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# Structural response of High rise Building with open ground storey

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**Abstract**— The typical multistorey with open ground storey configuration is arising rapidly in India. The unreinforced masonry wall may not contribute towards resisting gravity loads but it contributes under lateral loading. Masonry infills, which generally have high stiffness and strength, play a crucial role in lateral load response of reinforced concrete (RC) frame buildings. However in practice the infill stiffness is commonly ignored in frame analysis, resulting proper estimation of stiffness is not done. Hence, Indian code IS1893 (Part1):2002 gives provisions for soft storey analysis and design. It is instructive to study in detail the provisions of soft storey analysis and design with regard to assess a better approach for the soft storey effect under seismic loading and also in various seismic zones. Therefore, a comparative study is carried out considering different analytical models for soft storey behavior, and also the detailed study of provisions of soft storey as specified in IS1893(Part-I):2002 is carried out. Unreinforced masonry infill is modeled by using Equivalent Diagonal Strut method approach.

**Index Terms**— soft storey, infill, Equivalent diagonal strut method, modification factor, Ratio (R1), Ratio(R2), Storey Displacement

## 1 Introduction

THE soft storey configuration is arising rapidly in mega cities of India. It is because of functional and architectural purposes such as parking. This is due to land limitations and also many reasons for it. Soft storey failure is considered one of the most drastic failure.It is as illustrated in 26th Jan 2001, Bhuj earthquake in India, The Bingol, Turkey Earthquake of the 1 of May 2003. This paper attempts at studying the various parameters or solutions of soft storey effect. Seismic performance was compared in between the four cases using seismic coefficient method. Etabs 9.7 software is used for it.

Masonry Infill plays a vital role in resisting lateral loads. It enhances the performance of building during earthquakes. Its neglegance is commonly observed in current design practice. The four ananlytical models bare frame, infilled frame, center bay infilled frame at ground storey, open ground storey are considered for parametric behavior using both methods seismic coefficient method and response spectrum method. The stiffness effect of masonry infill is considered using one equivalent diagonal strut method approach. Demir's and sivri's formula is used for it. As per IS 1893(Part-I: 2002), the columns and beams of the soft storey are to be designed 2.5 times the storey shears and moments calculated under seismic loads. This is the one of the most important recommendation to reduce soft storey effect. So the modification factor for soft storey columns is checked for both infilled frame and open ground storey frame using seismic coefficient method.

The aim of present work is to know the proper range of modification factor for soft storey columns in Zone V.

## 2. Structural Model

RCC type of building is selected; plan considered for the study is simple. G+13 storied building is taken; ground floor height is of 4m. The material properties considered and their values are Unit weight of the concrete 25 $KN/m^3$, Unit weight of masonry 20 $KN/m^3$, Elastic modulus of steel, $2x10^8$ $KN/m^2$, Elastic modulus of concrete, 25000 $KN/m^2$, Elastic modulus of masonry 1255 KN /$m^2$, Poisson's ratio of concrete 0.2, Poisson's ratio of masonry 0.15, Characteristic strength of concrete 20 $N/mm^2$, Yield strength of steel 500 $N/mm^2$.
Analytical model:
1. Number of bays in X direction: 5
2. Number of bays in Y direction: 3
3. Spacing: 4m
4. Number of Storied: 14
5. Bottom storey Height: 4m
6. Storey Height (Except bottom storey): 3.2m
7. Seismic Zone is Zone V
8. Building is resting on Hard Soil.
9. Response Reduction Factor: 5
10. Special Moment Resisting Frame
11. Importance Factor: 1.
12. Column size is 350*800mm
13. Beam Size is 300*500mm


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## 3. Modeling of infill

Modeling of infill is very important part in the analysis of soft storey. The contribution of masonry infill increases the stiffness of the frame and decreases the natural period of the structure, resulting in the increased seismic forces than the bare frame (stiffness contribution of infill neglected). It is recommended to isolate masonry infill from the RC frames so that they can be treated as non-structural components. Along the equivalent diagonal strut has pinned ends.

As per Demir and Sivri's formula

$W_{ef} = 0.175\ (\lambda_h H)^{-0.4}\ \sqrt{H^2+L^2}$

$\lambda_h = \sqrt[4]{(Ei\ t\ sin\ 2\theta)/(4Ef\ Ic\ Hi\ )}$

Where,

*H, L* = Height and Length of the Frame

*Hi* = Clear Height of infill panel in m.

*Ef* = Modulus of elasticity of frame material, $Kn/m^2$

*Ei* = Modulus of elasticity of infill material,$Kn/m^2$

*Ic* = Moment of inertia of column, in $m^4$.

$\theta$ = Angle of Diagonal strut

*t* = Thickness of infill panel

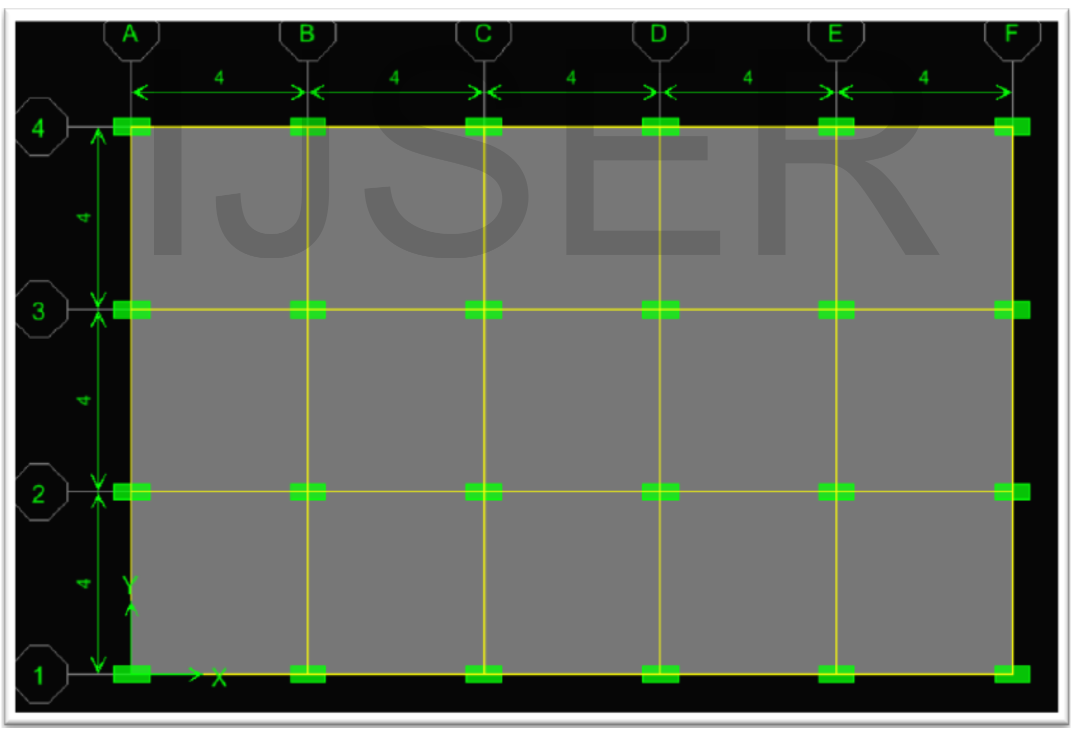
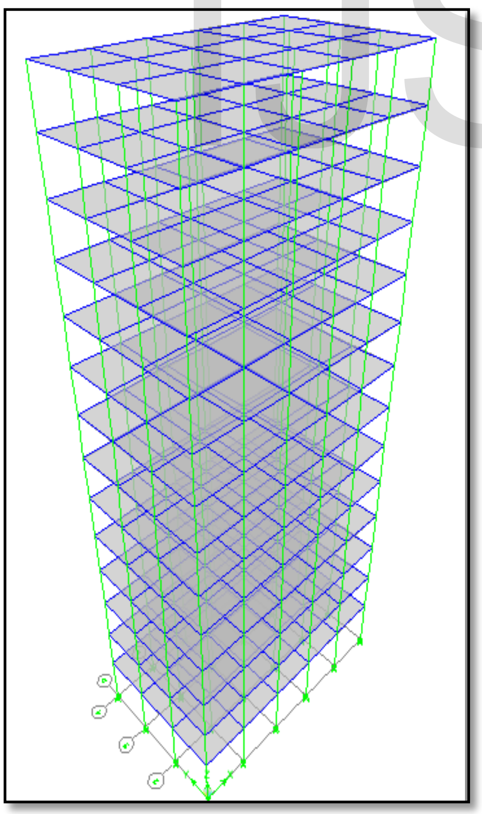


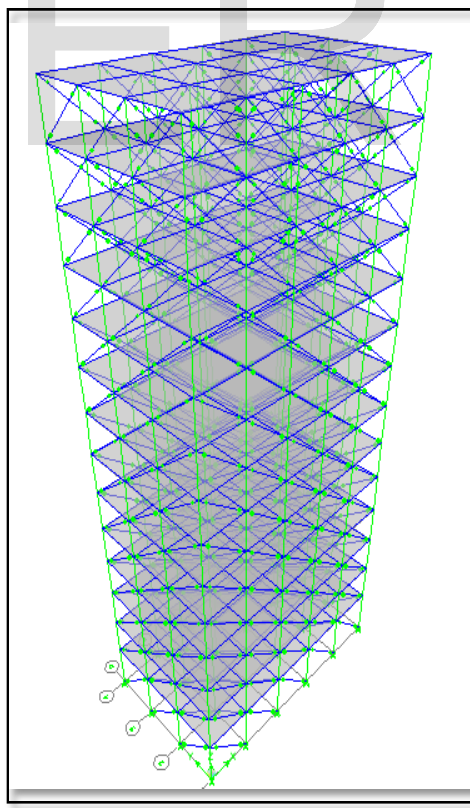

**Figure : Plan of P+13 RCCBuilding**


Figure : Plan of P+13 RCC Building showing columns and beams

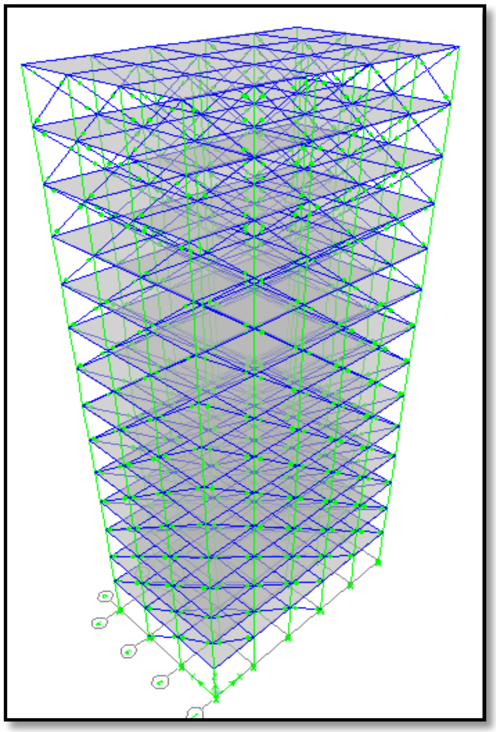




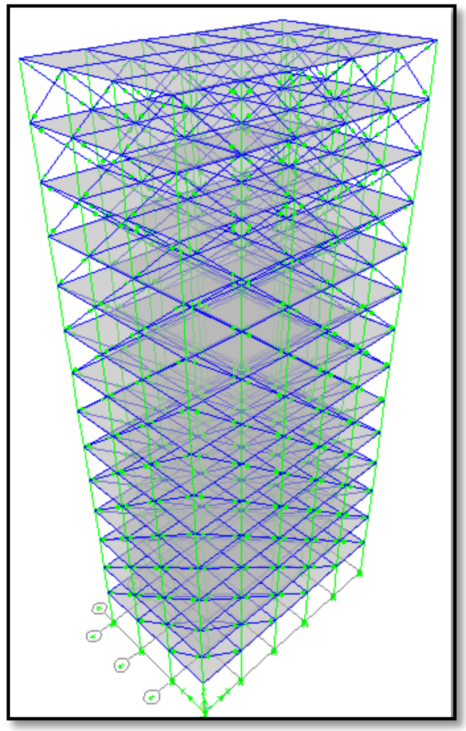
Model no.1: Bare Frame



Model no.2:Infilled Frame



Model no.3: Center Bay Infilled Frame



Model no.4: Open Ground Storey



## Methology:

Soft storey failure is mainely occurred because of absence of infill stiffness and strength. This infill effect is generally neglected in common design practice. As a result, soft storey leads to excessive deformations and there it actually cut from its base during earthquake excitations. Besides of going all these details of soft storey failure, IS 1893(Part- I: 2002) suggested that soft storey columns to be designed as an 2.5 times. To study this modification factor range to each column of soft storey ratio (R1) and ratio (R2) is considered.

To check out the proper range of modification factor for soft storey columns, the two different ratios are compared. Description of Ratio (R1) and Ratio (R2) are as follows:

Ratio (R1): It is the ratio of maximum shear force of the columns for the case of Infilled frame considered to that of bare frame.

Ratio (R1): It is the ratio of maximum bending moment of the columns for the case of Infilled frame considered to that of bare frame

Ratio (R2): It is the ratio of maximum shear force of the columns for the case of open ground storey frame considered to that of bare frame.

Ratio (R2): It is the ratio of maximum bending moment of the columns for the case of open ground storey frame considered to that of bare frame.

Building (G+13) is analyzed using seismic coefficient method where period is calculated on the basis of empirical formulae.

**Table 1.1 :Comparison of Shear Force in Columns of Soft Storey**

| Column index | Shear force in KN(S.C.M.) | | | | R1 | R2 |
|---|---|---|---|---|---|---|
| | M-I | M-II | M-III | M-IV | | |
| C1 | 56.912 | 60.925 | 66.147 | 67.101 | 1.07 | 1.179 |
| C2 | 60.122 | 115.15 | 140.119 | 144.17 | 1.915 | 2.397 |
| C3 | 60.122 | 116.83 | 140.534 | 143.802 | 1.943 | 2.391 |
| C4 | 56.912 | 116.696 | 67.202 | 67.756 | 2.05 | 1.19 |
| C5 | 96.393 | 102.707 | 112.991 | 114.657 | 1.06 | 1.189 |
| C6 | 97.988 | 129.994 | 114.973 | 116.566 | 1.326 | 1.189 |
| C7 | 97.998 | 131.929 | 115.645 | 117.002 | 1.3463 | 1.193 |
| C8 | 96.393 | 105.886 | 115.021 | 115.902 | 1.098 | 1.202 |
| C9 | 96.185 | 102.803 | 113.218 | 115.073 | 1.068 | 1.196 |
| C10 | 97.411 | 105.108 | 115.51 | 116.789 | 1.079 | 1.199 |
| C11 | 97.411 | 131.589 | 115.853 | 117.21 | 1.35 | 1.2032 |
| C12 | 96.185 | 106.082 | 115.324 | 116.40 | 1.1028 | 1.2101 |
| C13 | 96.185 | 101.841 | 112.00 | 114.090 | 1.058 | 1.186 |
| C14 | 97.411 | 103.991 | 114.041 | 115.627 | 1.0675 | 1.187 |
| C15 | 97.411 | 105.079 | 114.689 | 116.064 | 1.0787 | 1.191 |
| C16 | 96.185 | 105.82 | 114.049 | 115.392 | 1.1 | 1.199 |
| C17 | 96.393 | 97.747 | 108.423 | 110.328 | 1.01 | 1.144 |
| C18 | 96.393 | 99.167 | 109.404 | 110.328 | 1.028 | 1.144 |
| C19 | 97.998 | 100.218 | 110.67 | 111.434 | 1.022 | 1.137 |
| C20 | 96.393 | 100.881 | 110.388 | 111.48 | 1.0465 | 1.156 |
| C21 | 56.912 | 47.583 | 58.513 | 60.216 | 0.836 | 1.05 |
| C22 | 60.122 | 85.565 | 137.916 | 145.652 | 1.42 | 2.42 |
| C23 | 60.122 | 87.278 | 138.33 | 145.284 | 1.45 | 2.42 |
| C24 | 56.912 | 87.158 | 59.552 | 60.863 | 1.53 | 1.069 |

**Table1.2: Comparison of Bending Moment in Columns of Soft Storey**

| Column index | Bending moment in KNm (S.C.M.) | | | | R1 | R2 |
|---|---|---|---|---|---|---|
| | M-I | M-II | M-III | M-IV | | |
| C1 | 227.473 | 284.273 | 280.552 | 280.512 | 1.2496 | 1.233 |
| C2 | 207.441 | 541.767 | 602.665 | 613.398 | 2.61 | 2.956 |
| C3 | 207.441 | 547.587 | 605.786 | 614.073 | 2.639 | 2.96 |
| C4 | 227.473 | 530.698 | 278.739 | 279.303 | 2.33 | 1.227 |
| C5 | 242.852 | 290.326 | 287.455 | 287.765 | 1.1968 | 1.1849 |
| C6 | 237.286 | 523.375 | 266.538 | 266.193 | 2.205 | 1.1218 |
| C7 | 237.283 | 529.275 | 267.283 | 267.354 | 2.23 | 1.1267 |
| C8 | 242.852 | 284.133 | 287.113 | 287.71 | 1.1699 | 1.1847 |
| C9 | 250.719 | 299.438 | 295.62 | 296.962 | 1.1943 | 1.184 |
| C10 | 246.95 | 281.279 | 276.832 | 278.029 | 1.139 | 1.126 |
| C11 | 246.95 | 526.417 | 277.99 | 277.077 | 2.131 | 1.1219 |
| C12 | 250.719 | 293.176 | 295.813 | 297.842 | 1.169 | 1.187 |
| C13 | 250.719 | 299.992 | 297.10 | 297.462 | 1.1965 | 1.186 |
| C14 | 246.95 | 281.613 | 277.167 | 277.077 | 1.14 | 1.1219 |
| C15 | 246.95 | 526.417 | 278.317 | 278.331 | 2.13 | 1.127 |
| C16 | 250.719 | 294.202 | 297.269 | 297.842 | 1.1734 | 1.1879 |
| C17 | 242.852 | 292.248 | 289.265 | 289.518 | 1.20339 | 1.1921 |
| C18 | 237.283 | 272.167 | 267.791 | 267.443 | 1.147 | 1.1271 |
| C19 | 237.283 | 427.678 | 268.495 | 268.568 | 1.8023 | 1.1318 |
| C20 | 242.852 | 285.836 | 288.835 | 289.379 | 1.1769 | 1.1915 |
| C21 | 227.473 | 286.337 | 282.694 | 282.751 | 1.2587 | 1.243 |

**Table 1.2(Cont.) : Comparison of Bending Moment in Columns of Soft Storey**

| Column index | Bending moment in KNm (S.C.M.) | | | | R1 | R2 |
|---|---|---|---|---|---|---|
| | M-I | M-II | M-III | M-IV | | |
| C22 | 207.441 | 447.151 | 579.194 | 599.313 | 2.155 | 2.889 |
| C23 | 207.441 | 452.937 | 582.285 | 599.958 | 2.1834 | 2.8921 |
| C24 | 227.473 | 435.324 | 280.655 | 281.329 | 1.9137 | 1.2367 |

**Table 1.3: Period comparison between four models**

| Period in Seconds (X Direction) | | Period in Seconds (Y Direction) | |
|---|---|---|---|
| Model no.1 | 1.32 | Model no.1 | 1.32 |
| Model no.2 | 0.92 | Model no.2 | 1.18 |
| Model no.3 | 0.92 | Model no.3 | 1.18 |
| Model no.4 | 0.92 | Model no.4 | 1.18 |

**Table 1.4: Base shear Comparison Between Four Models**

| Base Shear in KN (X Direction) | | Base shear in KN (Y Direction) | |
|---|---|---|---|
| Model no.1 | 1501.57 | Model no.1 | 1501.7 |
| Model no.2 | 2451.61 | Model no.2 | 1898.7 |
| Model no.3 | 2440.39 | Model no.3 | 1890.18 |
| Model no.4 | 2439.07 | Model no.4 | 1889.16 |



## Results and Discussions:

The Ratio of maximum bending moments and Shear force of the columns for the case of open ground storey, considered to that of bare frame model for Zone V is 2.96 and 2.4 simultaneously. The Ratio of maximum bending moments and Shear force of the columns for the case of Infilled frame, considered to that of bare frame model for Zone V is 2.64 and 2.05 simultaneously. These ratios are varying column to column of soft storey. As the modification factor 2.5 but 2.96 value is obtained for soft storey column C2 and C3. I t can also be observed that external frame center column is mostly effected.

**Conclusions:** IS code method gives insuficient guildlines about infill effect .

(1) It is recommended that for Seismic Zone V (Very Severe), —The modification factor for Shear force and bending moment of soft storey column shall be 2.96.

(2)This 2.5 modification factor is approximate, as it is not distributed in proper manner to the soft storey columns. Hence, dynamic analysis and design approach is economical, easily applicable, and a most convenient approach.

(3) As it is observed that Soft storey failure is mostly occurred in external frame center column and end columns.

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