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Analysis, Design and Application of Retrofitting Techniques in Various Structures

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***Abstract*— This research paper is focused on the structures which lack the required strength as per the guidelines of earthquake building code to sustain the seismic force. Suitable retrofitting techniques are suggested after proper analysis and documentation at different sites. 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.**

Keywords—Seismic Retrofitting; Seismic Force; Flexibility; Stiffness; Ductility; Unity Of Structure; Critical Point

I. INTRODUCTION

India is one of the most earthquake prone country in the world and the recent devastation caused due to earthquake has exposed the seismic vulnerability of structures in our country. About 50-60% of the total geographical area comes under earthquake prone region. Almost, 4 out of 5 structures are non-engineered made up of earthen walls, stone walls, brick masonry walls etc. These structures cannot even sustain earthquake of minor intensity and result in heavy loss of life and property.

Earthquake engineers learnt a lesson from recent Nepal earthquake (2015) that seismic activity is not just a subject of earthquake prone zones but it may also affect the less prone region of north India including the Himalyan region.

Now-a-days, codes on earthquake resistant design are strictly followed for constructing new buildings. But nearly 85% of the buildings are constructed without adopting the guidelines of earthquake resistant building design code IS 1893:2002, because it was constructed prior to the implementation of the codes. It is uneconomical and impossible to demolish all the structurally deficient buildings and construct it again with earthquake resistant design techniques. The aim of the paper is to suggest various methodologies and techniques to access the seismic vulnerability of old structure and to propose suitable retrofit measures for deficient structures with cost consideration.

II. METHODOLOGY

A. Visual Inspection of Structure

Initial survey of the building is done by the method of visual inspection in which proper documentation of the building construction techniques and components done. The basic aim of visual inspection is to point out the critical section of the structure. Critical section is the weakest portion which is more vulnerable to damage at the time of earthquake due to heavy stress concentration at those points.

B. Rebound Hammer Test

To determine the existing strength of structure we performed the rebound hammer test. It is a Non destructive test performed on concrete surface to determine the compressive strength of the portion. Compressive strength is obtained by comparing the rebound number with the conversion chart provided by the manufacturer of rebound hammer.

Figure 1 :- Rebound Hammer Testing

C. Additional Testing of structure materials

Some complimentary tests are performed on the materials obtained from the site. Key test, Push test and Water spray test are some of the major test performed in this experiment.

On the basis of the above data obtained, the existing strength of the structure is compared with the required strength prescribed by the building codes in India.

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Table I:- Retrofitting Decision Criteria

Existing strength (% of initial strength)	Remark
Less than 33%	Rebuilding suggestion
33 – 70 %	Retrofitting required
More than 70 %	No need of retrofitting

III. RESULT AND DISCUSSIONS

A. *Visual inspection report*

I. Building Inspection Report

Table II:- Test Report 1

1	Type of the building	Brick masonry
2	Use of building	School
3	Plan size (approximate)	450 m^2
4	Building height	3.4 m
5	No. of storey above ground level	1
6	No. of basements below ground level	N.A
7	Type of foundation	Isolated
8	Roof –top water tank or any other type of large mass	N.A
9	Expansion / separation joints	N.A
10	Environment	Temperate
11	Deterioration noticed	yes

II. STRUCTURAL ANALYSIS REPORT

Table III:- Test Report 2

1.	Load path	Non-uniform
2.	Adjacent buildings	yes
3.	Mezzanines	No
4.	Deterioration of concrete	Yes
5.	Lintel band condition	Damaged
6.	Masonry units	Cracked
7.	Span of beams	Medium (2-3)m
8.	Cracks at beam, slab joints	yes
9.	Cracks in infill walls	yes
10.	Cracks in boundary column	yes
11.	Post - tensioning anchors	no
12.	Concrete wall cracks	no
13.	Deterioration of steel reinforcement	yes
14.	Plaster condition	damaged
15.	Water seepage condition	detected

III. GEOTECHNICAL AND GEOLOGICAL REPORT

Table IV:- Test Report 3

1.	Type of soil	soft
2.	Type of foundation	isolated
3.	Seismic zone	III
4.	Presence of liquefaction-susceptible saturated , loose granular soil at foundation level	no
5.	Building situated close to slope susceptible to fail under earthquake	No

B. *Rebound Hammer Test*

Table V:- Rebound No. Result

S. No.	Rebound no.	Compressive strength	Type of impact
1.	28	38	Horizontal
2.	24	32	Horizontal
3.	44	68	Vertical Down
4.	32	43	Horizontal
5.	27	36.5	Horizontal
6.	37	58	Vertical Down
7.	31	42	Horizontal
8.	48	61	Vertical Upward
9.	30	41.5	Horizontal
10.	22	25	Horizontal
11.	28	38	Horizontal
12.	42	53	Vertical Upward
13.	35	50	Horizontal
14.	29	41	Horizontal

Table VI:- Quality of Concrete on Rebound No.

Average rebound No.	Quality of concrete
>40	Very good hard layer
30 to 40	Good layer
20 to 30	Fair
<20	Poor concrete
0	Delaminated

From the analysis of rebound hammer test data, we concluded that the strength of the building is nearly **65%** of the required strength and it needs to be retrofitted.

C. *Key Test , Push Test and Water Spray Test*

Key test:-

Scratching the bed joints of masonry wall show the hidden cracks, pores or mortar mix quality.

Water spray test:-

Water absorption at the cracked portion is quite high as compared to the plain surface. The water spray test confirmed the presence of internal crack in the masonry wall of the building.

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IV. SUGGESTED RETROFITTING TECHNIQUES

1. *Cracks stitching* :- The cracked portion of the wall should be repaired by using bolts and metal wire to stitch it. To improve the quality of metal stitching V-groove can be cut on the surface.

2. *Use of steel plate* :- Steel plates or angle can be used to hold the wall corners and improve interlocking of brick work.

3. *Anchoring the walls*:- The anchorage of the roof is required to increase the lateral support of wall at the top. It also enhances the load transfer mechanism of the wall and slab. Therefore stress concentration can be minimized at the base.

Figure 2:- Roof Wall Crack Visible

Figure 3:- Cracked Hanging Slab

Figure 4:- Corner Wall Crack

4. *Repair of the cracks:-*

Table VII:- crack width prevention criteria

Crack width	Recommended Procedure
<1.0 mm	Injection with epoxy
0.3 to 3 mm	Cement grouting with admixture
>10 mm	Reconstruction of cracked portion with high mix cement mortar

5. *Reinforced concrete jacketing:-* To increase the lateral strength and energy dissipation capacity, external reinforcement with concrete on both sides of the wall should be applied.

6. *Strengthening using Shape Memory Alloys (SMA):-* Shape memory alloys (SMA) are metal alloys (nickel + titanium) with special thermo-mechanical properties. They should be used with steel standards to reduce the load transfer on cracked portion and a permanent compression on the wall.

7. *Strengthening of foundation:-* Weak foundation portion should be repaired by constructing a concrete block just adjacent to old foundation as a skin wall. Tie bars and metal bolts are used to attach the concrete block with the building foundation to improve the extent of load transfer at the bottom level.

V. CONCLUSIONS

i. Critical section in any structure is major area for the concern of seismic analysis and retrofitting assessment.

ii. The retrofitting techniques should be applied according to the existing strength of the component of buildings and required standard strength needed as per the building codes.

iii. The economy and cost of the structure possess an important aspect to suggest suitable retrofitting techniques.

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REFERENCES

1) Masonry: IS 1905: 1987, "Code of Practice for Structural Use of Unreinforced Masonry"
2) Concrete: IS 456: 2000, "Plain and Reinforced Concrete – Code of Practice"
3) Steel: IS 800 (Draft), "Indian Standard Code of Practice for General Construction in Steel".
4) IS 1893-2002, "Criteria For Earthquake Resistant Design Of Structure", Part- 1:general provision and buildings, Bureau Of Indian Standards, New Delhi.
5) CPWD HANDBOOK, 2005
6) Aggrawal P., Shrikhande M.," Earthquake Resistant Design Of Structure", PHI, New Delhi, 2006