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Performance appraisal of retrofit RC frames subjected to dynamic loading conditions

*Suresh Babu S.$^{1)}$ and Gobinath S.$^{2)}$

$^{1), 2)}$ *Department of Civil Engineering, Adhiyamaan College of Engineering,*
DR.M.G.R Nagar, Hosur, Tamilnadu, India
$^{1)}$ *sunisurp@gmail.com*; $^{2)}$ *sgobibecivil@gmail.com*

ABSTRACT

Earthquake is one of the fatal disasters in this planet. It is a strong ground motion induced by natural phenomena. This motion causes the structures founded on it to exhibit non-linear responses of dynamic nature. The safety of a framed structure to survive during the major earthquake mainly depends on the ability of the beam column joints to absorb and dissipate seismic energy without any decrease in strength of the frame. Reinforced concrete beam and column joint with inadequate/improper reinforcement do not possess the required ductility to dissipate the seismic energy. Investigations are carried out to appraise the performance of structures and retrofit structures and to critically appraise the diagnostic alternative out of Carbon Fiber Reinforced Polymer & Glass Fiber Reinforced Polymer wrappings. The present paper envisages the above investigations carried out on the scaled down models of RC framed structure subjected to broadband excitation. The specimen tested is three storied, single bay scaled down model. Non-linear static analysis is used to analyse the RC frame.

***Keywords**:* Structural Health Monitoring, seismic energy, Carbon Fiber Reinforced Polymer wrapping, Glass Fiber Reinforced Polymer wrappings, non-linear static analysis.

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1) Professor
2) Junior Research Fellow

1. Introduction

Reinforced Concrete (RC) structures designed according to present building codes as moment resisting space frames, shear walls, coupled shear walls or any combination thereof, to withstand strong earthquake motions that are expected to deform well into inelastic range and dissipate the energy input by the base motion through stable hysteric behaviour of structural components since, inelastic deformations are typically concentrated at critical regions with in the struts as shown in Figure1.

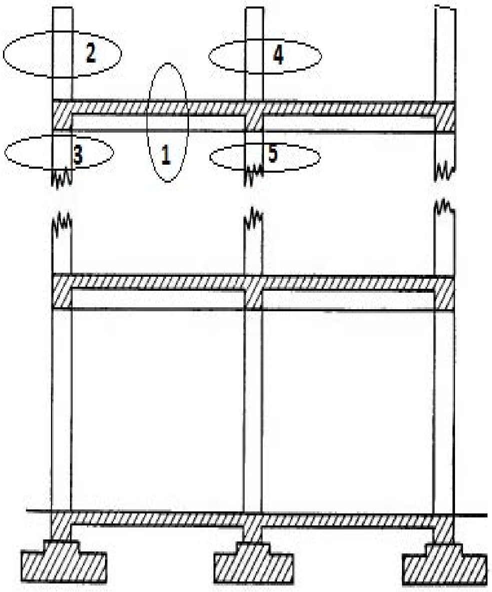

Fig.1 Critical regions in RC Frames subjected to cyclic excitation

The accurate prediction of behavior of the structures during random excitation depends on the accurate representation of material behavior taking into account the controlling states of stress or strain and identifying the main parameters which influences the hysteric behavior of each critical region in order to predict the behavior up to failure, of any structural component during earthquake. The various experimental investigations on the structural sub assemblage and dynamic tests on RC model frames conducted, have demonstrated that, when properly designed and defective regions of the structures are subjected to severe broad band excitations, the major concern is the deterioration in the stiffness.

The principle effects of stiffness deterioration are

i) an increase in the flexibility and period of vibration of the undamaged structure during large deformation reversals
ii) a decrease in energy dissipation capacity and
iii) a significant redistribution of internal stresses.

Since induced seismic forces and deformation are sensitive to structural flexibility, natural period of vibration and energy dissipation capacity, the stiffness deterioration modifies the overall response of the structure. The present investigations focus on the behavior of frames retrofitted with Carbon Fiber Reinforced Polymer & Glass Fiber Reinforced Polymer sheets at beam-column joints. The study is carried out with frequency domain approach.

2. Experimental Investigations

A scaled down model (1:3) of three storied, single bay RC frame with M20 grade concrete is casted. Beams are **100mm×100mm** and columns are **100mm×100mm** in cross section respectively. The footing size is **300mm×300mm×100mm**. Curing is done for 28 days. The frame is placed in position for testing. The tests are conducted at structural dynamics laboratory in department of civil engineering, Adhiyamaan College of Engineering, Hosur, India. The Controlled specimens are subjected to broad band excitation (0 to 10 Hz) Uni–axial accelerometers are used to quantify the absolute accelerations and LVDT’S are used to measure the sway. Loading is continued till specimen fails and failed specimens are strengthened by using Carbon Fiber Reinforced Polymer & Glass Fiber Reinforced Polymer wrapping .The retrofit frames are again subjected to broad band excitation,

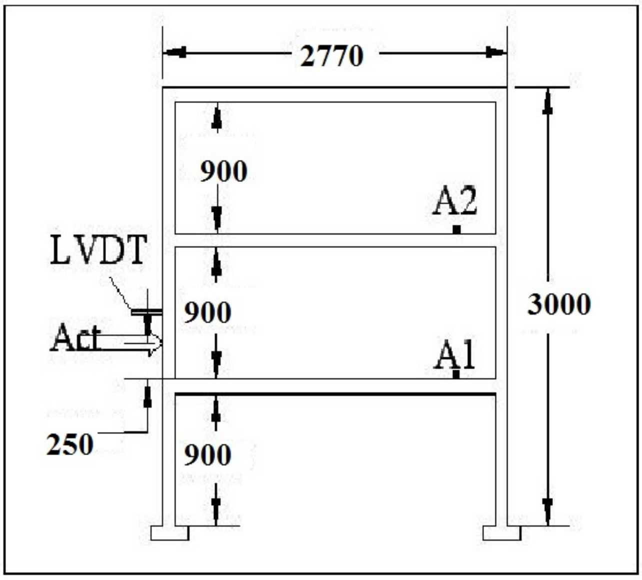

Fig.2 Typical Model Frame (All dimensions are in mm)

3. Experimental Testing.

The amplitude control tests are conducted at constant frequency by increasing the load in multiples of 3.0kN, on the test frame. The block diagram of general actuator-structure arrangement is shown in fig 3. The behaviour of the structure against dynamic loading is as indicated in the graph 4(a) and 4(b) .dynamic loading is applied in Servo controlled hydraulic actuator, its specification is shown in the table

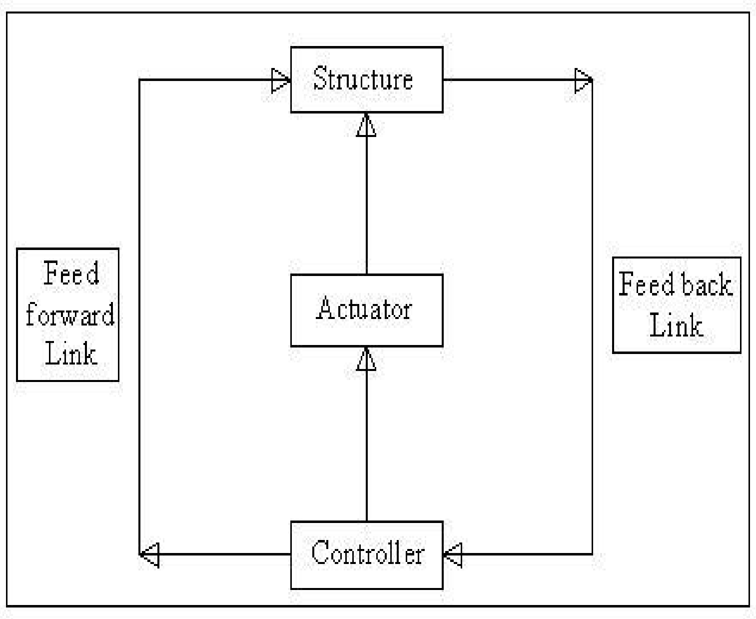

Fig.3 Block diagram of general actuator – structure arrangement system

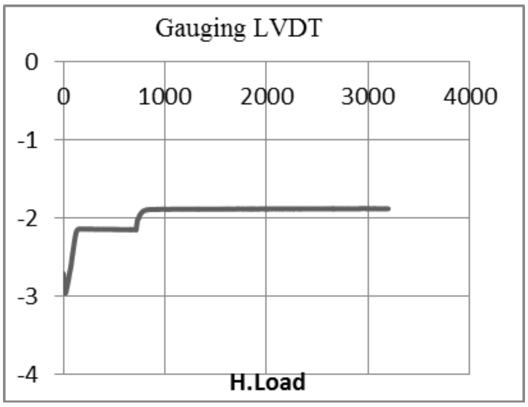

Fig.4 (a) Horizontal load & displacement

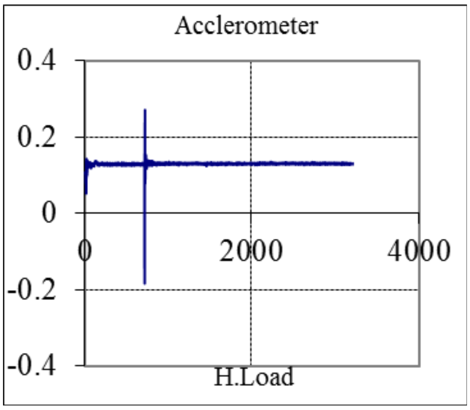

Fig 4 (b) Horizontal load & Acceleration

The frames tested upto 45 kN (8 Hz), failed at beam-column joint. In Fig.5, the failed structural joint is shown .The fractured portion of the RC frame is prepared for wrapping.

Fig 5. Cracked part of the beam-column joint

3.1 Instrumentation and Wrapping Materials.

3.1.1. LVDTs : ± 0.2 volts, 150 mm assembly unit.

3.1.2. Accelerometer: - Positioning the accelerometers is based on well-established controllability and observability theory Analytical Hierarchy Process is employed for positioning the accelerometer.

Specifications of Accelerometer:-

Make	Burel &Kjare
Model	4507B003
Frequency Range ,	0.3Hz to 6Hz
Phase	2Hz to 5 Hz
Mounted resonance	18Hz

Table1.Specifications of uni-axial accelerometer

3.1.3 Servo controlled hydraulic actuator

The specification is as mentioned in the Table.2

Table 2.Specifications of Servo controlled hydraulic actuator

Item	**Specification**
Maximum payload	50 kN
Maximum specimen dimension	0.3m x 0.3m
Exciting direction	X,Y (Simultaneous /Individually)
Degrees of Freedom	3 translational
Max. Height of the specimen	3.0m
Displacement/ Max. Stroke X&Y Direction Z - Direction	± 150mm ±100mm
Acceleration	±1g (X, Y & Z direction)
Frequency range	0.1 to 50 Hz
Yawing moment	50 kN-m
Overturning moment	200 kN-m
Actuators- Vertical Horizontal	4 nos. of 180 kN 4 nos. of 150 kN
Control System	DCS2000(Digital control system)

3.1.4. CFRP

The Carbon fiber-reinforced polymer is a polymer, which is used to enhance shear strength of reinforced concrete by wrapping fabrics or fibers around the section to be strengthened. The properties of the Carbon fiber-reinforced polymer is having its tensile strength is 2768 N/mm^2 Elastic modulus is 189900 N/mm^{2,} Tensile modulus is 420 GPa. Ultimate tensile strength is more than 10 times of mild steel.

3.1.5. GFRP

The Glass fiber is a polymer, which is strong in tension. The properties of the Glass fiber are specific gravity is 1.6, tensile strength 250N/mm^2 and compressive strength 150N/mm^2.

4. Wrapping Methodology

Outer Concrete cover of reinforcement is removed at the fractured part of the beam-column joint. Loose particles and dust are washed off, and on obtaining the dry surface condition, 1:2 rich cement mortar is applied and after mortar is dried, epoxy coating is laid. Later reinforced polymer is wrapped along the contour of the beam-column joint. The specimen is prepared for wrapping as per, IS 13935:1993[2].

The wrapped specimen is cured for 10days. The wrapped portion of the retrofit frame is as shown in Fig. 6(a) & (b). The retrofit frame is subjected to dynamic loads again.

Fig 6(a) Typical joint retrofitted with glass fiber reinforced polymer

Fig.6(b) Retrofitted Beam-Column joint with carbon fiber reinforced polymer

5. Results

5.1 Test results on retrofit Glass Fiber Reinforced Polymer (GFRP) retrofit frames

The glass fiber reinforced polymer retrofit frame withstands the load of 33kN. The following Figures 7(a) & 7(b) show the graph drawn between Horizontal load as abscissa and displacement and acceleration as ordinates of glass fiber reinforced polymer retrofitted frame respectively.

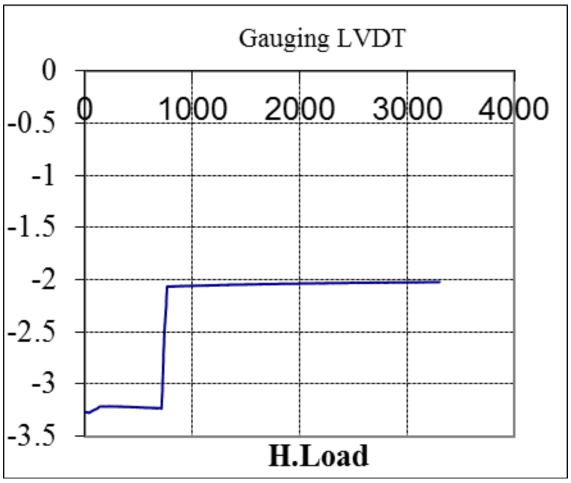

Fig 7 (a)

Horizontal load and displacement

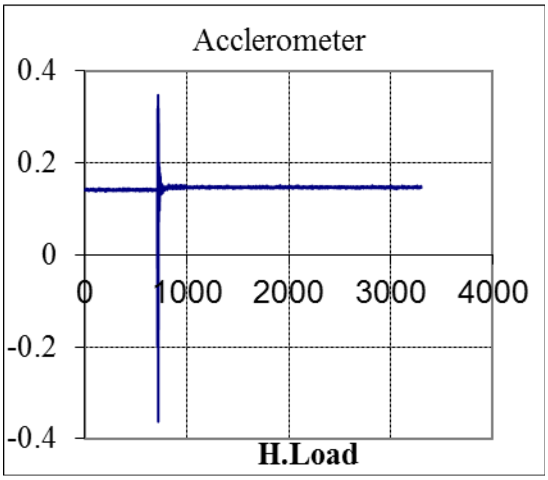

Fig 7(b)

Horizontal load and Acceleration

5.2 Test results of Carbon Fiber Reinforced Polymer (CFRP) retrofitted frames

The graph obtained at failure load is as shown in Fig 8(a) & 8(b)

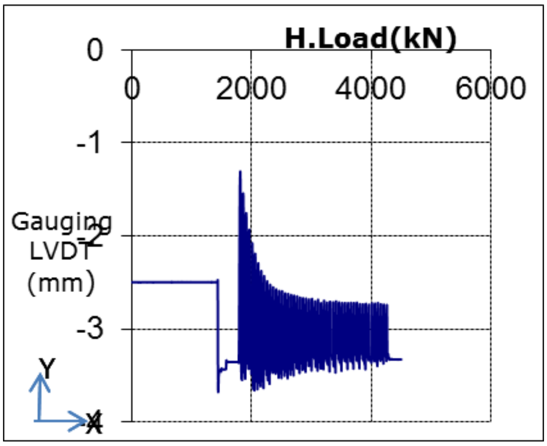

Fig.8(a)

Displacement as Quantified in LVDT'S

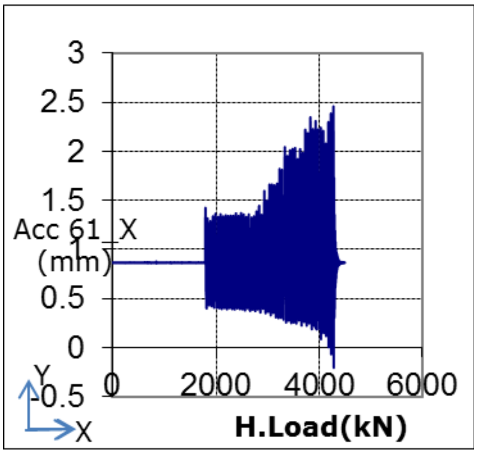

Fig.8(b)

Absolute acceleration as quantified in accelrometer

6. Conclusion

Both fiber reinforced polymers are used as surface laminates and it is concluded from the experimental investigations, that CFRP retrofit frame gain the strength upto 74% of the original frame, whereas GFRP retrofit frames gain only 68 %.

Sway control is appreciable in CFRP retrofit frames (around14%), whereas, around 9%sway is controlled in GFRP retrofit frames.

Acknowledgment

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