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# SEISMIC EVALUATION OF EXISTING REINFORCED CONCRETE BUILDING

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**ABSTRACT:**

***The vulnerability of existing reinforced concrete building in India has been exposed to recent earthquakes. The Bhuj earthquake (2001) has caused significant damage to multi-story buildings in Gujarat's urban area. The many existing Indian RC buildings, mainly designed for gravity loads, were seriously threatened. Following the damage and collapse of numerous concrete structures during recent earthquakes, the need to assess seismic adequacy of existing structures became clear. A simplified assessment process is highly needed for a country such as India that is prone to earthquakes in order to carry out a seismic assessment. The response of buildings to earthquakes in terms of reservation of life and risk management is important to estimate. The Response Spectrum analysis procedure is used to evaluate the existing design of a bare black frame of reinforced concrete, infill frame, and infill frame and soil effect. The response spectrum analysis for the seismic assessment of existing buildings is performed in order to assess the performance of these models. The analysis reinforcement needed in each format is determined and retrofitted accordingly. In this study, a different retrofitting method is studied. In seismic evaluation of existing RC buildings, it is also concluded that the effect of infill plays a critical role.***
***Keywords — Masonic infill wall, diagonal equivalents, reinforced cement, upgrading,***

# INTRODUCTION

Earthquakes can cause serious damage to engineered structures among the natural hazards. Given that earthquake forces are random in nature and unpredictable, engineering tools need to be sharpened to analyse their structures. In the last century, India has many of the greatest earthquakes in the world. More than 50% of the country's area is actually considered vulnerable to earthquakes. Both the north-east region and the entire Himalayan belt are susceptible to major earthquakes at more than 8.0.

*Fig 1: Area expose to seismic risk in Indian Classification*

During the last century, the country was affected by 4 major earthquakes in (1) a major Assam earthquake (1897), (2), a kangra earthquake (1905), (3) an earthquake in Bihar Nepal (1934) and (4) a squamous earthquake in Assam (1950). The recent earthquakes in our country include (1) the Bihar Nepal earthquake in 1998, (2) the Killari earthquake in 1991, (3) the Jabalpur earthquake in 1999, (5) the Chamoli earthquake in 1999 and (6) the Bhuj earthquake in 2001 and recently the West Bengal earthquake in recent years (2011). There is enormous loss of life and very great destruction of existing reinforced concrete (RC) buildings in all these earthquakes. The latest buildings in urban areas consist of poorly designed and built buildings. Although the old buildings were built to the prevailing standards, the more stringent specifications of IS 1893(Part 1):2002, IS 4326:1993 and IS 13920:1993 may not comply. The existing buildings may be seismically deficient because the requirements of the design code are constantly improved as engineering knowledge is progressed.

Research into the past and recent earthquake damage has shown that structures are vulnerable to severe damage and/or collapse in moderate to strong ground movement. An earthquake on a moderate scale can cause severe damage to manufactured buildings, bridges, industrial and port facilities and cause major economic losses.

Following the Bhuj earthquake (2001), considerable interest was shown in this country in the harmful effects of earthquakes and in the threat of seismic events. Most of the mega towns in India are located in seismically active areas and are intended for gravity only. The magnitudes of the design seismic forces were generally significantly increased and the seismic zoning of certain regions was also improved. Therefore, a large number of existing buildings in India require seismic assessments because of several reasons mentioned above. Therefore, assessment of existing RC buildings in India is a growing concern.

## 1.2 NEED FOR SEISMIC EVALUATION

It is known that a number of afterstocks and sometimes other main shocks follow damaging earthquakes. Past earthquakes have demonstrated that a significant percentage of structures achieve mild to moderate damage when urban areas are hit by damaging earthquakes. In addition, it is known that structures which suffered certain damages before the seismic event could collapse in a successive event. Such unfortunate events took many lives. These structures thus place human life, economic assets and the environment at potential risk. Decisions on the functionality of the post-earthquake and the repair of damaged structures are thus a crucial part of the recovery procedure post-earthquake. Moreover, the effects of major earthquakes in various parts of the country have resulted in an increasing seismic risk in urban areas that is far from socially acceptable. This situation therefore urgently needs to be reversed and one of the most effective methods is believed to be by:

(1) The seismic assessment of existing structures.

(2) Develop more reliable seismic standards and codal provisions than those currently available for the full engineering of new engineering facilities. Accurate estimates of structural performance during an earthquake are therefore critical to estimating the effects of this earthquake on the structure's vulnerability can be evaluated with greater accuracy and better informed decisions on possible improvement of seismic resistance of existing RC structures can be taken. In future earthquakes, for example, the critical components of the structure that are expected to sustain significant damage can be identified. The necessary immediate structural measures can therefore be

designed to reduce the demand for deformation of these components. Then the overall comport ability of the structure can be improved to achieve a satisfactory overall earthquake performance.

# 2. METHODS OF SEISMIC ANALYSIS AND RETROFITTING

## 2.1 METHODS OF ANALYSIS

A structural analysis of the structural mathematical model is required to determine strength and displacement demands in various components of the structure for seismic performance analysis. Several analytical methods are available to predict the seismic performance of structures, both elastic and inelastic. Some of the seismic analysis methods used in seismic assessment are provided below;

1. Elastic analytical methods 1.

A. Static linear analysis

B. Dynamic linear analysis

2. Inelastic analytical methods

A. Static Nonlinear Analysis

B. Dynamic nonlinear analysis.

2.1. Single diagonal strut equivalent models this method simulates the action of infill’s similar to the action of diagonal struts holding the frame. The infills are replaced by an equivalent strut of length D and width W and the frame-strut system analysis is performed using the common frame analysis methods. Main stone Walls' relationships must withstand the shear forces that try to push the walls over. It is widely used in the literature to calculate the width of the diagonal strut equivalent and is given by it.

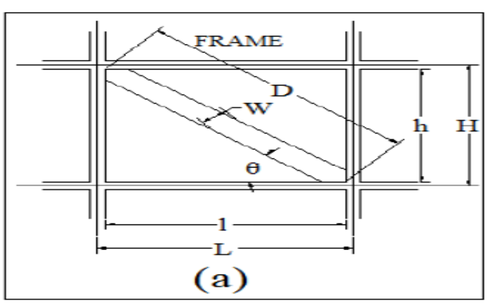



***Fig 2.1 shows equivalent diagonal strut model***

$$\lambda = \sqrt[4]{\frac{E_i\ t\,\mathrm{Sin}(2\theta)}{4\,E_f I_c h}}$$

Where λ =Stiffness reduction factor

Ei = the modules of elasticity of the infill material,

N/mm2 Ef= the modules of elasticity of the frame material,

N/mm2 IC= the moment of inertia of column,

Mm4 t = the thickness of infill,

Mm H =the center line height of frames

h = the height of infill

L =the center line width of frames

l = the width of infill

D = the diagonal length of infill panel

θ = the slope of infill diagonal to the horizontal.

**Width of strut without opening** (W)

$W = 0.175 (\lambda H)_{-0.4} D$

When setting the value of the stiffness reduction factor above equation, strut width for estimation of strut width without opening has been calculated,

## 2.2 RETROFITION what is seismic refurbishment?

A seismic retrofit offers existing structures more resistance to earthquakes seismic activity. This process typically involves enhancing poor connections in roofs to walls, continuous ties, shear walls and the diaphragm of the roof. In the past, building codes were less stringent than today's standards and it is therefore good to inspect buildings built before 1998 as they were built before current structural codes and requirements (1997 UBC). It is the method of strengthening the damaged/undamaged old/new structures that are found to be weak with future earthquake loads. Structuring's that are vulnerable to earthquakes are generally refurbished by steel jacket, concrete jacketing, galvanized steel mesh strengthening, new supporting walls/concrete shear walls, steel straps, reinforced fiber polymer (FRP) sheets or other appropriate means. In a well-built building, renovation works may also be necessary if additional floors are added. Even old-weak buildings can be extended to cover the increased safety demand due to the extended part by properly strengthening the older part.

### Selection of the correct retrofitting action

Proper study of the existing structure with various analytical tools is necessary to identify the weak areas of the structure before retrofitting work is carried out. It also helps to choose an appropriate retrofit measure to be taken in economic and security aspects. Construction structures in an acceleration sensitive region and the speed sensitive spectrum area may require various retrofitting measures. The retrofitting option suitable for one structure could prove to be ineffective for a different dynamic structure. Also, the rigidity of a building structure may increase significantly after retrofitting, thereby increasing the load consumption of the structure than before retrofitting. The increased rigidity also depends on the type of retrofitting.

In addition, a structure can increase significantly after retrofitting, increasing the demand for load on the structure than before retrofitting.

The increased rigidity also depends on the type of retrofitting. Conventional steel/concrete rehabilitation measures the jacketing and inclusion of new walls can significantly increase the rigidity of the structure. Thus its dynamic behavior is altered in such an analysis of the retrofitted structure Modern jacketing technology such as the wrapping of fiber-reinforced polymer (FRP) could be the best way of building capacity without altering rigidity. In addition to increasing structural stiffness, a major impact of the conventional method for retrofitting could be the development of new load paths leading to load concentration at the foundation level. This is done in the framework structures of reinforced concrete (RC) where the inclusion of concrete shear walls between the columns is done as a retrofit measures. In this way, the existing base of the adjacent columns will probably be stressed. The proper retrofitting technique shall be chosen by analyzing the existing structure in detail. Re-analysis including re-design may be necessary after retrofitting measures have been introduced. So that the goal of seismic refurbishment is achieved.

## Refurbishment of design principles

The design principles must follow several factors even in the case of retrofitting, as in the case of the new construction. For example, in order to benefit fully from the potential ductility of RC members retrofitted. It is desirable to ensure that flexure is the ultimate strength rather than shear. Shear failure is catastrophic and occurs without warning of trouble. Many existing RC columns and beams were deficient in shear strength and need to be strengthened.

Shear deficiencies occur due to several reasons, such as poor shear strengthening or decreases in steel area due to corrosion, increased service load, older code design principles and building defects. Shear should be improved as far as possible in case of retrofitting. The structural members' bending, axial & ductile capacity and structure as a whole. Most current practices appear to provide greater confinement for the mostly increasing axial, shear, and ductile behavior of the structural components. Bending capacity increases can also be achieved if proper detailing and design principles are observed.

## 2.2.1 Beton Jacketing

Beton jackets consist of the addition of a concrete layer of longitudinal bars and closely spaced ties. The jacket strength and shear strength of the column are increased. There has been an increase in ductility (Rodriguez and Park, 1994). There is no noticeable increase in rigidity if the thickness of the jacket is small. Circular ferro-cement jackets have been found to improve ductility. The disadvantage of concrete jackets is that the column is bigger. Binding on the beam column joints is difficult, if not impossible. Drilling troughs in existing beams damages the concrete, particularly if it is of poor quality. Although there are disadvantages, it is relatively cheap to use concrete jacket. It is important to note that with the increase in bending capacity, the demand for shear is also increasing (based on bending capacity). The additional ties satisfy the shear demand.

A concrete jacket can be supplied with several schemes. A scheme is selected based on the dimensions and the strength of the existing column, available room for placing longitudinal bars, is required. The additional longitudinal bars must be anchored to the foundation and continuously through the floor slab to increase flexural strength. The required bars are usually placed at the corners to prevent the beams that are framed into the column from intercepting. Moreover, longitudinal bars on the sides of the column cannot be positioned continuously throughout the floor. These bars provide the new ties laterally. Due to the blockage in placement, a single bar cannot be made from a fie. It can be built with two bars properly attached to the new longitudinal bars. 135 hooks with adequate extension are preferred at the ends of the bars.

**Fig: Concrete Jackting**

a) The strengths of the new materials shall equal or exceed those of the existing column. At least 5MPa greater than the existing concrete should be the compressive strength of concrete in the jacket.

b) For columns not requiring extra longitudinal bars with an additional bending capacity of at least 12mm, bars in diameter in four corners and ties in diameter of 8mm should be provided.

c) The minimum jacket thickness should be 100 mm.

d) The minimum ties shall be 8 mm in diameter and not less than? In diameter of the longitudinal bars. The bending angle of the end of the ties is 135.

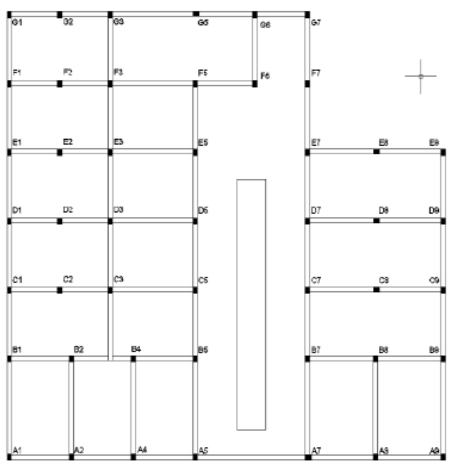
e) The center-to-center ties should not be more than 200 mm. The spacing should preferably not exceed the jacket thickness. Near the beam-column joints, for a clear column height of 1/2. The distance should not be more than 100 mm.

# 3 ANALYSIS PROBLEM

## 3.1 STRUCTURAL DETAILS:

| RC Frame Details | |
|---|---|
| 1] Grade of concrete | 20 $N/mm^2$ |
| 2] Grade of steel | 415 $N/mm^2$ |
| 3] modulus of elasticity of concrete | 22.36 $kN/m^2$ |
| 4] modulus of elasticity of steel | $2x10^5$ $kN/m^2$ |
| 5] unit weight of concrete | 25 $kN/m^3$ |
| 6] Poisson's ratio | 0.2 |
| 7] Sizes of beams | 230x300mm,230x380mm, 230 x 450mm |
| 8] Sizes of columns | 230x300mm,230x380mm, 230 x 450mm |

| **Brick masonry Infill Details** | |
|---|---|
| 1] strength of brick masonry | 4 $N/mm^2$ |
| 2] unit weight of masonry | 20 $kN/m^3$ |
| 3] modulus of elasticity of brick masonry(550$f_m$) | 2035 $N/mm^2$ |
| 4] Thickness of peripheral wall | 230mm |
| 5] Poisson's ratio | 0.15 |
| 6] Single strut model width<br>a) along X-direction<br>b) along Y-direction | <br><br>380,390,420,440,370,350mm<br>480,450,400,380,530mm |
| **Soil Properties** | |
| Type | Gravel |
| E (Modulus of Elasticity) | 120 $N/mm^2$ |
| Poisson's Ratio | 0.15 |



***View of building.***

### 3.2 Models of Analytics

For the purpose of analysis and design four models were considered as 1. Bare frame (S.M.R.F infill frame with masonary effect not considered)

2. Completely in filled frame (S.M.R.F infill frame with masonary effect considered)

3. In filled center opening frame (15 percent)

4. In filled corner opening frame (15 percent)

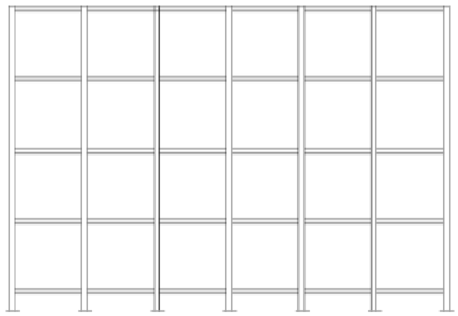


*Fig 3.2: bare frame model*

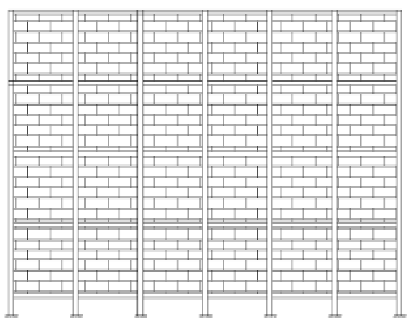


*Fig 3.3: Fully in filled frame model*

All frames above were designed with the help of STAAD-Pro software. Some columns were chosen to get results and they are as column no.C1, C2, C3 & C5. The results found are shown using the parameter graph.

## 4. RESULT COMPARISON 1.

The actual construction is reinforced and compared to the required reinforcement in the Brick Infill Model and Brick Infill + Soil Interaction Model under seismic design. If compression is more than the reinforcement required in the brick infill and the soil interaction effect than it is necessary to retrofit the actual section, the seismic forces will be sufficient to carry. But if the actual strengthening is less than the strengthening required.

In the brick infill or soil interaction model effect, the particular member needs to be retrofitted. The main parameter in the study is strengthening of members and maximum building displacement.

## Table: - 4.1. Reinforcement Comparison of building.

| Column ID | Size (mm x mm) | Ast Pro. (mm²) | Ast Required(mm²) | | | Retrofitting Required Yes/No |
|---|---|---|---|---|---|---|
| | | | Bare Frame | Infill Wall | Soil Effect | |
| G.F C1 | 230 x 300 | 678 | 847 | 783 | 730 | NO |
| F.F.C1 | 230 x 300 | 678 | 374 | 530 | 530 | NO |
| S.F.C1 | 230 x 300 | 678 | 121 | 616 | 616 | NO |
| T.F.C1 | 230 x 300 | 678 | 412 | 674 | 673 | NO |
| | | | | | | |
| G.F C2 | 230 x 380 | 904 | No Design | 903 | 869 | NO |
| F.F.C2 | 230 x 380 | 904 | No Design | 704 | 704 | NO |
| S.F.C2 | 230 x 380 | 904 | No Design | 477 | 477 | NO |
| T.F.C2 | 230 x 380 | 904 | No Design | 182 | 182 | NO |
| | | | | | | |
| G.F C3 | 230 x 300 | 678 | 1145 | 1029 | 970 | Yes |
| F.F.C3 | 230 x 300 | 678 | No Design | No Design | No Design | Yes |
| S.F.C3 | 230 x 300 | 678 | No Design | No Design | No Design | Yes |
| T.F.C3 | 230 x 300 | 678 | No Design | No Design | No Design | Yes |
| | | | | | | |
| G.F C5 | 230 x 300 | 678 | No Design | 678 | 660 | NO |
| F.F.C5 | 230 x 300 | 678 | No Design | 670 | 670 | NO |
| S.F.C5 | 230 x 300 | 678 | 679 | 440 | 440 | NO |
| T.F.C5 | 230 x 300 | 678 | 453 | 179 | 179 | NO |

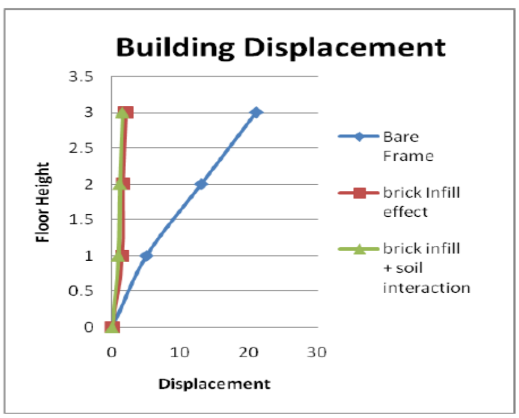



***Figure No.4.1. - Displacement comparison of building***

From the above figure it is found that, compared to the naked frame model, Brick infill + soil interaction effect model deflection was reduced by 90% - 92%.

## Retrofitting:

Building No 1 column C3 in case of study retrofitting.

The concrete jacketing method is therefore for retrofitting Recommended for additional concrete layer from all sides, longitudinal bars and about 75 mm.The ties are closely spaced. The analysis and design is retrofitted the reinforcement done again and required is calculated. Below The table shows the necessary reinforcement after retrofitting.

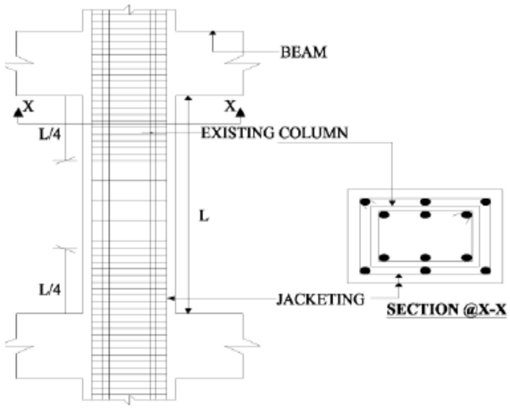



*Figure e No.4.2. Column Jacketing*

## Table: - 4.2. Reinforcement Comparison of building After Retrofitting.

| Element ID | Size (mm x mm) | Ast Provided (mm²) | Ast Required (mm²) | | |
|---|---|---|---|---|---|
| | | | Bare Frame | Infill Wall | Soil Effect |
| G.F.C3 | 450 x 380 | 904+452 | 1041 | 930 | 870 |
| F.F.C3 | 450 x 380 | 904+452 | 886 | 861 | 861 |
| S.F.C3 | 450 x 380 | 904+452 | 545 | 345 | 345 |
| T.F.C3 | 450 x 380 | 904+452 | 779 | 223 | 223 |

## CONCLUSIONS:-

The entire study is focused on the seismic assessment and rehabilitation of existing RC structures. Seismic analyses are Existing reinforced concrete building performed. The Building reinforcement is compared with all Three modeling formats i.e. bare frame modeling, Modeling and infilling of brick infill + soil effect Model interaction. After all the following study Findings are drawn.

It is concluded that the strengthening is done suggested the strength of the existing in this thesis The structure can be upgraded to the level and The seismic resistance will definitely improve Building capacity required for zone III.The concrete jacketing method has been conclude Easy, efficient and cost effective method for § Results indicate that infilling panels have a significant impact on the behavior of frames in the event of an earthquake. In general, infill panels increase structural rigidity. As a result, the stiffness of the frame increases due to the infilling effect and comparatively less reinforcement is required in comparison to the reinforcement required in a bare frame.

Towards deflection in the bare frame is very large in comparison with the filled frame.

The construction with brick infill + soil interaction effect is concluded that approximately 30 to 40 percent less reinforcement is required compared to the unbalanced frame in the floor. And in other upper floors relatively less difference in reinforcement.

If methodology (analysis of infill wall + soil effects for new constructions is adopted, then the cost-effective structural member sizes for earthquake resistance will be used.

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