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Impact of revised Earthquake code on Analysis and Design of RC Building with Soft Storey

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Abstract: **-- This paper presents the effect of revisions in IS: 1893(Part 1) and IS 13920 in 2016 on the analysis and design of Reinforced Concrete (RC) Buildings. In India, it is a common practice to construct residential buildings with the soft storey in order to generate parking space, gardening space, and other utility spaces for various purposes. The revision of IS: 1893(Part1) and IS: 13920 in 2016 requires some changes in the analysis and design of such buildings. The effect of these revisions on the analysis and design of RC Buildings has been illustrated in the paper with the help of Police Housing Building in Maharashtra. Effect of RC Structural wall plan density (SPD), modeling of unreinforced masonry infill walls etc., have been studied in the paper**

.**Keywords: - RC Buildings, IS: 1893(Part1):2016, IS 13920: 2016, Structural Wall Plan Density, Unreinforced Masonary Infill Wall.**

I. INTRODUCTION

In India, it is a common practice to construct RC frame building with soft storey in order to generate parking space, gardening space, and other utilities spaces for various purposes. Such buildings have shown poor performances during past earthquakes like Bhuj 2001. After the Bhuj earthquake took place, the IS 1893 code was revised in 2002, incorporating new design recommendations to address open ground storey framed buildings. Even after the 2002 revision, structures continued to show poor performance. Thus IS 1893 code was again revised in the year 2016 with various changes in the prevailing clauses and additional clauses were also introduced in it. The paper presents the effect of the revised clauses and additional clauses of IS 1893 (Part1):2016 & IS 13920:2016 on the Analysis and Design of RC Building with Soft Storey. To understand the effect of amendments on the structure a G+7 residential apartment of Police Housing Scheme regular and symmetrical in plan with soft storey and an additional floor at top has been considered. The analysis is carried out using seismic code IS 1893 (Part 1): 2016 and IS 13920: 2016. The building has been analysed using STAAD PRO V8i software. The effect of design earthquake loads applied on structures is considered using Response spectrum method

II. SPECIFICATION OF BUILDING

A G+7 building regular and symmetrical in plan with soft storey and an additional floor at top is been considered. The building is located in Zone II. The building is assumed to be situated on hard soil strata Type-I, as per IS: 1893: (Part 1) 2016 and the RC frames are infilled with brick masonary.

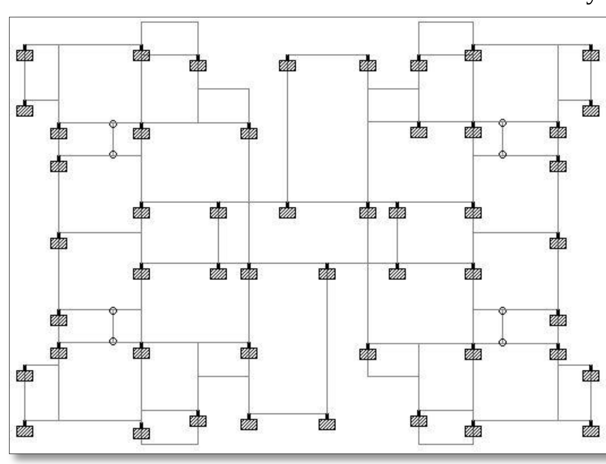

Fig. 1 Center line plan of building in STAAD-Pro

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III. LOADING ON STRUCTURE

(A) Dead Load

Self weight of the structural elements is automatically calculated by STAAD PRO V8i. The other dead loads considered in analysis are as mentioned in table 1.

Table 1 Dead loads [IS: 875: (Part 1) 1987]

Type of loading	H	T	L	Density	Loading
	m	m	m	kN/m^3	
Dead slab	-	0.15	1	25	$3.75\ kN/m^2$
Floor finish	-	-	-	-	$1\ kN/m^2$
Wall	2.55	0.15	1	20	$6\ kN/m$
Parapet wall	1	0.15	1	20	$3\ kN/m$
Sunk	1	0.30	1	20	$6\ kN/m^2$

(B) Imposed Load

Imposed live load as per IS: 875: (Part 2) 1987 has been considered as given in table 2.

Table 2 Imposed live load [IS: 875: (Part 2) 1987]

Sr. No	Occupancy	Imposed live load
1	All room & kitchen	$2\ kN/m^2$
2	Toilet & Bathroom	$2\ kN/m^2$
3	Corridor, Passage, Staircase	$3\ kN/m^2$
4	Balconies	$3\ kN/m^2$

(C)Earthquake Load

To evaluate the design base shear, it is of importance to know the seismic weight of building. For the purpose of estimating seismic weight of building full dead load plus a part of live load is considered as per IS: 1893 (Part 1):2016. While calculating design earthquake force live load on roof is not considered. Here, the seismic weight of structure is calculated using STAAD PRO V8i. Firstly all beam and column junctions are assigned pin supports and then the analysis is done for DL+0.25LL load combination case. The maximum reaction obtained at junction is then assigned to same junction in two lateral directions as shown in fig 2.

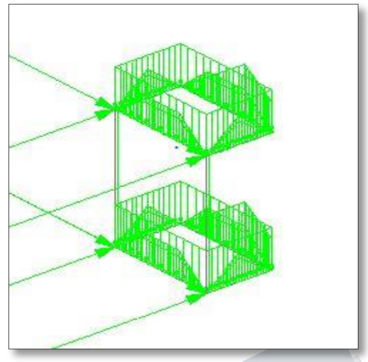

Fig.2 Assigned nodal forces for the load combination DL+0.25LL as Earthquake Load

(D) Factors considered for Seismic calculation

The following factors given in table 3 are used for the purpose of design base shear calculation.

Table 3 Factors considered for Design base shear calculation for Zone II

Factors	Symbol	IS: 1893: 2002	IS: 1893: 2016
Seismic Zone factor	Z	0.10	0.10
Importance factor	I	1	1.2
Response reduction factor	R	3	3

IV. LOAD COMBINATIONS

To take the uncertainties in loading over the life of structure we need to consider some load combinations which are specified in IS1893 while going for seismic analysis. The load combinations used in this structure is shown in table 4.

Table 4 Load combinations for seismic analysis as per [IS 1893 (Part 1): 2016]

Sr.No	Load Combination
1	1.5 DL + 1.5 LL
2	1.5 DL + 1.5 EQX/EQZ
3	1.5 DL - 1.5 EQX/EQZ
4	1.2 DL+1.2 LL + 1.2 EQX/EQZ
5	1.2 DL+1.2 LL - 1.2 EQX/EQZ
6	0.9 DL + 1.5 EQX/EQZ
7	0.9 DL - 1.5 EQX/EQZ

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V. MODELING OF STRUCTURE IN STAAD-PRO V8I

A. Modeling of beam, column and shear wall

The structure was modeled in STAAD PRO V8i .Beams & columns are modeled as frame elements, shear wall as plate element. The support condition given was fixed.

B. Modeling of URM infill

The Structural plan density (SPD) was calculated for the structure as per IS 1893 (Part 1): 2016. Since SPD was found to be less than 20% the effect of URM infill was not considered while modeling the structure. SPD calculations details are as given in table 5.

Table 5 SPD Calculation

Data for SPD calculation	
Length of URM infill in X-Direction	97.40 m
Length of URM infill in Z-direction	103.80 m
Thickness of URM infill	0.150 m
Area of URM infill	30.18 m^2
Plinth area	255 m^2
SPD	11.83%

VI. ANALYSIS AND RESULTS

The structure was analysed as ordinary moment resisting frame for Zone II and as special moment resisting frame for Zone III using STAAD PRO V8i. The height of building being more than 15m, as per IS1893 (Part 1): 2016 it is mandatory to analyse the structure by Dynamic analysis method, thus Response spectrum method was used.

When structure which was analysed for Zone II was later analysed for Zone III,the following changes as per revised earthquake codes were made.

i. Columns were resized in order to satisfy clause 7.1.1 of IS 13920:2016. The minimum dimension of column was increased from 300mm to 350mm.

ii. Ductile detailing was done as per IS 13920:2016

iii. At start the building was modeled as bare frame along with shear wall to lift duct only as shown in the fig 3.

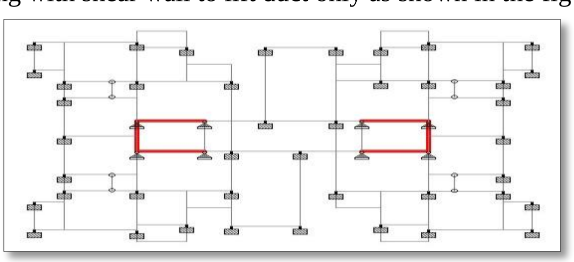

Fig.3 Plan view of building with shear wall to lift duct

iv. As per clause 7.10.4 of IS1893 (Part 1): 2016 in Zone III, IV, and V the RC structural wall plan density of the building shall be at least 2% along each principal direction, to satisfy this clause shear wall to lift duct, staircase room, edge of building, and L-shaped shear walls along the corners of building were placed as shown in the fig 4.

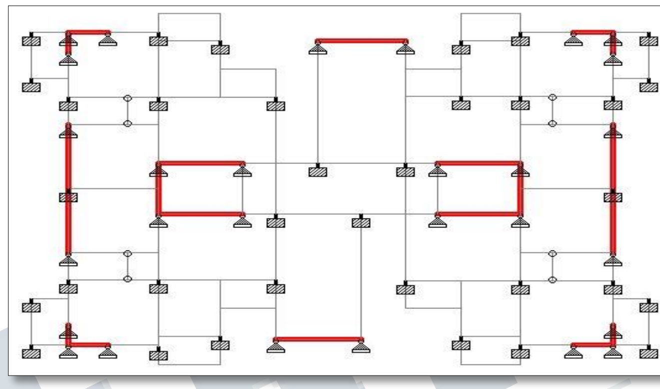

Fig.4 Plan view of building with satisfied RC Structural wall plan density

A. Base shear

The revised code has given separate expressions for calculating approximate fundamental translational natural period of building with and without RC structural wall. For the considered building it is seen that the time period is same (0.475s) for building with bare frame model and the model in which RC structural wall plan density was satisfied.

As per the Indian seismic code IS: 1893(Part 1), Design base shear is given by,

$$V_b = A_h W = \frac{ZI}{2R}\left(\frac{Sa}{g}\right)W$$

In the above expression the term remains unchanged for both the models. But in the view of satisfying 2% RC structural wall plan density in each translation direction, the weight of structure is increased due to increase in structural wall area. The base shear was increased as shown in table 6.

Table 6 Impact on Base shear

	IS 1893 (Part 1) 2002	IS 1893 (Part 1) 2016	% increase
Base shear (V_b)	1036.47kN	1124.47kN	8.49

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B. Storey Drift

Storey drift was checked for the complete structure which more or less followed the same at all floor levels. It was seen that storey drift increased for columns other than central columns for the considered building. Data for floor level is as given below in table 7.

Table 7 Storey drift comparison

Column designation	Zone III IS 1893 (Part 1) : 2002	Zone III IS 1893 (Part 1) : 2016
	Storey drift for 8^{th} Floor level	
Corner column	0.87mm	1.40mm
Edge column	0.81mm	1.35mm
Central column	0.76mm	0.66mm

C. Steel Requirement

The fulfillment of RC structural wall plan density increased the amount of reinforcement required. Even the volume of concrete increased making construction uneconomical.

The details about the change in requirements of steel and concrete for the Police Housing Scheme building due to revised code have been stated in the table 8.

Table 8 Change in requirement of concrete and steel

Material	IS 1893 (Part 1) : 2002	IS 1893 (Part 1) : 2016	% increase
Concrete	$143.6\,m^3$	$188.5\,m^3$	31.26
Steel	11906kg	16451kg	38.17

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