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Strengthening of Existing RC Building against Wind Loads

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***Abstract*: Many existing reinforced concrete multi storied buildings are inadequate when they are subjected to even moderate wind loads. Recent earthquakes which occurred during last few decades have witnessed major damages not only due to actions of earthquakes but also due to wind load sand poor performance of buildings during earthquakes. It is recognized that most effective method of reducing risk of damaging structure is retrofitting. In recent years there is a significant improvement of retrofitting techniques. This study highlights the principles of assessment, evaluation and retrofitting measures of existing R.C buildings against wind loads.**

***Keywords*: Strengthening of Structures, wind loads, RC buildings, design of RC structure.**

1. Introduction

Retrofitting is technical inventions 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. Ductility of the building is generated from the detailing, materials used, degree of seismic resistant etc. Earthquake load is generated from the site seismicity, mass of the structures, importance of buildings, degree of seismic resistant etc. Seismic retrofit becomes necessary if it is shown that, through a seismic performance evaluation, the building code provisions and may suffer severe damage or even collapse during a seismic event. The retrofitting of a building requires an application for the technical, economic and social aspects, of the issue in hand. Changes in construction technologies and innovation in retrofit technologies present added challenge to engineers in selecting a technically, economically and socially acceptable solution.

Conventional upgrading techniques usually include the addition or strengthening of existing walls, frames and foundation. Adopting these recommendations often leads to heavy demolition, lengthy construction, and occupant relocation with all associated directed and indirect costs. It is often the indirect costs, the environmentally hostile approach, and the inconvenience associated with conventional techniques that deter building owners and custodians from committing to seismic retrofit. Adopting these recommendations often leads to heavy demolition, lengthy construction time, reconstruction, and occupant relocation with all the associated direct and indirect costs. It is often the indirect costs, the environmentally hostile approach, and the inconvenience associated with conventional techniques that deter building owners and custodians from committing to seismic retrofit. In less than a decade, much progress has been made in developing innovative structural and non-structural hazard reduction measures in buildings. Advanced composite materials and new technologies have been extensively researched and to a lesser extent, applied in seismic retrofit projects. Buckling and bulging are the common phenomenon of RC column failure. For a flexural member like beam bending and deflection are the common phenomenon of RC beam failure. The joint has been always considered as weaker section of the structure. Insufficiencies is not taken for the beam-column or slab-column connection at designing stage as well as at the construction stage, it may lead to the degradation of the building in early age.

2. Description and Analysis

A 5-storey apartment building is chosen for analysis & design of various structural elements. Then after carrying out analysis when the structure is subjected to both gravity loads and wind loads separately. After obtaining the bending moment & shears in different elements of both cases, if the values of any element due to wind load is greater than those of gravity loads then the element is retrofitted. Normally column will be subjected to more moments due to wind compared to gravity loads because shear will not be considered in gravity loads.

The retrofitting technique for strengthening columns is also presented in the report.

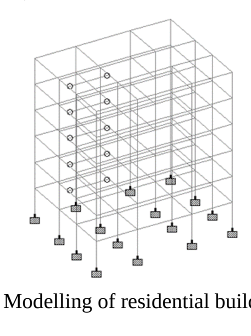

Fig. 1. 3D Modelling of residential building in staad

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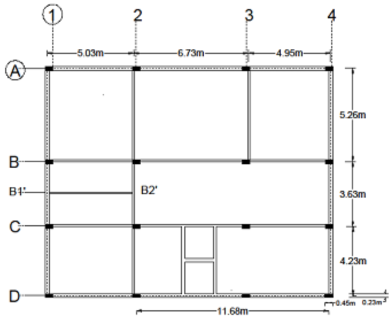

Fig. 2. Beam column lay out of one flat of the building

1) Specifications

These are the Specifications followed in the design criterion

1. Grade of concrete M20
2. Grade of steel Fe 415
3. Thickness of slab 120 mm
4. Thickness of inner wall 115 mm
5. Thickness of outer wall 230 mm
6. Size of the column 230 x 450 mm
7. Size of the beam 230 x 600 mm
8. Height of ground floor 3.2 m
9. Height of first floor 3.2 m

3. Wind Load Calculations

Height of the story =3.2m

Height of the structure =5×3.2 =16m

Topography – Plane with upwind slope (θ<3)

1) Design wind velocity (V_z)

$V_z = V_b \times K_1 \times K_2 \times K_3$

K_1 =Probability factor

K_2 =1.0 for 50 years life span

Our structure comes under category 3

Class C $K_2 = 0.97$

K_3 = Topography factor

K_3 =1.0 for ground level

At 16 m height.

Design wind speed $V_z = V_b \times K_1 \times K_2 \times K_3$

$= 50 \times 1 \times 0.97 \times 1$

= 48.5m/sec

Design wind pressure $P_z = 0.6 \times (V_z)^2$

$= 0.6 \times (48.5)^2$

$= 1411.35 N/m^2$

At 12.8m height.

Design wind speed $Vz = V_b \times K_1 \times K_2 \times K_3$

$= 50 \times 1 \times 0.94 \times 1$

= 47m/sec

Design wind pressure $P_z = 0.6 \times (V_z)^2$

$= 0.6 \times (47)^2$

$= 1325.4 N/m^2$

Design wind load (F)

$= 4.44 \times 1.6 \times 1.411 = 10.02 KN/m^2$ (At 16m)

$= 4.44 \times 1.6 \times 1.325 = 18.82 KN/m^2$ (At 12.8)

Table 1
Gravity Loads Calculation

Element	**Load from beam B1-B2(KN)**	**Load from beam B2-B3(KN)**	**Load from beam A2-B2(KN)**	**Load from beam B2-C2(KN)**	**Point load if any (KN)**	**Self-weight of column (KN)**	**Total load (KN)**	**Grand total load (KN)**
16.0	48.94	77.83	52.6	27.22	18.26	6.98	231.83	231.83
12.8	66.59	102.46	70.72	**38**.47	26.66	6.98	311.88	543.71
9.6	66.59	102.46	70.72	38.47	26.66	6.98	311.88	855.59
6.4	66.59	102.46	70.72	38.47	26.66	6.98	311.88	1167.47
3.2	66.59	102.46	70.72	38.47	26.66	6.98	311.88	1479.35
G. L	40.34	53.97	42.18	29.11	-	-	165.6	16449.95

Total = 1644.95 KN

Table 2
Wind Load Calculations (Without Live Load)

Element	**Load from beam B1-B2(KN)**	**Load from beam B2-B3 (KN)**	**Load from beam A2-B2 (KN)**	**Load from beam B2-C2 (KN)**	**Point load if any (KN)**	**Self-weight of column (KN)**	**Total load (KN)**	**Grand total load (KN)**
16.0	49.97	74.03	53.25	26.93	14.83	6.98	225.99	225.99
12.8	64.45	93.41	68.40	37.38	22.05	6.98	292.67	518.66
9.6	64.45	93.41	68.40	37.38	22.05	6.98	292.67	855.59
6.4	66.59	102.46	70.72	38.47	26.66	6.98	292.67	1104.0
3.2	66.59	102.46	70.72	38.47	26.66	6.98	292.67	1396.67
G. L	40.34	53.97	42.18	29.11	-	-	165.6	1562.27

Numbers of stories =5

Location of the structure = Vijayawada

Design life of structure = 50 years

Category = 3

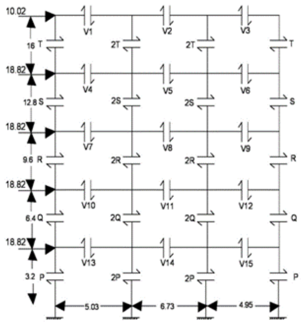

Fig. 3. Wind forces acting on a frame

2) Calculations of Column Moment

Top floor

$M_{QU} = M_{UQ} = T\times8 = 1.67\times8 = 13.36$KN-m

$M_{VR} = M_{RV} = 2T\times8 = 3.34\times8 = 26.72$KN-m

Fourth floor

$M_{MQ} = M_{QM} = S\times6.4 = 4.8\times6.4 = 30.72$KN-m

$M_{RN} = M_{NR} = 2S\times6.4 = 9.61\times6.4 = 61.50$KN-m

Third floor

$M_{IM} = M_{IM} = R\times4.8 = 7.9\times4.8 = 37.92$KN-m

$M_{NJ} = M_{JN} = 2R\times4.8 = 15.8\times4.8 = 75.84$KN-m

Second floor

$M_{IE} = M_{EI} = Q\times3.2 = 11.08\times3.2 = 35.45$KN-m

$M_{JF} = M_{FJ} = 2Q\times3.2 = 22.16\times3.2 = 70.91$KN-m

First floor

$M_{EA} = M_{AE} = P\times1.6 = 14.21\times1.6 = 22.73$KN-m

$M_{FB} = M_{BF} = 2P\times1.6 = 28.4\times1.6 = 45.44$KN-m

3) Reinforcement detailing for columns: Design of B2 Column with Uniaxial Bending at G.L for Gravity Loading

Size of Column - (230×450) mm

Concrete mix - M20

Characteristic strength of reinforcement - 415 N/mm^2

Length of column = 3.2m

load, P = 1645 KN

Factored Load, $P_u = 1.5\times1645 = 2467.5$KN

Moment, M= 30.7 KN-m

Factored Moment, $M_u = 1.5\times30.7 = 46.05$KN-m

$\frac{Pu}{f_{ck}bD} = \frac{2467.5\times10^3}{20\times230\times450} = 1.19$

$\frac{Mu}{f_{ck}bD^2} = \frac{46.05\times10^6}{20\times230\times450^2} = 0.05$

For $f_y = 415$ and $\frac{d'}{D} = \frac{50}{450} = 0.11$

From chart 33 of SP16, we have

$\frac{P}{f_{ck}} = 0.265$

P = 0.265 × 20 = 5.3% > 4%

4) Design of B2 Column with Uniaxial Bending at G.L for Wind Loading

Size of Column - (230×450) mm

Concrete mix -M20

Characteristic strength of reinforcement -415 N/mm^2

Length of column =3.2m

Load, P = 1563 KN

Factored Load, $P_u = 1.5\times1563 = 2344.5$KN

Moment due to wind load, M = 61.5 KN-m

Factored Moment, $M_u = 1.5\times61.5 = 92.25$KN-m

$\frac{Pu}{f_{ck}bD} = \frac{2344.5\times10^3}{20\times230\times450} = 1.13$

$\frac{Mu}{f_{ck}bD^2} = \frac{92.25\times10^6}{20\times230\times450^2} = 0.099$

For $f_y = 415$ and $\frac{d'}{D} = \frac{50}{450} = 0.11$

From chart 33 of SP16, We have

$\frac{P}{f_{ck}} = 0.275$

P = 0.275 × 20 = 5.5% > 4%

Hence Retrofitting is required.

5) Design of column to be Retrofitted

Column Size = 330 × 500

load, P = 1563 KN

Factored Load, $P_u = 1.5\times1563 = 2344.5$KN

Moment due to wind load, M = 61.5 KN-m

Factored Moment, $M_u = 1.5\times61.5 = 92.25$KN-m

$\frac{Pu}{f_{ck}bD} = \frac{2344.5\times10^3}{20\times330\times500} = 0.71$

$\frac{Mu}{f_{ck}bD^2} = \frac{92.25\times10^6}{20\times330\times500^2} = 0.055$

For $f_y = 415$ and $\frac{d'}{D} = \frac{50}{500} = 0.1$

From chart 33 of SP16, we have

$\frac{P}{f_{ck}} = 0.12$

P = 0.12 × 20 = 2.4% < 4%

Hence ok.

6) Calculation of area of steel

$92.25\times10^6 = 0.87\times415\times A_{st}\times410\times[1 - A_{st}\times415/(230\times450\times20)]$

$= 148030.5\times A_{st}\times[1-0.000200\times A_{st}]$

$29.6061\times A_{st}^2 - 148030.5\times A_{st} + 92.25\times10^6 = 0$

$(A_{st})_{pro} = 729.66$ mm^2

There was 6 number of bars with 12mm dia for old column, therefore

$A_{st1} = 6\times(\Pi/4)\times12^2$

$A_{st1} = 678.58$mm^2

Also, there was another 6 number of bars with 12mm dia for new column, therefore $A_{st2} = 6\times(\Pi/4)\times12^2 = 678.58$mm^2

Therefore, $A'_{st} = 678.58 + 678.58 = 1357.168$mm^2> 729.66mm^2.

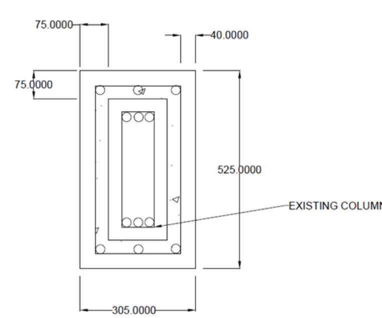

Fig. 4. Layout of Retrofitted Column

4. Typical Structural Restoration

It is a general practice to have structural retrofitting to primarily restore or enhance either concrete or steel in the structure. Seismic retrofit is defined as the design of measures to improve the seismic performance of structural or non-structural components of a building by correcting deficiencies identified in a seismic evaluation. There are primarily the following methods used for this purpose.

1) Concrete

- Jacketing of beams, columns and increasing slab thickness.
- Restoration of cover and loose concrete.
- Steel plates to enhance the strength of the structure.

2) Footings

- Extension of footings.
- Steel
- Replacement of steel
- Fiber wrapping

3) Suggested Retrofitting Techniques

There are many seismic retrofit techniques available, depending upon the various types and conditions of structures. Therefore, the selection of the type of intervention is a complex process, and is governed by technical as well as financial and sociological considerations.

Retrofitting techniques are classified into:

4) Global techniques

- Local modification of components
- Lessening of existing irregularities
- Global structural stiffening
- Base isolation
- Energy dissipation

5) Local techniques

- Jacketing of existing beams, columns or joints
- Use of fiber reinforced cement
- Use of metal shear panels
- Use of steel fiber reinforced motor
- Steel bracing
- Use of fiber reinforced cement

6) Jacketing of existing Beams, Columns or Joints

It is the one of the most frequently used methods for strengthening of the reinforced concrete columns and beams. Jacketing existing beams, columns, or joints with new reinforced concrete, steel, can be carried out here.

Three different Jacketing methods we can apply

1. Concrete Jacketing
2. Steel Jacketing
3. FRP Jacketing

Fig. 5. Concrete jacketing

Fig. 6. Steel Jacketing

Fig. 7. FRP Jacketing

5. Conclusions

- A Five story apartment building is chosen for analysis and design of various structure elements. Then after carrying out the analysis when the structure is subjected to both gravity and wind loads separately after applying the bending moment and shear force in different elements of both cases.
- If the values of any element wind load are greater than those of gravity load then the element is to be retrofitted.
- It was observed that normally column will be subjected to more moments due to wind compared to gravity loads because shear will not be considered in gravity loads.
- And the column was retrofitted and the reinforcement details were also drawn
- The columns may fail against lateral wind forces which were designed only for gravity loads. The retrofitting technique for strengthening which is also presented in this presentation.

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