Retrofitting of Existing RCC Buildings by Method of Jacketing

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Abstract:

Many parts of the country have suffered earthquake in last three decades. In costal part of South India faced Tsunami. In first three earthquakes it was found that many of damaged structures were build in non-engineered masonry techniques. Unreinforced masonry structures are the most vulnerable during an earthquake. Normally they are designed for vertical loads and since masonry has adequate compressive strength, the structures behave well as long as the loads are vertical. When such a masonry structure is subjected to lateral inertial loads during an earthquake, the walls develop shear and flexural stresses. The strength of masonry under these conditions often depends on the bond between brick and mortar (or stone and mortar), which is quite poor. This bond is also often very poor when lime mortars or mud mortars are used. A masonry wall can also undergo failure in-plane shear, if the inertial forces are in the plane of the wall. Shear failure in the form of diagonal cracks is observed due to this. However, catastrophic collapses take place when the wall experiences out-of-plane flexure. This can bring down a roof and cause more damage. Masonry buildings with light roofs such as tiled roofs are more vulnerable to out-of-plane vibrations since the top edge can undergo large deformations. It is always useful to investigate the behavior of masonry buildings after an earthquake, so as to identify any inadequacies in earthquake resistant design. Studying types of masonry construction, their performance and failure patterns helps in improving the design and detailing aspects.

In previous earthquakes many R.C.C buildings have also collapsed and are found unsafe due to faulty workmanship. Many other causes are responsible for major collapse and damage to the R.C.C structures.

The review of the codes shows that there were five zones of earth quakes of Indian subcontinents, But its revision is now shoeing four zones of earth quake. Some part of Gujarat lies in zone V which has largest severity of Earthquake. So as the districts that are located on the boundary of

Gujarat – Maharashtra like Nasik, Dhule, Nandoorbar lye in zone III of earthquake zone, zone III is second largest zone of earth quake in India. Therefore it seems to be an compulsion to have an review of the old RCC structures (Likely have completed their service period) in and around Nashik for the structural behaviour to avoid future inconvenience.

This project is just a similar attempt. A health building in the heart of Nashik city is being strengthened to overcome the future disorders. From the physical and experimental investigations it was concluded that the building either should be demolished or at least should be retrofitted with suitable technique to increase its service life.

It was then decided to implement RCC column jacketing technique due to its feasibility and ease for execution.

All the columns on both the floors are now suitably jacketed, the loose pockets of concrete that were investigated during the test are reconcreted, the faulty slabs are completely opened and the rusted reinforcement is replaced with new reinforcement as per the design requirement. And the slabs are recasted with M25 grade of ready mix concrete.

Keywords: *RC jacketing, Rehabilitation, Retrofitting, Strengthening, Structural repair*

1. Introduction

1.1 Seismic Strengthening (retrofitting)

Actions taken to upgrade the seismic resistance of an existing building so that it becomes safer under future earthquakes. This can be in the form of providing seismic bands, eliminating sources of weakness or concentrations of large mass and openings in walls, adding shear walls or strong column points in walls, bracing roofs and floors to be able to act as horizontal diaphragms, adequately connecting roofs to walls and columns and also connecting between walls and foundations.

1.2 Concept of Retrofitting

Retrofitting is technical interventions in structural system of a building that improve the resistance to earthquake by optimizing the strength, ductility and earthquake loads. Strength of the building is generated from the structural dimensions, materials, shape, and number of structural elements, etc. Ductility of the building is generated from good detailing, materials used, degree of seismic resistant, etc. Earthquake load is generated from the site seismicity, mass of the structures, important of buildings, degree of seismic resistant, etc.

Due to the variety of structural condition of building, it is hard to develop typical rules for retrofitting. Each building has different approaches depending on the structural deficiencies.
Hence, engineers are needed to prepare and design the retrofitting approaches. In the design of retrofitting approach, the engineer must comply with the building codes. The results generated by the adopted retrofitting techniques must fulfill the minimum requirements on the buildings codes, such as deformation, detailing, strength, etc.

1.3 Causes of failure

Damage to buildings were caused by a combination of affects:

- Old decaying buildings predating modern construction practices
- New Buildings not being designed to Indian earthquake codes

- Lack of knowledge, understanding or training in the use of these codes by local engineers
- Unawareness that Gujarat is a highly seismic region
- Buildings erected without owners seeking proper engineering advice
- Improper detailing of masonry and reinforced structures
- Poor materials, construction and workmanship used, particularly in commercial buildings
- Alterations and extensions being carried out without proper regard for effects on structure during an earthquake
- Buildings having poor quality foundations or foundations built on poor soils
- Little or no regularity authority administering or policing the codes

Generally, commercial buildings were worst affected by the earthquake because of poor workmanship, use of materials and inadequate attention to detailing.

1.4 Recent Retrofitting Methods

There are many relatively new technologies developed for seismic Retrofitting which are based on "Response control". These techniques includes providing additional damping using dampers (Elasto-plastic dampers, friction dampers, tuned mass and tuned liquid dampers, visco-elastic dampers, lead extrusion dampers etc.) and techniques such as base isolation which are introduced to take care of seismic control.

1.4.1 Methods of Retrofitting

Increase the capacity/strength of the system (Seismic Resistance Based Design):

(i) Concrete Jacketing.
(ii) Steel Jacketing.
(iii) FRP Wrapping.

2. Retrofitting of health building at Nasik

2.1 General

In order to overcome the future disorders that may have occurred due to unwanted and no predicted disasters it was decided to strengthen the existing Health building located in the central part of Nashik city. This building was proposed in 1984 and accordingly was designed for B + G + 4 storeys. The building during its life span at the end in2008 found completely detoriated and was not capable to sustain further loads. And was predicted that it may fail due to the following reasons.

a) Higher ground water table in the locality.
b) Faulty workmanship during the stage of execution at initial stage.
c) The columns were not centered properly in their position.
d) Improper methods of compaction to the concrete.
e) Insufficient cover to the steel reinforcement.

In addition to this it may also have caused failure due to the non predicted disasters as was caused too many buildings in the past which are listed in the next bit.

2.2 Causes of failure and damages to the building in past few earthquakes

Following were the main causes of failure and damages to the buildings in Gujarat & Maharashtra; causes to buildings same in rest part India.

Damages to buildings were caused by a combination of affects:

1. Old decaying buildings predating modern construction practices

2. New Buildings not being designed to Indian earthquake codes
3. Lack of knowledge, understanding or training in the use of these codes by local engineers
4. Unawareness that Gujarat and some part of Maharashtra is a highly seismic region
5. Buildings erected without owners seeking proper engineering advice
6. Improper detailing of masonry and reinforced structures
7. Poor materials, construction and workmanship used, particularly in commercial buildings
8. Alterations and extensions being carried out without proper regard for effects on structure during an earthquake.
9. Buildings having poor quality foundations or foundations built on poor soils.
10. Little or no regularity authority administering or policing the codes.

It's necessary to every civil engineer to have knowledge of proper repairs and strengthening of earthquake damaged buildings. Indian standards exist but are not used by local engineers or builders in urban or rural areas, mainly due to lack of knowledge and training. As a result, many of the owner-occupiers have unknowingly been carrying out bad repairs in Gujarat. Many buildings have been severely weakened, and the experts are concerned to that there could be another disaster in waiting from a future earthquake. Good repairs, using well-recognized seismic standards may reduce this vulnerability.

This project aims in simple terms to explain to the engineers why earthquakes happen in India, which regions are seismically active, how buildings respond in an earthquake; and how to safely carry out good repair and strengthening techniques to damaged and low strength buildings.

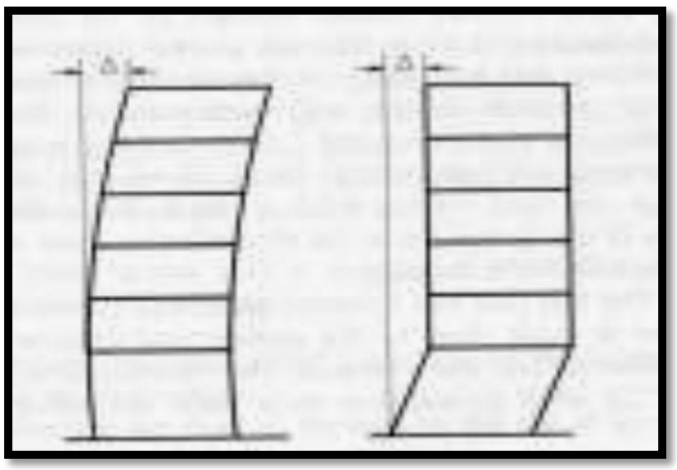

Fig.1 Some damages those were occurred after earth quake at Gujarat in non engineered R.C.C building construction

The inset shows large deformations were concentrated at column heads, which caused many soft storey failures, as per picture. Buildings if designed with uniform deflections of insert would have survived without collapse."

2.2.1 Crushing of column head and bases

When masonry infill walls were ineffective because of large openings, column heads were subjected to large vertical and lateral seismic forces. The heavy eccentric compressive stresses

crushed column heads and large shear deformations caused concrete to spall away from the main bars because of links being too far apart. The extent of damage to the column heads often depended on how well the infill wall panels were bonded to the columns.

Some common problems, which resulted in severe damage to the column heads or bases, were from poor detailing as follows:

(a) Drain pipes and other services placed inside columns, caused severe weakening of the columns making it less resistant to lateral loading;

(b) Shear link spacing was too large (typically 200-300mm), thus not providing adequate confinement to the main bars, causing concrete to fall out;

(c) Links were not bent backwards into the columns so they easily separated, again letting concrete out of the main bars;

(d) Very small links (6mm diameter) were used;

(e) Main bars were not bent back into the floor or ground beams so that reversal of shear loads could not be resisted by the beam and column connections. Many failures occurred at beam/column junctions.

2.2.2 Roof failures & Canopy structures

Damage to flat roofs was rare. However, pitched roofs often experienced non-structural damage by tiles falling through open space between the timber battens as no tiles were nailed into the timbers. Many tiles were manufactured with no holes to allow them to be nailed to the roof. Several modern buildings had a single storey canopy with a flat roof supported by columns at one end and beams running into the main structural frame at the other end. These suffered varying degrees of damage depending on how slim the columns were.

2.3 Responsibility of building owners

The building owner is responsible for determining the need for the repair and its extent, whether it is practical and safe to carry out the repair and whether it is within his budget. It is advised that the building owner should in all cases seek professional advice from a qualified structural engineer before carrying out any repairs. It is also equally important to retain the services of a qualified builder when carrying out repairs.

2.4 Responsibility consulting engineers

Its responsibility of consulting engineers to provide safe structural design that can withstand the earth quake load without any damage to the structures, regular sites visits and technical advice to the site supervisors and workers is very essential to reduce the bad practices that would be produce safe and economical shelters to the society.

2.5 Retrofitting of R.C.C Building by Method of Jacketing

As it's shown in above part of chapter no five, that Nasik and some part of Maharashtra is along the border part of Gujarat, Gujarat has suffered from severe earth quake in last two decades, nobody knows which would be the next time of future earth quake & its intensity. Like Gujarat many constructions in Maharashtra and at Nasik are found as non engineered unsafe & quality compromised constructions, this would be future risk for coming days. So it is necessary to carry

out the non destructive tests of all construction in Nasik and rest part of India, to save valuable lives and properties, now a days many advance retrofitting techniques are available in the world, those can be used to repair & strengthen the unsafe and damaged buildings. Here the paper has its focus on a Health building which is under execution (for re modification and strengthening of existing structure).

2.5.1 History of Health Building

A group proposed to start a hospital in Nasik in 1984. And as per the decision the detail plan & the structural details for the same were prepared. It was proposed to construct a Basement + G + 4 storey structure and the designs were prepared so. The site for the hospital was near Dwarka circle. Nasik: 11.

Though it was planned to construct 6 storey in all, only 2 storey (i. e. Basement + G) structure was constructed in actual when structural details were for 6 storey. The built up area for basement is 1236 sq.mt. and that of the ground floor is 1178 sq. mt.

This group had a smooth functioning upto 2004. Then in 2005 the administration of the hospital was changed. New administrative body utilized the same infrastructure up to 2008.

Then in 2009 was decided to extend the building as per the initial plan and structural details. And for the same had the structural audit in that respect. From the audit that all the defects were at the execution stage. The faults that were concluded were as below.

a) The high ground water table in the region.
b) Eccentricity of all the columns was a serious problem observed.
c) Improper techniques that were followed during mixing, placing & compacting the concrete.
d) There were many loose pockets found in the concrete.
e) Sufficient concrete cover at different stages to the steel reinforcement was not maintained.
f) The terrace slabs are provided with unwanted thickness of IPS flooring at the top.

From the NDT test results it was suggested that the management should demolish the entire existing structure instead of extending it and go for complete new structure. The management refused to do so and asked to suggest such a measure so that the existing infrastructure at least can withstand and be utilized for 5 – 7 years more. As the final conclusion and the requirement of the management it was decided to go for 'Retrofitting of the Structure'.

2.5.2 The steps that were suggested and are adopted are as below

(A) The entire flooring at the basement to be removed & to be provided again with a raft below it. To overcome the uplift pressure that could be generated due to the higher ground water table it was suggested to provide a raft below the basement floor.

(B) All the columns should be jacketed. In the existing structure it was found that the columns were not centered properly in their position, due to which they were subjected to unwanted eccentric loads. Also the concrete in columns, beams, slabs was not compacted properly which created loose pockets & honey combs in the components. Suitable cover for the reinforcement was not maintained.

To overcome the above difficulties it was decided to jacket all the columns such that the eccentricity of loading will be reduced, the loose pockets of concrete will be capable to sustain the load to which the column is subjected & all the steel get the required concrete covering.
(C) The loose pockets in the concrete in the beams are also removed and recasted in M25 grade.
(D) The unwanted heavy loading of water proofing (IPS flooring) damaged the slab to greater extent.

Therefore, five slabs are entirely opened, strengthened with additional reinforcement and are casted with 150 mm thick M25 grade concrete layer.

The estimated cost of retrofitting the existing structure is 4.5 crore. To meet the further requirement of infrastructure the management now is constructing additional new building with G + 2 storey, instead of razing the existing building.

1 **2** **3**

Fig. 2 Photographs shows the step by step stages of retrofitting work for the considered Health Building at Nashik

View 1. "Column jacketing at basement stage" **2.** "beam column junction strengthening in basement" **3.** "finished Column after jacketing work"

Figures shows the work of column jacketing for existing columns for additional strengthening, for its renovation work. These columns give the additional strength for its future use & make the structure safe against seismic forces.

4 **5** **6**

View 4. "Rusting condition of existing slabs reinforcement" **6.** "Replaced slab reinforcement for existing rusted steel reinforcement." **7.** "Application of chemical admixtures at the joint of new and old concrete"

7 **8**

Fig. 3 Photographs shows the step by step stages of retrofitting work for the considered Health Building at Nashik

View 7. "compaction of concrete by needle vibrator and placement of cover blocks" **8.**"Finished slab - ready to cure"

As discussed above all works those were carried out on strengthening of the Health building at Nasik, will definitely increases the strength of existing building, this practice would be necessary for many buildings at Nasik and rest of India, it will save the many lives, when any natural disasters will occur.

3. Conclusion

Strengthening of building considered in the report is an attempt to increase the life and to sustain the unwanted disturbances like, earthquakes floods etc. The building though was proposed to have been constructed as six storied building and was designed as per requirements, but was constructed only up to two storey, it should have worked or served for a period mre than the designed life span, which is not so. And recommended the strengthening at early stage due to minor effects of disaster, uplift pressure of ground water table, bad workmanships, hence had to be retrofitted. **Timely Repair of the structures can be concluded as, 'A stitch in time, Saves nine.'**

3.1 Future scope for the work in Nasik area

Project work has focused on strengthening the RCC buildings. There is an large scope to create an awareness in the occupants/ residents of the buildings those may have completed the service period and or will probably be completing the service period in short future.
All such buildings in and around Nashik and all the metro cities in the state and country cn be retrofitted with suitable technique to save the lives and property.

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