. The analysis was carried out on existing building which G+3 located in Pune (Seismic zone III) by SAP2000 with help of guidelines following code I.S 1893:2002 (Part I), FEMA356, ATC 40.Based on the result of analysis the capacity of existing building for the given demand earthquake .study and the structure was not achieved the specific demand of earthquake, strengthening of existing was carried out by using CFRP. The comparison of existing building with and without FRP was carried out ,It was observed that with retrofitting that building result which based on pushover curve, hinge formation pattern, and inter storey drift ratio formation was within limit.**

***Index Terms*— Carbon fiber reinforced polymer (CFRP), Linear analysis, Nonlinear analysis, Retrofitting.**

I. INTRODUCTION

Many of the existing building are lacking in adequate earthquake resistance because these are not designed according to modern codes and prevalent earthquake resistance practice. Also many building that are damaged in earthquake may need not only repaired but also upgraded of their strength in order to make them seismically resistant. The aim of seismic evaluation is to assess the possible seismic response of building, which may be seismically deficient or earthquake damaged, for its possible future use. The evaluations are also helpful for adopting the retrofitting of structure. Seismic evaluations of building mean the strengthening of building pre earthquake or post-earthquake. Strengthening required because of due changes zone of area, depending on soil behavior. The aim of this paper to strengthening or retrofitting of existing building. Strengthening means increase the seismic resistance of building beyond its pre earthquake state. Strengthening may be carried out in existing seismically deficient building or earthquake damaged building. And also reconstruction or renewal of any part of an existing building to provide better structural capacity. The essence of virtually all seismic evaluation procedures is a comparison between capacity curve and demand curve. To get minimum damage and less psychological fear in the mind of people during the earthquake, IS 1893: 2002 permits maximum inter-storey drifts as 0.004 times the storey height. Inter-storey drifts always depend upon the stiffness of the respective storey. The capacity of structure to resist seismic demand is a property known as ductility. It is the ability to deform to beyond initial yielding without failing abruptly.

A. Necessity of seismic evaluation

1. The building may not have been designed and detailed to resist seismic force.
2. Earthquake vulnerable building that have not experience to sever earthquake building
3. Lack of timely revisions of codes of practice and standards, seismic zone map of country and construction technique.
4. Building designed to meet modern seismic code but deficiencies exist in design or construction.
5. Essential building strengthens like hospital, historical monument and architectural building. Important building whose services is assumed to be essential even just after an earthquake.

II. FIBER REINFORCED POLYMER

FRPs have been used in the automotive and aerospace industries for more than 50 years, in applications where their high strength and light weight can be used to greatest advantage. The fiber reinforced (FRP) composite are useful for repair, rehabilitation and retrofit of structure because High strength-to-weight ratios, Outstanding durability in a variety of environments; Ease and speed of installation, flexibility, and Outstanding fatigue characteristics (carbon FRP); and low thermal conductivity. The following are the reasons for Superior properties of Carbon- FRP than that of A-FRP and G-FRP (Shown in Fig.1)

Modulus of elasticity: For the same Fibre Wt., the strength and Modulus of Carbon Fibre Wrap is far more superior to that of Aramid (75% higher) and Glass (150% higher).

The Design Strength is considerably higher for carbon than that of aramid and glass fibre wrap. This gives a higher Design capacity and range with carbon fibre wraps for strengthening.

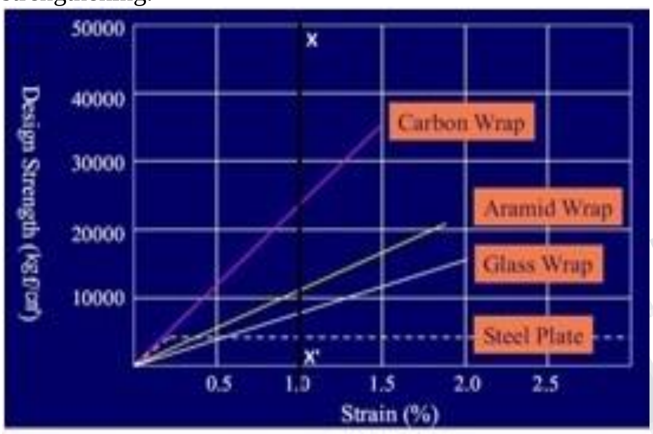

Fig. 1. Graph showing Design Strength vs. Strain Graph for all three Fibre wraps

A. Strengthening of flexural capacity

FRP has been successfully used to increase the flexural and shear capacities of RC beams. It is recommended that the FRP is placed such that the principal fiber orientation is either 450 or 900 to the longitudinal axis of the member. The capacities can be increased up to about 40%. Fig.2 shows the ultimate limit state of a singly reinforced rectangular section with the strain and stress diagrams across the depth and the internal forces.

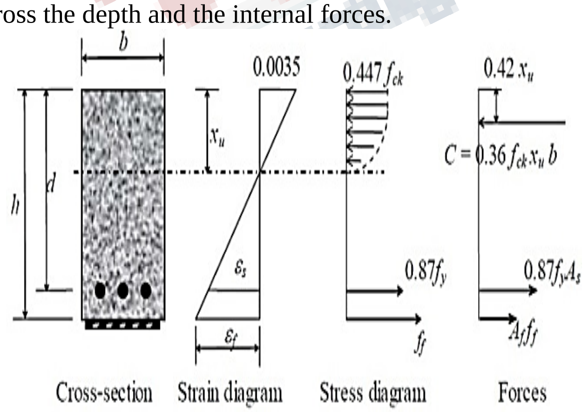

Fig.2. Analysis of a beam section bonded with FRP laminates

The demand under factored loads is obtain from the analysis of the building

$M_{uR} > M_u$…………….. (2.1)

The ultimate flexural capacity is calculated using Eq. 2.2

$M_{uR} = 0.8 \times fy \times As(d - 0.42Xu) + 0.85 \times Af \times f_{fe}(h - 0.42xu)$………… (2.2)

Mechanical Properties of CFRP

The required mechanical properties of carbon fiber reinforced polymer are tensile strength, elasticity modulus, and elongation at failure.

Table.1. Mechanical properties of CFRP

Fiber	Tensile strength N/mm^2	Modulus of Elasticity KN/mm^2	Effective thickness (mm)	Specific density (KN/m^3)
Carbon: high strength	4200	230	0.165	14.71

III. DESCRIPTION OF STRUCTURE

The existing structure that is considered represents the G+3 reinforced concrete framed building. This building is designed according to IS 456-2000 for reinforced concrete and IS 1893-2002 for earthquake forces. The structure is located in medium seismicity region (ZONE III) in Pune region. The number of stories is "G+3"which floor to floor height 2.9m.Material properties are assumed to be M20 grade concrete for compressive strength of concrete and Fe415 for yield strength of the longitudinal and transverse reinforcement, the other details of structure are shown in the following ,Table 2, 3 and 4

Table. 2. Schedule OF Slab

Slab No.	Thickness(mm)	Type
S1	115	One Way
S2	100	Two Way
S3	115	One Way
S4	125	One Way
S5	125	One Way
S6	100	Two Way

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Table.3. Schedule of Column

Column Nos.	Floor	
	Size (bxd)mm	Vertical reinforcement
1,4,13	230X380	8Φ12
2,3	230X450	8Φ12
5,9	230X530	8Φ12
6,8	230X450	4Φ16+4Φ12
7	230X450	8Φ12
10,16	230X380	8Φ12
12,14	230X380	8Φ12
11,15	230X380	8Φ12

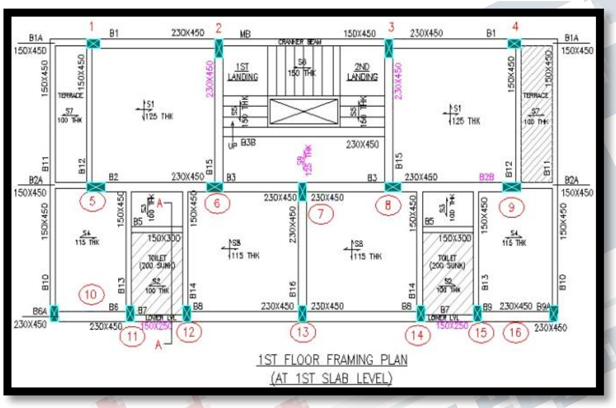

Fig.3. Plan of existing building

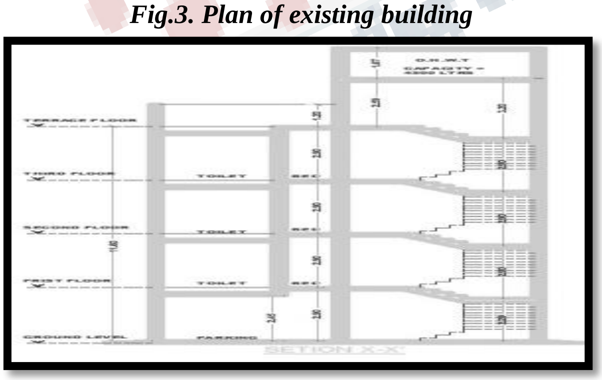

Fig.4. Sectional elevation of building

Table.3. Schedule of Beam

Beam No.	O/All size(mm)		Bottom Reinf.	Top Reinf.	Stirrups	
	B	D		Full Span	Dia. (mm)	No. And Spacing from face of support
B1	230	450	2Φ10	2Φ10	Φ6	6@150,@230c/c
MB	150	450	2Φ16	2Φ12	Φ8	7@150,@230c/c
B2	150	450	2Φ16	2Φ12	Φ8	6@150,@230c/c
B2A	150	450	2Φ16	2Φ16+2Φ12	Φ8	@230c/c
B3	230	450	2Φ12	2Φ10	Φ6	@230c/c
B6,6A	230	450	2Φ12	2Φ16+2Φ12	Φ8	@230c/c
B7	150	450	2Φ12	2Φ10	Φ6	@230c/c
B8	230	450	2Φ12	2Φ10	Φ6	5@150,@230c/c
B9	230	450	2Φ12	2Φ10	Φ6	@230c/c
B10	150	450	2Φ12	2Φ10	Φ6	4@150,@230c/c

IV. METHODS OF ANALYSIS

For seismic performance evaluation, a structural analysis is required to determine force and displacement demands in various components of the structure. Several analysis methods, in static analysis, the vibration mode shapes or the time wise variation of quantities are considered. In dynamic analysis these are considered to a certain extent. The method of analysis can be grouped in shown in Table. 5

Table.5.Method of Structural Analysis

	Linear Elastic	Non-linear Elastic
Static	Equivalent static method	Pushover analysis
Dynamic	Response spectra method, Linear time history	Non-linear time history analysis

Nonlinear static analysis is an improvement over the linear static or dynamic analysis in the sense that it allows the inelastic behavior of the structure. These methods depend on height of structure. The method is relatively simple to be implemented, and provides information of the strength, deformation and ductility of the structure and the distribution of demands. Calculation of base shear as per IS 1893:2002 by using manually calculation and SAP2000 software using. Table 6 and 7 comparison of base shear and time period manually and software of demands. Calculation of base shear as per IS 1893:2002 by using manually calculation and SAP2000 software using. Table 6 and 7 comparison of base shear and time period manually and software

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Table.6. Comparison of base shear by manually and software

	Manually		SAP2000		
	ESA (KN)	RSA (KN)	ESA (KN)	RSA (KN)	Modified RSA (KN)
X axis	319.42	157.7	408.96	131.68	408.96
Y axis	319.42	157.7	408.96	101.63	408.96

Table.7. Comparison of time period by manually and software

	Manually		SAP2000		
	ESA (Sec)	RSA (Sec)	ESA (Sec)	RSA (Sec)	Modified RSA (Sec)
X axis	0.4714	1.004	1.450	1.450	1.450
Y axis	0.4714	1.004	0.520	0.520	0.520

Table.8. Comparison of time period after and before strengthening SAP200 software

	Time before Strengthening(sec.)	Time after Strengthening(sec)
X-axis	1.45	1.30
Y-axis	0.52	0.49

A. Pushover analysis

The pushover analysis of a structure is a static non-linear analysis under permanent vertical loads and gradually increasing lateral loads. A graph of the total base shear versus top displacement in a structure is obtained by this analysis that would indicate any premature failure or weakness. The analysis is carried out up to failure, thus it enables determine of collapse load and ductility capacity. On a building frame, and plastic rotation is monitored, and lateral inelastic forces vs. displacement response for the complete structure is calculated. Consequently, at each event, the structures experiences a stiffness change as shown in Fig 5. Where IO, LS and CP stand for immediate occupancy, life safety and collapse prevention respectively.

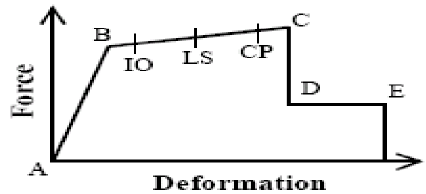

Fig.5. Force V/s Deformation curve

B. Nonlinear Parameter of Pushover analysis in SAP2000

In nonlinear frame behavior, frame hinges must be used. The nonlinear material behavior is only used to develop the moment rotation or other response curves for the hinges. The effective strength of the hinges is used for deformation controlled actions. Pushover analysis is carried out for either user defined nonlinear hinge properties or default -hinge properties, available in SAP2000 based on the FEMA-356 and ATC-40 guidelines. The user should be careful; the misuse of default-hinge properties may lead to unreasonable displacement capacities for existing structures. SAP2000 provided default-hinge properties which recommends P-M-M hinges for columns and M3 hinges for beams. (Fig.7)

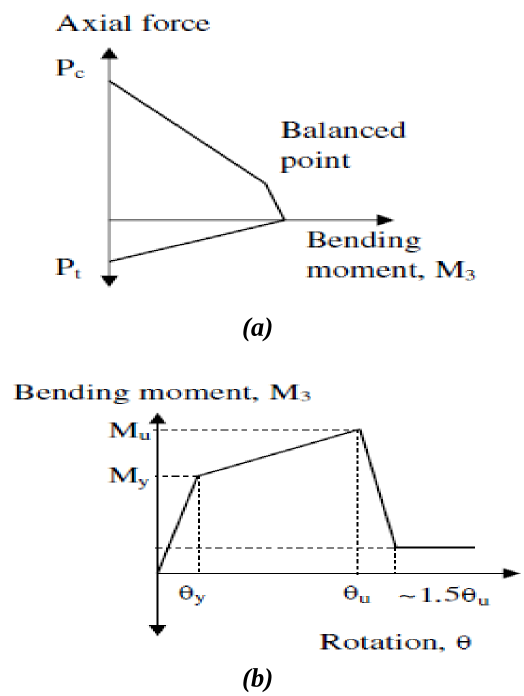

Fig.6.Typical plastic hinge properties assigned to reinforced concrete (RC) members (a) P-M and (b) M-θ

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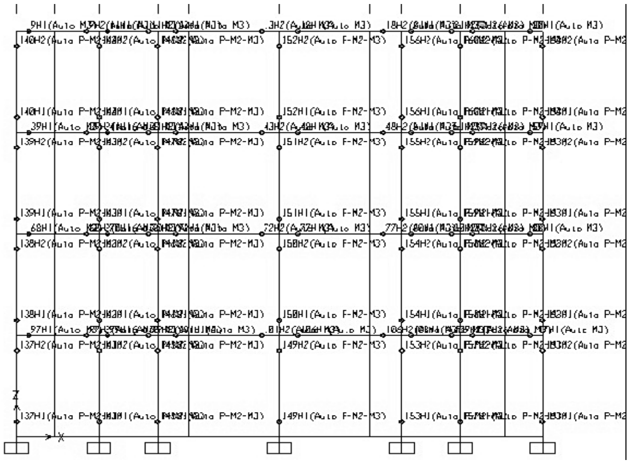

Fig.7. Assigning hinges SAP2000

V. RESULT AND DISCUSSION

The resulting pushover curve for existing G+3 building shown in the fig.7. The curve was initially linear but starts to deviate from linearity as the beams and columns undergo inelastic actions in x and y direction. The building was pushed well into the nonlinear range, the curve become linear again but with a smaller slope. From the Fig.7 it is obvious that the demand curve intersects the capacity curve between the point Collapse prevention and C. The residual Strength and stiffness left in all stories. Damage to partitions. Building shows some failure of beam which fails in collapse prevention point .hence Building required strengthening in which by using carbon fiber reinforced polymer increase the strength of beam and hence after strengthening this beam within IO limit i.e. Immediate Occupancy level.

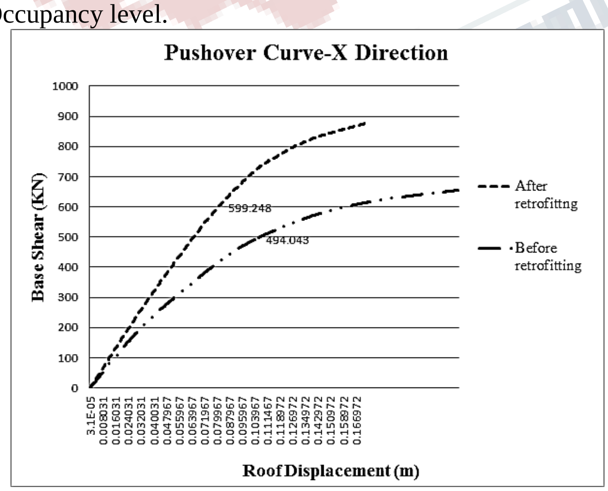

Fig.8 Pushover Curve before and after retrofitting (In X-direction)

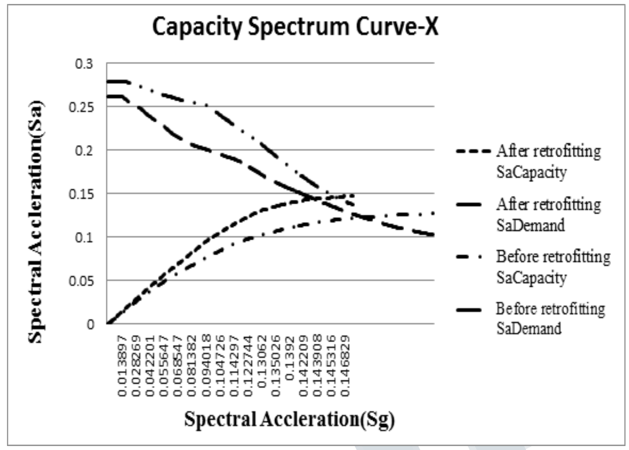

Fig.9. Capacity spectrum curve before after and before (X-Direction)

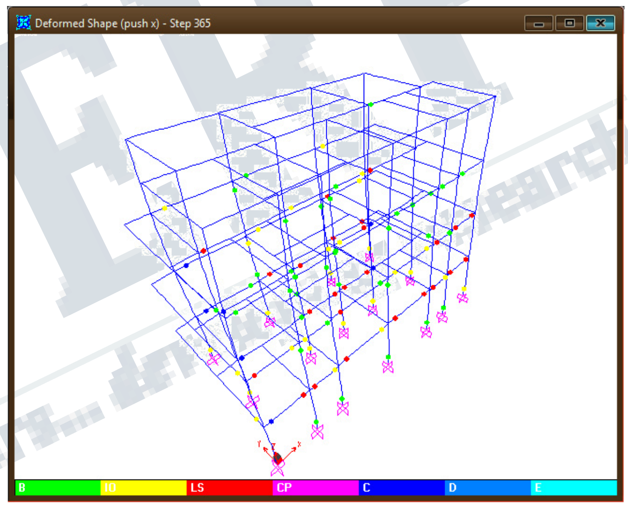

Fig.10. Plastic hinge mechanism at performance level (In X-Direction) before retrofitting

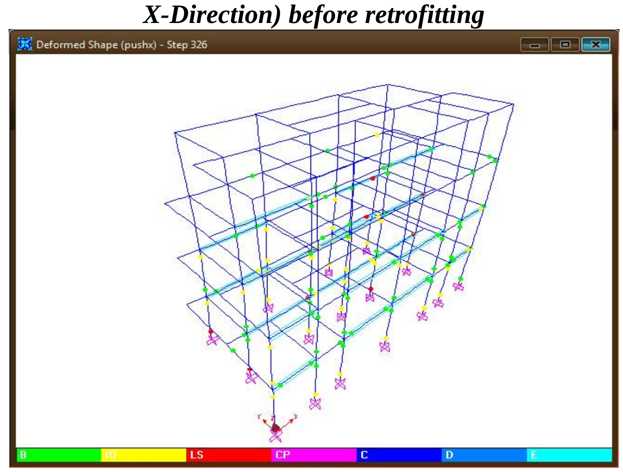

Fig.11. Plastic hinge mechanism at performance level (In X-Direction) after retrofitting

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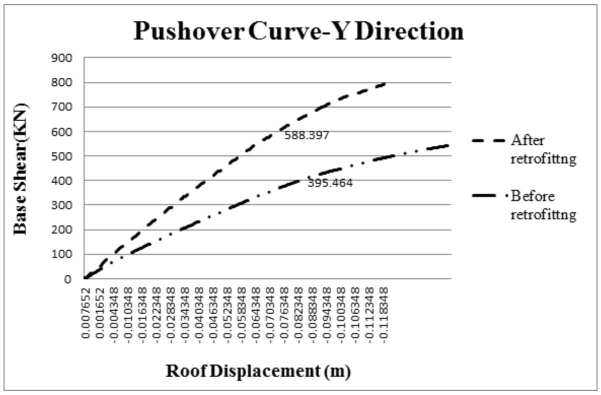

Fig.12. Pushover Curve before and after retrofitting (In Y-direction)

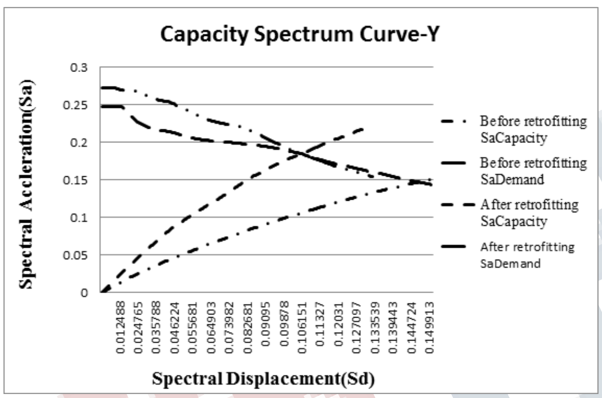

Fig.13. Capacity spectrum curve before after and before retrofitting(Y-Direction)

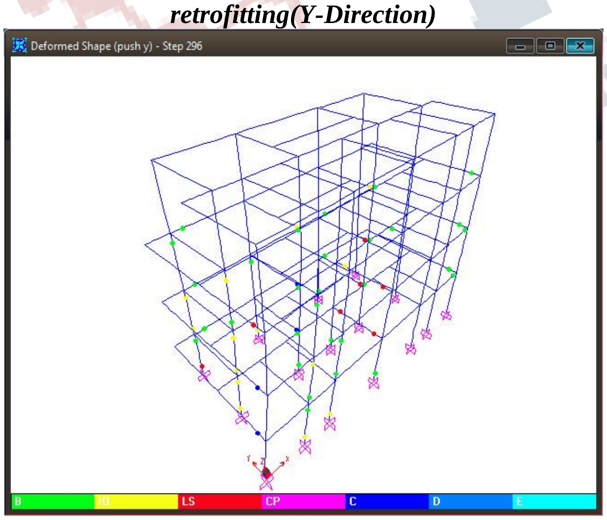

Fig.14. Plastic hinge mechanism at performance level before retrofitting(Y-Direction)

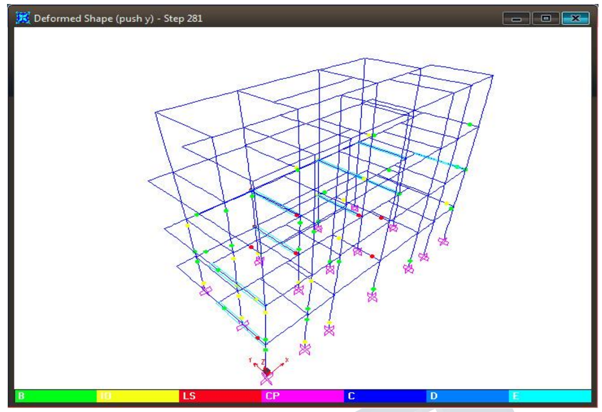

Fig.15 Plastic hinge mechanism at performance level after retrofitting(Y-Direction)

Inter storey drift ratio of existing building which beyond permissible limit but after apply carbon fiber polymer strengthening material the building goes on within permissible limit(Fig.16 and 17)

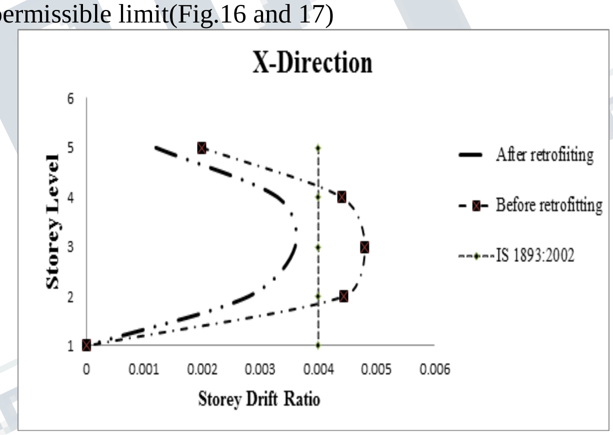

Fig.16. Comparison of Inter storey drift ratio after and before retrofitting(X-Direction)

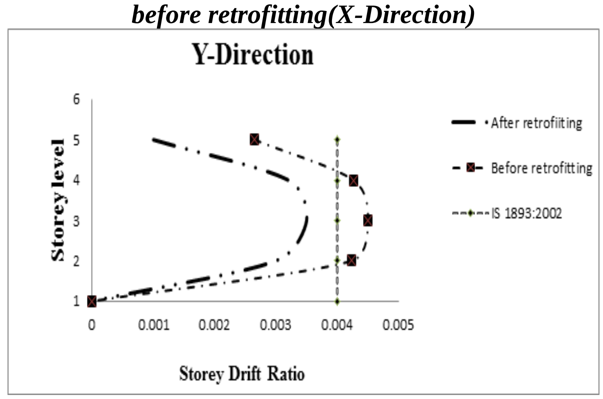

Fig.17 Comparison of Inter storey drift ratio after and before retrofitting(Y-Direction)

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VI. CONCLUSION

The performance of the existing G+3 building was investigated using the pushover Analysis. In this project we do the comparative study of existing building before and after retrofitting. These are the conclusions drawn from the pushover analyses.

The study of hinge formation patterns shows that most of the hinges are formed in beams and very few in columns. This shows that weak beam-strong column.

These buildings are found that collapse prevention (CP-C) range for design basis earthquake condition. after retrofitting Fibre reinforced polymer in which Carbon Fibre Reinforced Polymer(CFRP) are employed for strengthening of these buildings, performance level requirement of operational to immediate occupancy (B-IO) under design basis earthquake

Existing building having inter storey drift ratio beyond the permissible limit but after retrofitting building having inter storey drift ratio within limit.

Base shear of existing building after applying one layer of CFRP material was increase the base shear 20.25%.It is concluded that with CFRP ductility of gravity designed buildings is improved.

CFRP material reduced time period than existing gravity design building. When time period iwas compare with gravity building model total reduction is 7%.

REFERENCES

[1] ACI 440.2R-08. "Guide for Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures", American Concrete Society committee, New Delhi, 2008.

[2] Agarwal Pankaj and Shrikhande Manish, "Earthquake resistance design of structures", PHI learning private limited, pp.524-555, 2011.

[3] Aghaei H.R., Nia M.I, Elyasian I., "RC Frame Strengthened by CFRP laminates", The 14th World Conference on Earthquake Engineering, pp.12-17, Beijing, China, 2008.

[4] A. Ismail, "Nonlinear static analysis of a retrofitted reinforced concrete building", Housing and Building National Research Center, Vol.1687-4048, 2013.

[5] ATC-40, "Seismic evaluation and retrofit of concrete buildings", Applied Technology Council, Vol.1 and 2, Redwood City, USA, Report No. SSC 96-01, 1996.

[6] Beena Kumari, Naveen Kwatra, "Finite Element Modeling of a Multi-Storeyed Retrofitted Reinforced Concrete Frame", IOSR Journal of Mechanical and Civil Engineering, Vol.8, No.3,pp. 08-22, 2013.

[7] Dr.Rai G., Indolia Y (2011)."Fiber reinforced polymer composites, a novel way for strengthening structures", National Conference on Repair and Rehabilitation of Concrete Structure, Noida, Utter Pradesh, India.

[8] Habibur R.S., Ehsan A., Md. Sadiqul H., Md. Alhaz U (2011)," Use of carbon fiber laminates for strengthening reinforced concrete beams in bending", International Journal of Civil and Structural Engineering ,ISSN 0976 – 4399,Vol. 2, No.1, pp.69-85.

[9] "Handbook on seismic retrofitting of building" (April2007), CPWD and Indian Building Congress in association with IIT Chennai.

[10] FEMA 356, "Prestandard and commentary for the seismic rehabilitation of buildings", American society of civil engineers, Reston, Virginia, 2000.

[11] Habibur R.S., Ehsan A., Md. Sadiqul H., Md. Alhaz U, " Use of carbon fiber laminates for strengthening reinforced concrete beams in bending", International Journal of Civil and Structural Engineering ,ISSN 0976 – 4399,Vol. 2, No.1, pp.69-85, 2011.

[12] IS 1893:2000, "Criteria for earthquake resistant design of structures", Part 1: General Provision and Building", Bureau of Indian standards, New Delhi, 2002.

[13] IS 13920:1993, "ductile detailing of reinforced Concrete structures subjected to Seismic forces-code practice, Bureau of Indian Standards, New Delhi, 2002.

[14] IS 456:2000, "Plain and Reinforced Concrete-code of Practices", Bureau of Indian standards, New Delhi, 2000.

[15] IS 13935:1993, "Repair and Seismic Strengthening of Building-Guidelines", Bureau of Indian standards, New delhi,1993

[16] Khalid S.Z., Shinde S.B. "Seismic response Of FRP strengthen RC frame", International Journal of Civil And Technology, ISSN0976-6316,Vo.3, No.2, pp. 305-321,

2012.

[17] SAP2000 V14.2.4, "Integrated finite element analysis and design of structures basic analysis reference manual", Berkeley, CA, USA: Computers and structures INC, Aug. 2010.

[18] Sengupta A.K., Reddy C.S., Narayanan V.T., Asokan A, "seismic analysis and retrofit of existing multistoried buildings in India – an overview with a case study", 13th World Conference on Earthquake Engineering ,Vancouver, B.C., Canada , Paper No. 257, pp.1-6, 2004.

[19] Shah Mrugesh D., Desai Atul N. et al (2011). "Performance based analysis of R.C.C. frames", National Conference on Recent Trends in Engineering and Technology, .V.M. Engineering College, V. V. Nagar, Gujarat, India.

[20] TR-55, "Design guidance for strengthening concrete structures using fibre composite materials", Second Edition, Technical Report No. 55 of the Concrete Society, U.K, 2004.

[21] Vijayakumar A., Dr. Venkatesh babu D.L, " A Survey of Methodologies for Seismic Evaluation of Building", Canadian Journal on Environmental, Construction and Civil Engineering ,Vol.2, No. 5, 2011.

