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Earthquake Resistant Analysis and Design of G+7 Soft Storey Building

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Abstract - *Open Ground Storey or soft Storey are the framed buildings where the ground Storey is kept open without infill walls, mainly to facilitate parking, which is increasing commonly worldwide. However, threat of this type of buildings has been exposed a lot in past earthquakes. OGS buildings are normally designed by a bare frame analysis that ignore the stiffness of the infill walls present in the upper storey, but doing so underestimates the inter-storey drift (ISD) and thereby the force demand in the ground storey columns located. This study focuses on the seismic performance of typical OGS or also called as soft storey buildings designed by means of MFs. As soft storey buildings are not safe, to ensure safety against seismic forces of multi-storied buildings, there is need to study the seismic analysis to design earthquake resistance structures. The main objective of this paper is to study the seismic analysis of medium rise structure for static and dynamic analysis in ordinary moment resisting frame (OMRF) and special moment resisting frame (SMRF). We considered a residential building of G+7 storey for the seismic analysis and is located in seismic zone III. The total structure was analyzed by computer with using STAAD.PRO V8i software. We observed the response reduction of ordinary moment resisting frame and special moment resisting frame values with deflection diagrams in seismic analysis. The special moment of resisting frame structure is good in resisting the seismic loads.*

***Key Words*: Soft Storey, Open Ground Storey, Multiplication Factor, Ordinary Moment resisting frame, Special moment resisting frame, Staad Pro V8i**

1.INTRODUCTION *(Size 11 , cambria font)*

Open ground storey structures are those buildings whose ground floor are left open without any partition walls mainly to provide parking facilities. One of the major reasons for choosing open ground structures are less availability of land in urban areas due to the recent increase in population and urbanization. Failures observed in past earthquakes show that the collapse of such buildings is predominantly due to the formation of soft-storey mechanism in the ground storey columns. In conventional design practice, the contribution of stiffness of infill wall presents in upper storey of OGS framed buildings are ignored in structural modeling. From the past earthquakes it was evident that the major type of failure that occurred in OGS buildings included snapping of lateral ties, crushing of core concrete, buckling of longitudinal reinforcement bars etc. 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 columns in 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. The vulnerability of this type of building is attributed to the sudden lowering of lateral stiffness and strength in ground storey, compared to upper storey with infill walls. A bare frame is much less stiff than a fully Infilled frame, it resists the applied lateral load through frame action and shows well-distributed plastic hinges at failure but when, frame is fully Infilled, truss action is introduced. A fully infilled frame shows less inter-storey drift, although it attracts higher base shear (due to increased stiffness). In the aftermath of the Bhuj earthquake, the IS 1893 code was revised in 2002, incorporating new design recommendations to address OGS buildings. Clause 7.10.3(a) states: "The columns and beams of the soft storey are to be designed for 2.5 times the storey shears and moments calculated under seismic loads of bare frames. This MF is supposed to be in compensation for the stiffness discontinuity. The conservative nature of this empirical recommendation of IS code was first pointed out by Kanitkar and Kanitkar (2001), Subramanian (2004) and Kaushik (2006). Hence the aim of this thesis is to check the applicability of the multiplication factor of 2.5 in the ground storey beams and column when the building is to be designed as open ground storey framed building and to study the effect of infill strength and stiffness in the seismic analysis of low and medium rise open ground storey building.

Fig-1: Soft storey

1.1 OBJECTIVES OF THE WORK

The particular objectives of the study are:

1) To Study the application of Multiplication Factor, 2.5 as given by IS Code 1893 Part-1(2002), for low and also Medium Rise Open ground storey Building.
2) To study the effect of infill strength and stiffness in the seismic analysis of Open ground storey building.
3) To perform a comparative study on the results obtained from the analysis carried out.
4) Minimize the hazard to life for all the structures.
5) Increase the expected performance of structures having a substantial public hazard due to occupancy or use.
6) Improve the capability of essential facilities to function after an earthquake.
7) Staad pro analysis and design of the earthquake resistance structure.

1.2 SCOPE OF THE WORK

In general, most earthquake code provisions implicitly require that structures be able to resist

1) Minor earthquakes without any damage.
2) Moderate earthquakes with negligible structural damage and some nonstructural damage.
3) Major earthquakes with some structural and nonstructural damage but without collapse. The structure is expected to undergo fairly large deformations by yielding in some structural members.

2. MODELLING AND ANALYSIS OF STRUCTURE

The building considered in the present report is G+7 Frame structure, Open ground story structure. Complete analysis is carried out for dead load, live load & seismic load using STAAD-Pro V8i. All combinations are Considered as per IS 1893:2002.
Typical plan of the building is shown in Fig-2

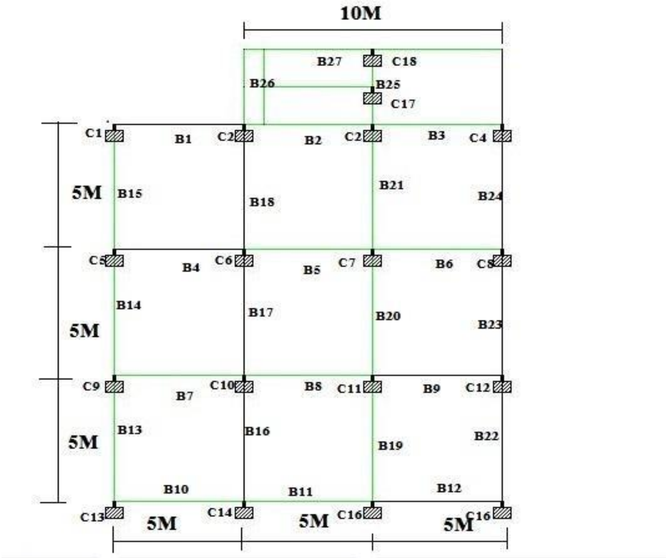

Fig-2: Building Plan

2.1 BUILDING PROPERTIES FOR ANALYSIS

2.1.1 Site Properties:

Details of building: G+7
Outer wall thickness: 150 mm
Inner wall thickness: 150 mm
Depth of foundation: 2500 mm
Bearing capacity of Soil: 200 kN/m^2

2.1.2 Seismic Properties:

Seismic zone: III
Zone factor: 0.16
Importance factor: 1.0
Response Reduction factor R: 5
Soil Type: Medium

2.1.3 Material Properties:

Material grades of M30 & Fe415 were used for the design.

2.1.4 Loading on structure:

Dead load: self-weight of structure is taken by staad itself
Weight of 230mm wall
Live load: Floor 4 kN/m^2
Roof Load: 1.5 kN/m^2
Floor Finish: 1.0 kN/m^2
Water proofing: 1.5 kn/m^2
Terrace finish: 1.0 kN/m^2
Wind load: Not considered

2.1.5 Preliminary Sizes of members:

Column: 230 X 1200 mm
Beam: 230mm X 700mm
Slab thickness: 125mm

2.2 LOAD COMBINATIONS

Load combinations are used as per generated in staad-pro.

2.3 MODELING

The isometric 3D view and plan of the building model is shown in figure. The support condition is considered as fixed

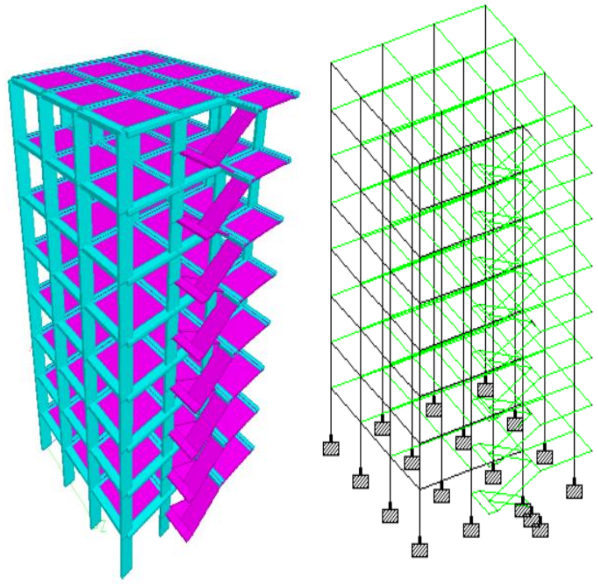

Fig-3: 3D Modelling in Staad-pro

2.4 SEISMIC DESIGN CONCEPT

An effective seismic design generally includes

1. Selecting an overall structural concept including layout of a lateral-force resisting system that is appropriate to the anticipated level of ground shaking. This includes providing a redundant and continuous load path to ensure that a building responds as a unit when subjected to ground motion.
2. Determining code-prescribed forces and deformations generated by the ground motion, and distributing the forces vertically to the lateral-force-resisting system. The structural system, configuration, and site characteristics are all considered when determining these forces.
3. Analysis of the building for the combined effects of gravity and seismic loads to verify that adequate vertical and lateral strength and stiffness are achieved to satisfy the structural performance and acceptable deformation levels prescribed in the governing building code.
4. Providing details to assure that the structure has sufficient inelastic deformability to undergo fairly large deformations when subjected to a major earthquake. Appropriately detailed members possess the necessary characteristics to dissipate energy by inelastic deformations.

2.4.1 SEISMIC WEIGHT CALCULATION

The seismic weights are calculated in a manner similar to gravity loads. The weight of columns and walls in any storey shall be equally distributed to the floors above and below the storey. Following reduced live loads are used for analysis: Zero on terrace, and 50% on other floors [IS: 1893 (Part 1): 2002, Clause 7.4)

STOREY 8

STOREY 7, 6,5,4,3,

STOREY 2

STOREY 1

STOREY 8

		DL + LL
From slab	15 x 15 (5.625+0)	1265.625 + 0
Parapet	4 x 15 (3.33 + 0)	199.8 + 0
Walls	0.5 x 4 x 15 x (11.5 + 0)	345 + 0
Secondary beams	18 x 5 x (3.25 + 0)	292.5+ 0
Main beams	8 x 15 x (4.025 + 0)	483 + 0
Columns	0.5 x 5 x 16 x (6.9 + 0)	276 + 0
Total		2861.925
		= 2862 kN

STOREY 7,6,5,4,3

		DL + LL
From slab	15 x 15 x(4.125 + 0.5 x 4)	928.125 + 450
Walls	4 x 15 x (11.5 + 0)	690 + 0
Secondary beams	18 x 5 x (3.25 + 0)	292.5 + 0
Main beams	8 x 15 x (4.025 + 0)	483 + 0
Columns	16 x 5 x (6.9 + 0)	552+0
Total		2945.625+450
		=3396kN

STOREY 2

		DL + LL
From slab	15 x 15 x (4.125 + 0.5 x 4)	928.125 + 450
Walls	0.5 x 4 x 15 x (11.5 + 0)	345 + 0
Walls	0.5 x 4 x 15 x (11.5 + 0))	345 + 0
Secondary beams	18 x 5 x (3.25 + 0)	292.5 + 0
Main beams	8 x 15 x (4.025 + 0)	483 + 0
Columns	16 x 0.5 x (3.45+ 3.55) x (6.9 + 0)	386.4 + 0
Total		2780 +450
		= 3230kN

STOREY 1 (PLINTH)

		DL + LL
Walls	0.5 x 4 x 15 (11.5+ 0)	345 + 0
Walls	0.5 x 4 x 15 x (11.5 + 0)	345 + 0
Main beams	8 x 15 x (4.025 + 0)	483+ 0
Column	16 x 0.5 x 3.55 x (6.9 + 0) 16 x 0.5 x 1.1 x (6.9 + 0)	196 +0 61+ 0
Total		1430 + 0
		= 1430 kN

Seismic weight of the entire building = 2862 + (5 x 3396) + 3230 + 1430

= 24502 KN.

The seismic weight of the floor is the lumped weight, which acts at the respective floor level at the center of mass of the floor.

Design Seismic Load

The infill walls in upper floors may contain large openings, although the solid walls are considered in load calculations.

Therefore, fundamental time period T is obtained by using the following formula:

Ta = 0.075 h 0.75 [IS 1893 (Part 1):2002, Clause 7.6.1]

= 0.075 x (27.7)0.75

= 0.9055 sec.

Zone factor, Z = 0.16 for Zone III, IS: 1893 (Part 1):2002, Table2

Table 3 Seismic Zone Factor *Z*

(*Clause* 6.4.2)

Seismic Zone Factor (1)	II (2)	III (3)	IV (4)	V (5)
Z	0.10	0.16	0.24	0.36

Importance factor, I = 1.5 (public building) Medium soil site and 5% damping Sa/g=1.36/0.97=1.402

IS: 1893 (Part 1): 2002, Figure

Ductile detailing is assumed for the structure. Hence, Response Reduction Factor, R, is taken equal to 5.0. It may be noted however, that ductile detailing is mandatory in Zones III, IV and V.

Hence,

VB = Ah W

= (ZI/ 2R) X {Sa/g} X W

= (0.16/2) X (1.5/5) X1.5

= 0.036

Base Shear, VB = Ah W

= 0.036 x 24502= 882 kN.

The total horizontal load of 882 kN is now distributed along the height of the building as per clause 7.7.1 of IS1893 (Part 1): 2002.

2.5 STAAD PRO DESIGN

Introduction to STAAD-Pro

Our paper involves analysis and design of multistoried (8-story) using a worldwide most common used designing software STAAD-Pro.

Advantages of STAAD-Pro:

- Confirmation with Indian Standard Codes,
- Versatile nature of solving any type of problem,
- Easy to use interface,
- Accuracy of the solution.

STAAD-Pro SEISMIC ANALYSIS

Ta = 0.90312 sec.,

Sa/g = 1.506.

Load Factor =1,

Ah =0.0241,

Total Weight=16436.42kN,

VB= 396.03Kn

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*
* TIME PERIOD FOR Z 1893 LOADING =     0.90312 SEC
* SA/G PER 1893=     1.506, LOAD FACTOR= 1.000
* VB PER 1893=     0.0241 X     16436.42=     396.03 KN
*
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3. CONCLUSIONS

- The G+7 residential building has been analyzed and designed using Staad-pro.
- Seismic forces have been considered and the structure is designed as an earthquake resistant structure.
- To conclude, staad pro is versatile software having the ability to determine the reinforcement required for any concrete section based on its loading and determine the nodal deflection against lateral forces.
- It experience static as well a dynamic analysis of the structure and gives accurate results which are required. The following points have been obtained at the end of the design.

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