DESIGNING OF SOFT STOREY FOR RC STRUCTURE USING IS-1893(PART I)-2016, AND IS-13920-2016

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Abstract- *With urbanization and increasing unbalance of required space to availability, it is becoming imperative to provide open ground storey in commercial and residential building. These provisions reduce the stiffness of the lateral load resisting system and a progressive collapse becomes unavoidable in a severe earthquake for such buildings due to soft storey. Soft storey behavior exhibits higher stresses at the columns and the columns fail as the plastic hinges are not formed on predermined positions. Thus the vulnerability of soft storey effect has caused structural engineers to rethink the design of a soft storey building. In the current study the focus is on the design of soft storey for RC structure according to updations given in IS 1893(part I)-2016 and some clauses of IS 13920-2016 using different models*

Keywords:- *Soft storey, open storey, shear wall, braces(infill),Dynamic analysis, seismic loads*

I. INTRODUCTION

Reinforced-concrete framed structure in recent times has a special feature i.e the ground story is left open for the purpose of social and functional needs like vehicle parking, shops, reception lobbies, a large space for meeting rooms or a banking hall etc. such buildings are often called open ground storey buildings or soft storey buildings. Experience of different nations with the poor and devastating performance of such buildings during earthquakes always seriously discouraged construction of such a building with a soft ground floor. This storey known as weak storey because this storey stiffness is lower compare to above storey. So that easily collapses by earthquake.

II. BEHAVIOUR OF SOFT STOREY

Large open areas with less or no infill and exterior walls in ground floor compared to upper floors are the cause of damages. Due to the presence of infill walls in the entire upper storey except for the ground storey makes the upper storey much stiffer than the open ground storey. Thus, the upper storey move almost together as a single block and most of the horizontal displacement of the building occurs in the soft ground storey itself. In other words, this type of buildings sway back and forth like inverted pendulum during earthquake shaking, and hence the ground storey columns and beams are heavily stressed. Therefore it is required that the ground storey columns must have sufficient strength and adequate ductility.

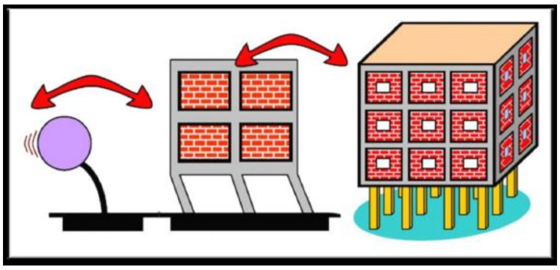

Figure 1 Building with soft storey behaving as inverted pendulum

III. Revisions in IS 1893(Part I)-2016, for design of soft storey

Clause 7.10.1-Open ground storey buildings shall be provided with

1-RC Structural walls, or

2-Braced Frames, in selected bays of the building .

Clause 7.10.2-When RC Structural walls are provided,they shall be

1-founded on properly designed foundations;

2-continuous preferably over the full height of the building; and

3-connected preferably to the moment resisting frame of the building.

Clause 7.10.3-When the RC structural walls are provided, they shall be designed such that the building does **NOT** have;

a)Additional torsional irregularity in plan than that already present in the building. In assessing this, lateral stiffness shall be included of all elements that resist lateral actions at all levels of the buildings;

b)Lateral stiffness in open storey is less than 80% of that in the storey above;

c)Lateral strength in the open storey is less than 90% of that in the storey above.

Clause 7.10.4-When the RC structural walls are provided, the RC structural wall plan density ρ_{sw} of the building shall be at least 2% along each principal directions in seismic zones III,IV, and V. These walls shall be well distributed in the plan of the building, along each plan direction.

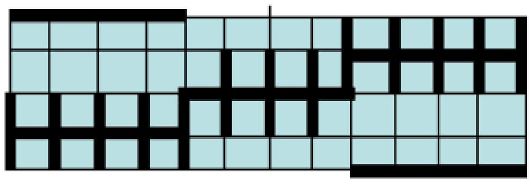

Figure 2 Symmetrical placing of 2% shear wall in a building

For ex- If total plan area of a building is 60*20=1200m^2, than the total RC wall area to be provided in each direction of the building should be 2% of 1200m^2 i.e 24m^2. And this RC wall should be symmetrically placed in all directions to avoid torsional effect.

IV. OBJECTIVES

The salient objectives of the present study have been identified as follows:

1) To perform analysis and design of multi storey buildings for soft storey effect using response spectrum analysis method.

2) To compare the behavior of multi storey buildings having soft storey designed with and without shear wall and struts.

3) To compare the behavior of multi storey buildings having minimum size of structural elements and there quantities area of steel.

4) To know which type of system is more effective in resisting lateral forces and economical.

5) The contribution of infill wall to the stiffness is considered.

V. LITERATURE REVIEW

Technical articles published in the proceedings and other journals have been referred to determine the scope of work and to understand the present status of such project undertaken. The following papers reveals the work done on the topic related to this project work until now.

1. **Devendra Dohare and Dr. Savita Maru, "Seismic Behavior of Soft Storey Building:A Critical Review"-** In this paper an investigation has been made to study the seismic behavior of soft storey building with different arrangement in soft storey building when subjected to static and dynamic earthquake loading. It is observed that , providing infill improves resistant behavior of the structure when compared to soft storey provided. It has been found earthquake forces by treating them as ordinary frames results in an underestimation of base shear. Investigators analysis numerically and use various computer programs such as Staad Pro, ETABS, SAP2000 etc. Calculation shows that, when RC framed buildings having brick masonry infill on upper floor with soft ground floors subjected to earthquake loading, base shear can be more than twice to that predicted by equivalent earthquake force method with or without infill or even by response spectrum method when no infill in the analysis model.

2. **Hiral .D. Adhiya and Dr. P. S. Pajgade "Review on Effective utilization of RCC Shear walls for Design of Soft Storey Buildings"-**This study investigates the analytical results and designing provisions for soft storey buildings with and without shear walls. They concluded that it is very necessary to locate the effective position of shear wall otherwise it will create overturning and twisting effect on the structure. They has studied the behavior of multi storey building for soft storey effect, shear wall and struts using equivalent static analysis method using ETAAB2015. In the thesis, the multi storey buildings of G+9 Storey are modeled in five different configurations and are compared in EQX and EQY respectively considering parameters such as storey drift, displacement, column bending moment, column shear force, column area of steel, beam bending moment, beam shear force, beam area of steel, shear wall bending moment, shear wall shear force, shear wall area of steel. They have concluded that storey displacement and storey drif parameters are considerably reduced with the help of shear wall effect and struts.

3. **Vipin V.Halde and Aditi H. Deshmukh, "Review on Behavior Of Soft Storey In Building"-**In this study the focus is on the investigation of the effect of the soft storey on the behavior of the structure. This is a therotical study of behavior of soft storey under earthquake,causes of failures in soft storey and effect of irregularirties on soft storey. They concluded that deflection of floor has increased when soft storey is considered. Hence it is suggested that expert designs and detailing are needed in soft storey building.

4. **Dr. Saraswati Setia and Vineet Sharma, 'Seismic Response of R.C.C Building with Soft Storey'-** They investigated the influence of some parameters on behavior of a building with soft storey. The modeling of the whole building is carried out using the computer program STAAD.Pro 2006. Parametric studies on displacement, inter storey drift and storey shear have been carried out using equivalent static analysis to investigate the influence of these parameter on the behavior of buildings with soft storey. The selected building analyzed through five numerical models. Concluded minimum displacement for corner column is observed in the building in which a shear wall is introduced in X-direction as well as in Z-direction.

5. **S.Arunkumar and Dr. G. Nandini Devi, 'Seismic demand study of Soft-Storey building and its strengthening for Seismic Resistance' -** The study includes the analysis of soft storey building with ETABS software by pushover analysis method and the results and conclusion of the analysis is to be included. A 10 storey building with and without shear wall in soft storey has been analysed and different parameters such as base shear, storey force, storey drift, displacements are compared. Various conclusions of the study are as follows:

   1) Building with shear wall in soft storey exhibits 30% – 40% higher base shear than the other one.

   2) The inter-storey drift of building with shear wall is minimum i.e. 0.0019 as compared to 0.0057 of the other one. IS code value for inter-storey drift for the corresponding building is 0.004.

   3) Building with shear wall attracts more storey force and moments about 5% - 10% then without shear wall.

6. **Prof. Patil S.S. and Mr. Sagare S. D.,' Dynamic Analysis of Soft Storey-High Rise Building with Shear Wall'-** They studied a building with open ground storey to bring out the importance of explicitly recognizing the presence of soft ground storey in the analysis. Usually the most economical way to eliminate the failure of soft storey by adding shear walls. The shear walls are one of the most efficient lateral force resisting elements in high rise buildings. This paper deals with occurring of soft storey at lower level at high rise building subjected to earthquake has been studied. Also has been tried to investigate on adding of shear wall to structures in order to reduce soft storey effect on seismic response of building.

7. **Piyush Tiwari, P.J.Salunke and N.G.Gore, 'Earthquake Resistant Design of Open Ground Storey Building' –** In this paper, they have studied the applicability of the Multiplication Factor of 2.5 as given by IS Code 1893 Part-1(2002), for Low Rise and Medium Rise Open ground storey Building. A G+4, G+7 and G+10 RC framed Open ground storey building is considered in Seismic zone-V with Special Moment Resisting Frame (SMRF) is analyzed and Modeled in Etabs Software. They concluded that for different types of analysis such as equivalent static analysis, response spectrum analysis and pushover analysis, the value of multiplication factor is less by 40% - 45% than what is prescribed by IS Code of 2.5 Value for (G+4) building. Similarly for (G+7) its 36% - 40% and for (G+10) its 32% - 35% less value than which is given by IS Code of 2.5. 15

8. **P.B.Lamb, Dr R.S. Londhe, 'Seismic Behavior of Soft First Storey'–** They studied a building with the help of different mathematical models considering various methods for improving the seismic performance of the building with soft first storey. Analytical models represent all existing components that influence the mass, strength, stiffness and deformability of structure. The equivalent static and multimodal dynamic analysis is carried out on the entire mathematical 3D model using the software SAP2000 and the comparisons of these models are presented. Finally, the performance of all the building models is observed in high seismic zone V.

9. **Piyush Tiwari, P.J.Salunke and N.G.Gore, 'Earthquake Resistant Design of Open Ground Storey Building' –** In this paper, they have studied the applicability of the Multiplication Factor of 2.5 as given by IS Code 1893 Part-1(2002), for Low Rise and Medium Rise Open ground storey Building. A G+4, G+7 and G+10 RC framed Open ground storey building is considered in Seismic zone-V with Special Moment Resisting Frame (SMRF) is analyzed and Modeled in Etabs Software. They concluded that for different types of analysis such as equivalent static analysis, response spectrum analysis and pushover analysis, the value of multiplication factor is less by 40% - 45% than what is prescribed by IS Code of 2.5 Value for (G+4) building. Similarly for (G+7) its 36% - 40% and for (G+10) its 32% - 35% less value than which is given by IS Code of 2.5. 15

VI. MODELS, DESIGN AND ANALYSIS

Basic aim of the present work is to study behavior of multi storey building for soft storey effect, shear wall and struts using response spectrum analysis method. In this paper, the structural system of the public building consists of RC beams, columns, slabs, shear wall, struts etc having 5m grid spacing.

In the paper, the multi storey buildings of G+15 Storey is modeled in six different configurations.

Part A - 5m Grid Spacing Building.

Model 1 - Building with Bare Frame.

Model 2 - Building with infill wall considered as braces.

Model 3 - Building with struts and 0.48% shear wall upto 2^{nd} storey (soft storey.)

Model 4 - Building with struts and 0.36% shear wall upto full height of the building.

Model 5 - Building with struts and 2% shear wall upto 2^{nd} storey (soft storey.)

Model 6 - Building with struts and 2% shear wall upto full height of the building.

5mx5m grid spacing building is model in ETAAB with following data. Walls are considered at each bay both inner and outer side. For model 3,200mm x 3m shear wall is provided at each corner(i.e 0.48% of plan area). For model 4, 150mm x 3m shear wall is provided at each corner (i.e 0.36% of plan area). For model 5 & 6, 200mm x 25m shear wall is provided in each direction of the building (i.e 2% of plan area). Staircase is considered as isolated from the building

Table 1 - Design data for all models.

Grade of concrete = M30

Grade of steel = Fe500

Density of concrete = 25kN/m3

Density of brick = 9 kN /m3

Table 2 - Earthquake data

Seismic Zone = III (Z=.16)

Importance factor = 1.2

Response reduction factor = 5 (SMRF)

Type of soil = TYPE II (Medium)

Damping = 5%

Time Period (x-direction) = 0.9x H/ √D =0.837sec

Time Period (y-direction) = 0.9x H/ √D =0.935sec

Building Details:

The structural data

Table 3 - Structural data for buildings.

Dimension of 5m spacing = 25 X 20 m

No of storey = 15

Ground storey height = 3.00 m

Intermediate storey height = 3.00 m

Slab thickness = 150 mm

Shear wall thickness = 150mm

Wall thickness = 200mm

Wall Load = 0.2x9x3x1=5.4 KN/m^2

Live Load = 3 KN/m^2

Roof Live Load = 3 KN/m^2

Floor Finish = 1.875 KN/m^2

Column Sizes = 300 mm x 600 mm (storey 1to6)

= 300 mm x 450 mm (storey 7 to12)

= 300 mm x 300 mm (storey13 to16)

Beams Sizes = 300mm x 380mm (storey 1 to10)

= 300mm x 300mm (storey 11 to16)

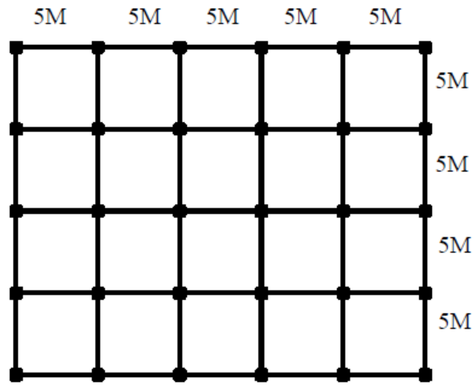

Figure3. Plan view of 5mx5m grid building

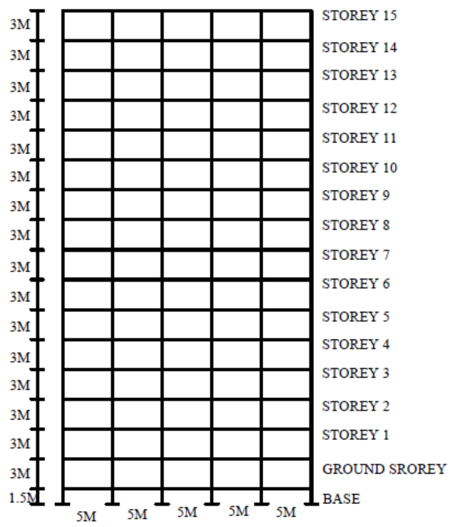

Figure 4 Elevation view of 5mx5m grid building

VII. RESULT AND DISCUSSION

The models are analysed by response spectrum analysis employing ETBAS using IS 1893:2016(part 1) code. The design is carried out for all buildings using IS 456:2000 and some clauses of IS 13920:2016 codes. The designed forces *i.e.* base shear, axial force, moments and shear forces are taken from the ETABS analysis results. The study is carried out on the variation of percentage of plan density of shear wall in the open storey. The maximum storey displacement, storey stiffness and area of reinforcement in columns are compared and their permissible values are discussed.

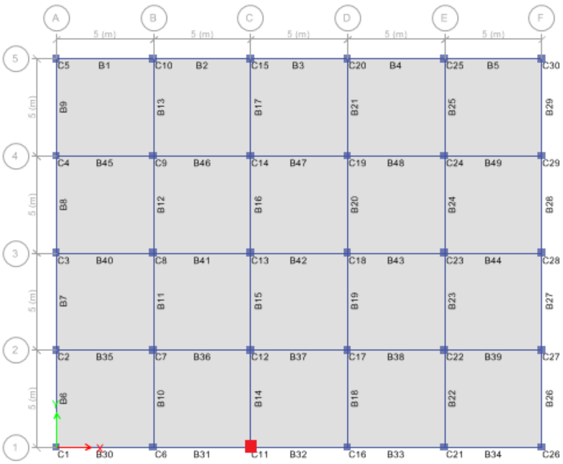

Figure 5 showing column no. 11

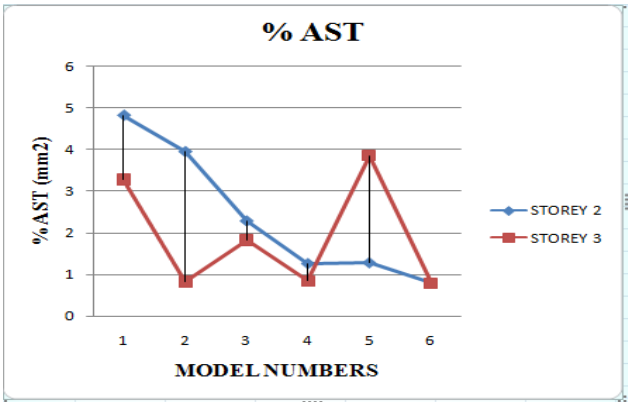

Figure 6 Comparison of %AST for storey 2 and 3 for all 6 models

Area of reinforcement for column no.11 of all 6 models is compared for storey 2 and storey 3.The graph shows that %AST of model 1 and 2 i.e with bar frame and with braces(infill wall) for storey 2 is greater than storey 3. %AST gets drastically decreases for model 3 and 4 where 0.48% shear wall upto 2nd storey and 0.36% shear wall upto full height of the building is provided.

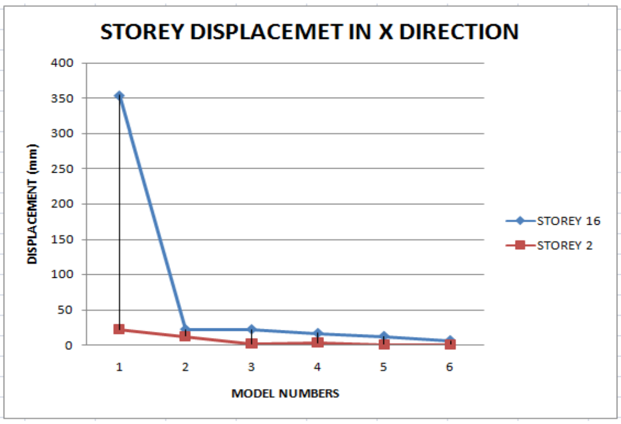

Figure 7 Comparison of maximum storey displacementin X direction for storey 2 and 16 for all 6 models

The maximum storey displacement in X direction for model 1, is invariably greater than other models as well as allowable storey displacement . In model 2, 53% of total storey displacement of storey 16 is observed at storey 2 only. In model 3, where 0.48% (200mm thick 3m at each corner) shear wall is provided upto 2nd storey, only 6% of total storey displacement of storey 16 is observed at 2nd storey. In model 4, where 0.36% (150mm thick 3m at each corner) shear wall is provided upto full height of building, 17% of total storey displacement of storey 16 is observed at 2nd storey. In model 5, where 2% (200mm thick 25m in each direction) shear wall is provided up to 2nd storey, only 3.2% of total storey displacement of storey 11 is observed at 2nd storey. In model 6, where 2% (200mm thick 25m in each direction) shear wall is provided up to full height of building, total storey displacement is very less as compared to other models but 6% of total storey displacement is observed at storey 2 only.

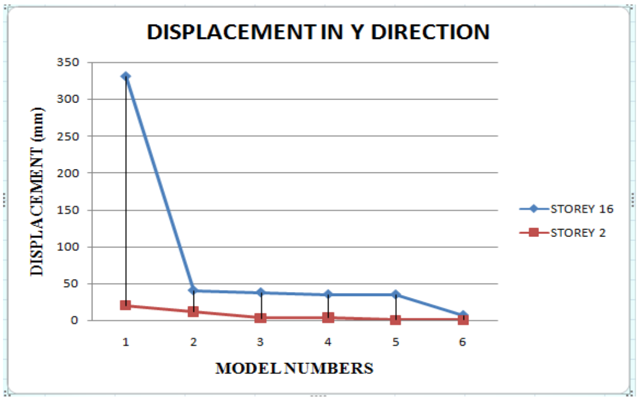

Figure 8 Comparison of maximum storey displacementin Y direction for storey 2 and 16 for all 6 models

The maximum storey displacement in Y direction for model 1, is invariably greater than other models as well as allowable storey displacement . In model 2, 28% of total storey displacement of storey 16 is observed at storey 2 only. In model 3, where 0.48% (200mm thick 3m at each corner) shear wall is provided up to 2nd storey, only 6.6% of total storey displacement of storey 16 is observed at 2nd storey. In model 4, where 0.36% (150mm thick 3m at each corner) shear wall is provided up to full height of building, 9.3% of total storey displacement of storey 16 is observed at 2nd storey. In model 5, where 2% (200mm thick 25m in each direction) shear wall is provided up to 2nd storey, only 1.14% of total storey displacement of storey 11 is observed at 2nd storey. In model 6, where 2% (200mm thick 25m in each direction) shear wall is provided up to full height of building, total storey displacement is very less as compared to other models but 5.8% of total storey displacement is observed at storey 2 only.

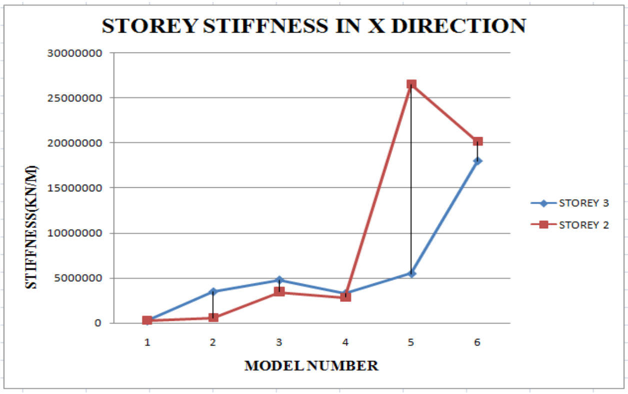

Figure 9 Comparison of maximum storey stiffness in X direction for storey 2 and 3 for all 6 models

The difference between storey stiffness in x direction for model 5 where 2 % i.e 200mm thick 25m in each direction, is very large. Sudden change is in stiffness for storey 2 and 3 is observed in model 5 which is not safe. In model 2,3 and 6 storey stiffness for storey 3 is greater than storey 2 and is in permissible limits. In model 4, wher 0.36% shear wall is provided upto full height of the building, the difference between storey stiffness for storey 2 and 3 is very less.

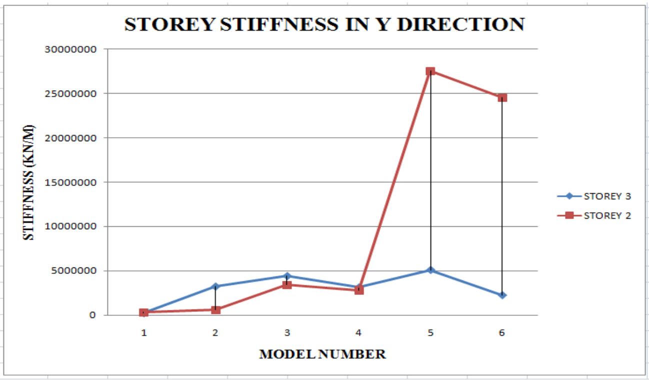

Figure 10.Comparison of maximum storey stiffness in Y direction for storey 2 and 3 for all 6 models

The difference between storey stiffness in y direction for model 5 and 6 where 2 % i.e 200mm thick 25m in each direction up to 2nd storey and up to full height of the building respectively, is very large. Sudden change is in stiffness for storey 2 and 3 is observed in model 5 which is not safe. In model 2 and 3 storey stiffness for storey 3 is greater than storey 2 and is in permissible limits. In model 4, where 0.36% shear wall is provided upto full height of the building, the difference between storey stiffness for storey 2 and 3 is very less.

VIII. CONCLUSSION

From the above discussed results following conclusions are drawn are as-

- As per IS 1893(part I)-2016, full height shear wall is preferred, but from above results it can be concluded that building with shear wall upto soft storey is also sufficient.
- Column sizes can be reduced for upper storeys above soft storey where shear wall is not provided.
- From the analysis it is clear that 2% plan density of shear wall (as per IS1893-2016 (PART 1)) is not necessary, by providing lesser percentage of plan density of shear wall the structure is safe.
- In bare frame model , deflection was not under permissible limits, but when effect of infill wall was considered as braces (masonary), deflection observed was under permissible limits.

IX. REFFERENCES

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