Seismic Retrofitting

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Abstract - *Seismic retrofitting of building can be done by conventional design such as jacketing of beams and columns, strengthening of beams and columns by use of new materials, stiffness strengthening by adding shear walls, shear panels and bracings and secondly by a seismic design by adding devices to reduces the seismic forces such as base isolators, energy absorbers like visco elastic dampers, friction dampers and tuned mass dampers etc.*

This paper analyses the nature and the extent of the problem, explores the remedies available and presents some case studies where retrofitting can be done which is a life line to the structures.

Key Words: *Retrofitting[1], NDT[2], Jacketing[3].*

1.INTRODUCTION

If the buildings are built with life cycle cost consideration with sustainable development and with holistic approach, then there should be no early deterioration unfortunately majority of the reinforced cement concrete (RCC) buildings built during the last 10 to 30 years requires major rehabilitation to RCC frame members and to other RCC members.

Need of retrofitting[1] a structure may arise due to reduction in strength of the structure due to deterioration of construction material with time, or damage caused by earthquake or structure not designed to withstand the expected loads. Retrofitting of a structure may be carried out by damage diagnosis and structural modification. The very first step in structural retrofitting is the diagnosis of the damage in the existing structure or assessment of the current strength of the structure. This is a very important step of retrofitting as the accuracy depends on how accurately the current strength of the structure has been estimated .It can be done by simple visual inspection, by destructive methods and various non-destructive methods. The second step involves the proper retrofitting strategies adopted to modify the structure such as structural strengthening and a seismic retrofitting. Retrofitting increases the strength, stiffness, ductility and resistance to seismic load of the structure.

Need of Retrofit

There is need of retrofitting to regain the above mention properties which are decline due to following causes

- Defects in design, materials, and construction.
- Moisture Deterioration of Structure due to oxygen, chemical environment like acidic gases, biological environment like growth of algae, erosion due To Winds in High Buildings/Structure.
- Damage to structure due to earthquake, cyclone, flood, fire, acidic rain, overload.

Strength and durability of the existing structures without affecting the properties of the structures. It is also been applicable to determine the crack depth, micro cracks and progressive deterioration. NDT may used in determining the necessity or demand of retrofitting required for the structure/building.

There are various NDT[2] methods available such as M.S. Shetty (2009), TCS-17, IAEA (2002)

- Surface Hardness Tests
- Schmidt Rebound Test
- Penetration and Pull out Technique
- Dynamic or Vibration Tests
- Resonant frequency
- Pulse velocity method
- Combined Methods
- Radioactive and Nuclear Methods
- Magnetic and Electrical methods
- Acoustic Emission Technique

For the present case studies of retrofitting we have carried out Schmidt Rebound test and Ultra sonic pulse velocity methods.

The Schmidt rebound hammer is principally a surface hardness tester. It works on the principle that the rebound of an elastic mass depends on the hardness of the surface against which the mass impinges. Empirical correlations have been established between strength properties and the rebound number.

A pulse of longitudinal vibrations is produced by an electro-acoustical transducer, which is held in contact with one surface of the concrete under test. When the pulse generated is transmitted into the concrete from the transducer using a liquid coupling material such as grease or cellulose paste, it undergoes multiple reflections at the boundaries of the different material phases within the concrete. A complex system of stress waves develops, which include both longitudinal and shear waves, and propagates through the concrete. The first waves to reach the receiving transducer are the longitudinal waves, which are converted into an electrical signal by a second transducer. Electronic timing circuits enable the transit time t of the pulse to be measured. Longitudinal pulse velocity (in km/s or m/s) is given by Eqn.1

$$v = L/t \quad (1)$$

where, v is the longitudinal pulse velocity,

L is the path length, t is the time taken by the pulse to traverse that length. Direct transmission method was used for measuring the velocity.

Case study no.1

On M.G. Road, Jabalpur, water tank of the storage capacity 50,000 gallon which is not in working condition was damaged in Jabalpur earthquake (Fig.1).

Water tank has four circular columns without diagonal bracing. On the visual inspection of the structure we observed cracks on column, beam and slab members and spalling of concrete.

The column and beam members were divided into 30 cm length and in each zone minimum 15 readings were observed by Schmidt hammer and ultra sonic pulse velocity. The observed readings are tabulated (Table 1) shows the average compressive strength of concrete in MPa for each member. (Fig. 2) shows the graphical representation of compressive strength of concrete in MPa for each member for first floor and (Fig.3) for second floor.

Based on the investigation carried out on water tank the retrofitting measures to be carry out are jacketing by fiber reinforced plastics as they are resistant to corrosion caused by acids ,alkalis and salts or plate jacketing[3] to column. Steel angle or channels section diagonal bracing is to be added in between the columns by bolting the steel section to the column by steel plates to increase the lateral resistance of the structure, as it is easier to add structural steel rather than concrete bracings because new concrete beam would require formwork and shoring and are difficult to construct. Slab is to be jacketed by fiber reinforced plastics. Beam section can also be strengthening by bolting the steel channel section (Fig.4).

Cracks in the structural members are repaired by injection of cement slurry or epoxy materials into cracks, then stitching the cracks with dowels or pinning (Fig.5)

Case study no.2

Bal Vihar is a commercial building in Bhopal, R.C.C. two storey building. On inspection, we find cracks in columns, beams, slabs, and R.C.C. parapet wall and also deflection in the beams (Fig. 6)

The reinforcements of beam are exposed to the environment (Fig. 7). The readings were observed by Schmidt hammer (Fig.8) and ultra sonic pulse velocity. The observed readings are tabulated (Table 2) shows the average compressive strength of concrete in MPa for each member.

(Fig. 9) shows the graphical representation of compressive strength of concrete in MPa for each member for first floor (Fig.9) and for second floor(Fig.10).

Based on the test results the remedial measures to be adopted are jacketing the column by adding the new reinforcement and inserting the dowels (Fig.11).

Addition of reinforcing mesh on both faces of the cracked column, holding it to the wall through spikes or bolts and then covering it suitably with micro concrete.

Removing the deteriorated or damaged portions of existing concrete members and then restoring these members to their originality. Filling cracks, cavities within existing concrete with resin and mortar for repairing the sectional members. The deflection of the existing beam can be reduced by connecting the steel plate in the tension zone and providing the extra supports to the beam (Fig.12)

Conclusion

The following are the conclusions from our case studies:

- Retrofitting can be done by adding steel sections to the existing concrete without any additional formwork and difficulty to build it.
- Retrofitting of important public buildings like water tanks, school buildings, commercial buildings are to be carried out first to avoid any loss of life and property.
- Application of NDT for carrying out retrofitting is the initial step which can investigate the various properties of the existing structural members.

Table 1. NDT tests results for water tank

Member		Rebound Hammer	Ultra sonic pulse velocity method
Column	FF	18.6	17.2 MPa
	SF	19.2	18.8
Beam	FF	20.21	19.3
	SF	20.4	19.6
Slab		20.4	20.2

Table 2. NDT tests results for Bal Vihar building

Member		Rebound hammer	Ultra sonic pulse velocity method
Column	FF	19.2 MPa	18.84 MPa
	SF	19.4	18.9
Beam	FF	19.2	19.1
	SF	18.9	18.6
Slab	SF	18.4	19.1
R.C.C. wall	SF	18.2	19.3

Fig. 1 Water tank at M.G. Road

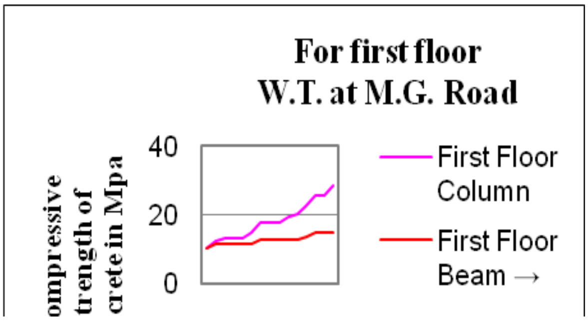

Fig. 2 Rebound hammers results for first floor of water tank

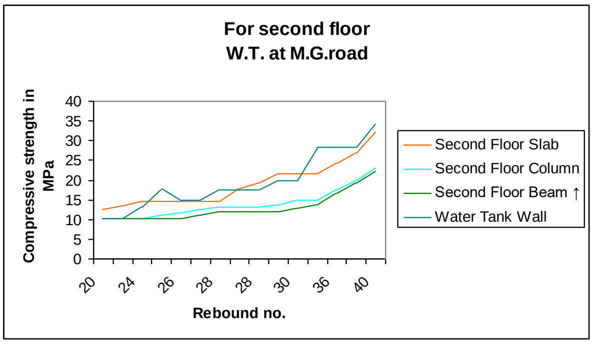

Fig. 3 Rebound hammers results for second floor of water tank

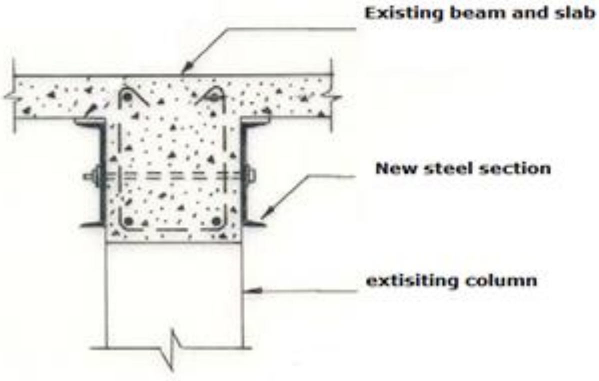

Fig.4 Adding steel section on existing concrete beam

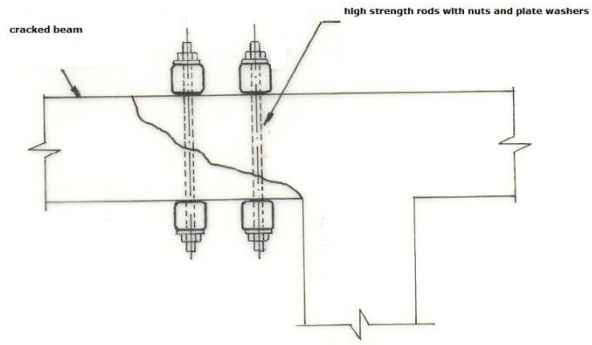

Fig .5 Cracked beams

Fig.6 Bal Vihar building

Fig.7 Beam of Bal Vihar building

Fig.8 Rebound hammer test carried out on beam of Bal vihar

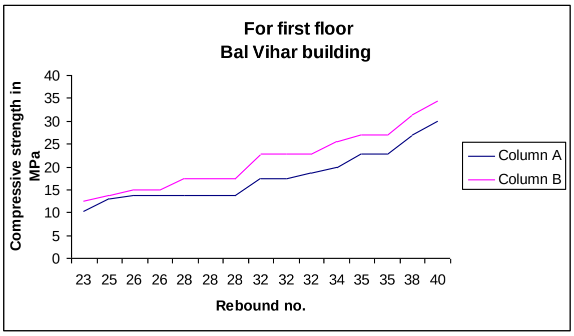

Fig.9 Rebound hammers result for first floor Bal Vihar building

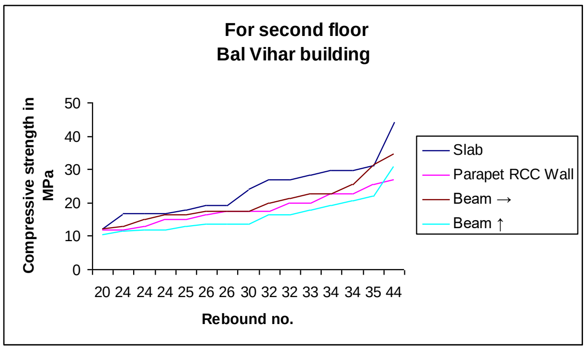

Fig. 10 Rebound hammers results for second floor Bal Vihar building

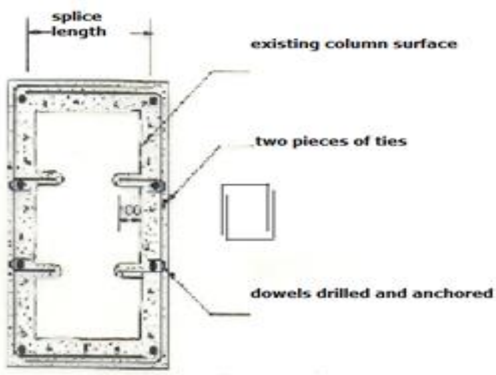

Fig.11 strengthening of the existing colum

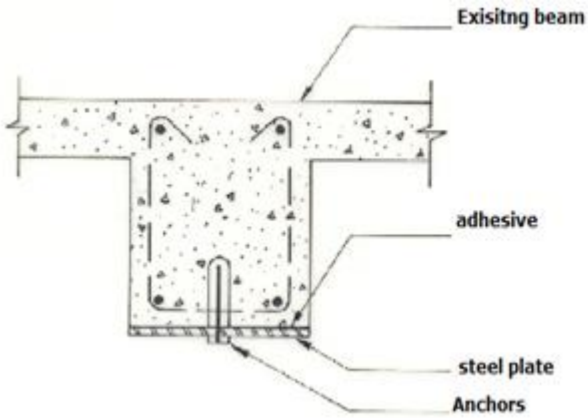

Fig.12 strengthening of the existing beam

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AURTHER

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BIOGRAPHIES

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