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A COMPARATIVE STUDY OF SEISMIC ANALYSIS OF LOW-RISE AND MEDIUM-RISE BUILDING AS PER IS: 1893-2002 AND IS: 1893-2016

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Abstract:- From the past record, earthquake ranks as one of the most detrimental and destructive event in India in terms of death toll and damage to infrastructure. With every earthquake, we have gone through the path of misery. Therefore, it is important to design our structure for seismic forces too. In this paper, total 6 different models were analyzed and designed in STAAD.Pro with static and dynamic seismic analysis in Zone IV as per IS: 1893-2002 and IS: 1893-2016, the static and dynamic seismic analysis (Response spectrum analysis) and different parameters (displacement, shear force, bending moment and base shear) of structural components shall be examined and then a comparison study shall be carried out during this paper.

Keywords:- Earthquake Resisting Structure, Seismic Analysis, Low-Rise Building, Medium-Rise Building.

I. INTRODUCTION

Recommendations provided by seismic codes help the designer to improve the behaviour of structures so that they may withstand the earthquake effects without significant loss. Seismic codes are unique to a particular region or country. They take into account the local seismology, accepted level of seismic risk, properties of available materials, methods used in construction and building typologies. Further, they are indicative of the level of progress a country has made in the field of earthquake engineering and property. Most of the recommendations of IS codes are based on observation during past earthquakes as well as experimental and analytical studies made by scientists, engineers and seismologists. The structure shall be designed as per their respective codes as they provide the basic and essentials guidelines on how the structure should be designed. Following are some most common codes which are being used in India while designing a structure:

- IS: 456:2000
- IS 800:1984
- IS 875 (Part 1):1987
- IS 875 (Part 2):1987
- IS 875 (Part 3):1987
- IS 875 (Part 4):1987
- IS 875 (Part 5):1987
- IS 1893 (Part 1):2016

IS: 1893-2002/2016 is associated with the earthquake and its forces, which tells about the guidelines on designing the structure for:

- Equivalent Static Seismic Analysis
- Dynamic Seismic Analysis.

A. Equivalent Static Seismic Analysis

Series of forces act on a building which represents the effect of earthquake ground motion, generally called by seismic design response spectrum. Assumption is made in this analysis that the building responds in its own fundamental mode. This is true only for the low-rise building and it must not twist significantly when subjected to ground motion. The application of this method is extensive as it is used by many building codes by applying correction factors to account for high-rise building with some higher modes, and for low levels of twisting. To account for effects due to "yielding" of the structure, many codes apply modification factors that reduce the design forces (e.g. force reduction factors).

B. Dynamic Seismic Analysis

Static seismic analysis is appropriate when higher mode effects are not significant as it is normally true for short, regular buildings. Therefore, for tall buildings, buildings with torsional irregularities, or non-orthogonal systems, a dynamic seismic analysis is essential. In the linear dynamic procedure, the building is modelled as a multi-degree-of-freedom (MDOF) system with a linear elastic stiffness matrix and an equivalent viscous damping matrix. Dynamic seismic analysis can be performed in three ways:

- Response Spectrum Method.
- Modal Time History Method
- Time History Method.

Application of these methods may vary according to the structure type, height of structure, zone in which the structure is being constructed, foundation soil type etc.

II. RESEARCH METHODOLOGY

The orientation for research program mainly focuses on:

- To study "Criteria for Earthquake Resistant Design of Structures, IS: 1893-2016".
- To perform the static and dynamic seismic analysis (Response spectrum analysis) on multi-storey buildings for seismic zone-4 as per code IS: 1893-2002 and IS: 1893-2016 in STAAD.Pro
- To study and compare the different parameters (displacement, shear force, bending moment and base shear) of multi-storey building designed with IS: 1893-2002 and IS: 1893-2016.
- To study and compare the cross-section and reinforcement of beams and columns of multi-storey building designed with IS: 1893-2002 and IS: 1893-2016.

The steps of research methodology are following:-

A. Modelling in STAAD.PRO:

The analysis shall be carried out in Bentley's Staad.pro Software (a designing tool). Total 6 models shall be made, having 5 bays in X-direction as well as in Z-direction, as under:

- G+3 as per IS: 1893-2002
- G+7 as per IS: 1893-2002
- G+10 as per IS: 1893-2002
- G+3 as per IS: 1893-2016
- G+7 as per IS: 1893-2016
- G+10 as per IS: 1893-2016

The height of each floor shall be kept 3.6 m and dimension of each bay shall be 6m in X-direction and 5m in Z-direction.

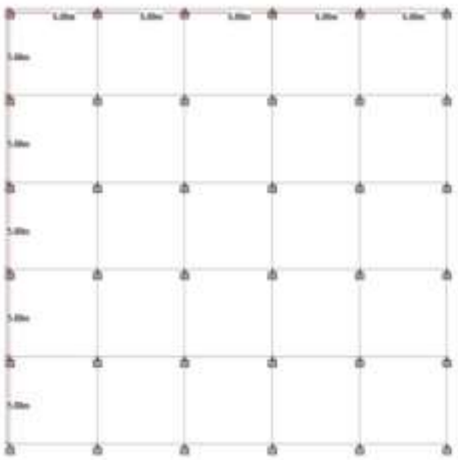

Fig. 1. Plan of the Building

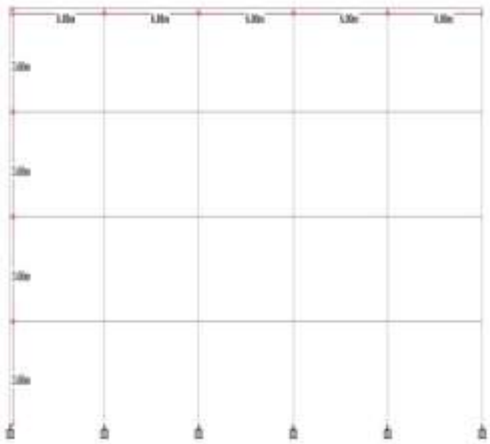

Fig. 2. Elevation of G+3 Building.

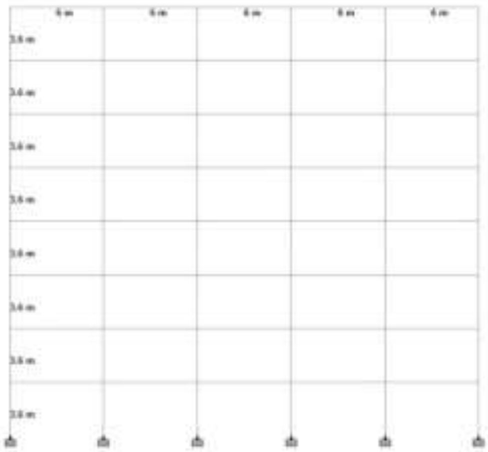

Fig. 3. Elevation of G+7 Building

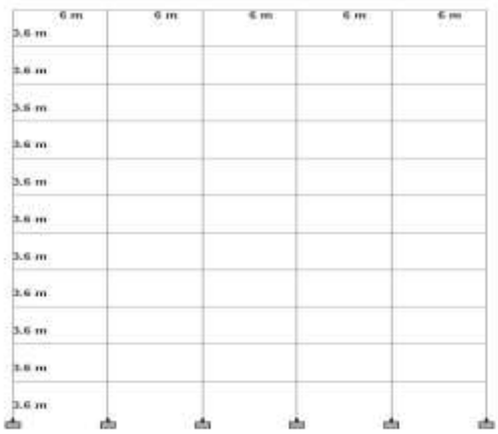

Fig. 4. Elevation of G+10 Building.

STAAD.Pro INPUT DATA

GRADES OF MATERIAL	
Grade of Concrete	M-25
Grade of Steel reinforcement	Fe-500
DEAD LOAD	
Outer Wall Load	13.8 kN/m
Inner Walls Load	6.9 kN/m
Parapet Wall Load	2.6 kN/m
Slab Load	6 kN/sqm
LIVE LOAD	
Floor Load	3 kN/sqm
Roof Load	1.5 kN/sqm

SEISMIC PARAMTERS		
SEISMIC PARAMTERS	**As Per OLD CODE**	**As Per New CODE**
Seismic Zone	IV	IV
Response reduction factor	5 (SMRF)	5 (SMRF)
Importance factor	1	1.2

CONCRETE MEMBER PROPERTIES FOR G+3	
Column	0.45 x 0.45 m
Beams	0.3 x 0.3 m

CONCRETE MEMBER PROPERTIES FOR G+7	
COLUMN	**SIZE**
1st to 4th Floor	0.6 x 0.45 m
5th to 8th Floor	0.45 x 0.38 m
BEAM	**SIZE**
1st to 4th Floor	0.45 x 0.3 m
5th to 8th Floor	0.38 x 0.3 m

CONCRETE MEMBER PROPERTIES FOR G+10	
COLUMN	**SIZE**
1st to 4th Floor	0.825 x 0.6 m
5th to 8th Floor	0.6 x 0.45 m
9th to 11th Floor	0.45 x 0.38 m
BEAM	**SIZE**
1st to 4th Floor	0.525 x 0.3 m
5th to 8th Floor	0.45 x 0.3 m
9th to 11th Floor	0.38 x 0.3 m

B. Perform Static and Dynamic Seismic analysis:

It focuses on static and dynamic seismic analysis of buildings. The analysis shall be performed as per the provisions of old code IS: 1893-2002 and new code IS: 1893-2016 which are as under:

- Old code stated that for regular buildings, dynamic seismic analysis shall be performed for those buildings greater than 40m in height in Zone IV and V, and those greater than 90m in height in Zone II and III.
- New code stated that dynamic seismic analysis shall be performed for all buildings, other than regular buildings lower than 15m in height in Zone II.

C. Optimization of models:

Optimizing the structure shall be done after performing static and dynamic seismic analysis. Economy and safety of the structure shall be kept in mind during this stage.

D. Study the various components of structure

At this stage, different components of the building (beams and columns) shall be studied for different parameters (displacement, bending moment, base shear etc) for old and new earthquake code. Then, these parameters shall be recorded in a tabular form.

E. Compare analysis results obtained for old and new code

After analyzing the building with static and dynamic design method, different models shall be studied in a scrutinized manner and the results shall be recorded. Comparative study shall then be carried out for the difference introduced in new code (IS: 1893-2016) with respect to old code (IS: 1893-2002) and the final conclusion shall be made.

F. Expected Outcome:

As we have modelled low-rise and medium-rise buildings with IS: 1893-2002 and IS: 1893-2016, it is expected that the building designed with new code will show less forces and moments than the building designed with old code. Less displacement will be noted for the buildings with new code.

III. RESULTS

Following locations of column and beam were considered for results:

- Outermost (corner) columns of all floors (as shown in Fig. 5)
- Outer beams (1006, 1017, 1028, 1039 and 1050) of first floor (as shown in Fig. 6)

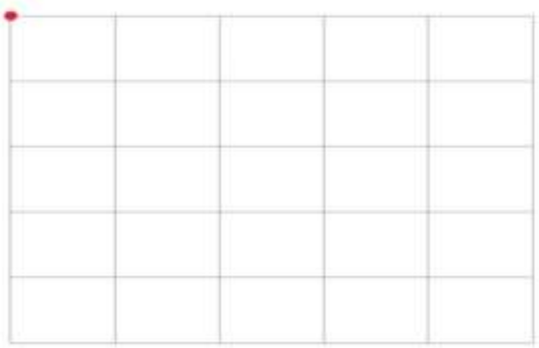

Fig. 5. Location of Column in plan.

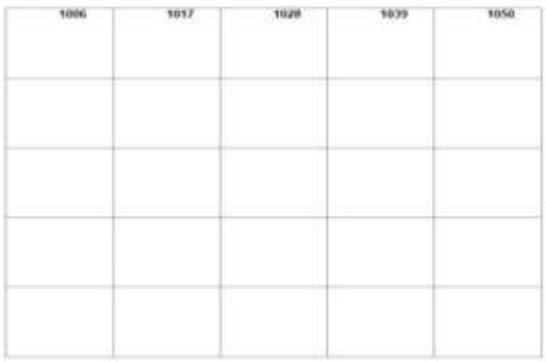

Fig. 6. Location of Beam in plan (G.F. Roof).

A. Results of Staad.Pro for G+3 building:

The values of axial force, bending moment and percentage of steel in columns are taken from the critical load cases / load combination for which the column had been designed in Staad.Pro. Therefore, the critical load case / load combination may vary for columns in same building as well.

The results collected for G+3 building which was designed for seismic Zone 4 are represented as under:

AXIAL FORCES IN COLUMN OF G+3 BUILDING		
Floor	Old Code	New Code
1	927.33	672.36
2	671.08	483.6
3	382.16	385.38
4	126.42	128.7

BENDING MOMENT IN COLUMN OF G+3 BUILDING		
Floor	Old Code	New Code
1	299.32	344.24
2	189.48	198.35
3	172.21	181.2
4	131.46	138.57
% OF STEEL IN COLUMN OF G+3 BUILDING		
Floor	Old Code	New Code
1	1.93	2.38
2	1.11	1.34
3	1.11	1.19
4	1.11	1.11

DISPLACEMENT IN COLUMN OF G+3 BUILDING		
Floor	Old Code	New Code
1	11.16	12.606
2	31.953	34.282
3	51.844	53.637
4	66.226	67.343

SHEAR FORCES IN BEAMS OF G+3 BUILDING		
BEAM NO.	Old Code	New Code
1006	143.569	146.668
1017	143.727	146.687
1028	143.719	146.687
1039	143.668	146.638
1050	145.896	149.01

BENDING MOMENT IN BEAMS OF G+3 BUILDING		
BEAM NO.	Old Code	New Code
1006	222.588	231.789
1017	218.76	227.637
1028	218.731	227.632
1039	218.76	227.637
1050	222.588	231.789

TOTAL QUANTITES OF G+3 BUILDING		
MATERIAL	Old Code	New Code
Concrete	223.8	222.3
Steel	40.55	46.82

B. Results of Staad.Pro for G+7 building:

The values of axial force, bending moment and percentage of steel in columns are taken from the critical load cases / load combination for which the column had been designed in Staad.Pro. Therefore, the critical load case / load combination may vary for columns in same building as well.

The results collected for G+7 building which was designed for seismic Zone 4 are represented as under:

AXIAL FORCES IN COLUMN OF G+7 BUILDING		
Floor	Old Code	New Code
1	2290.04	2283.12
2	232.63	221.4
3	186.59	178.35
4	139.06	136.1
5	979.15	643.75
6	666.17	681.21
7	386.01	399.36
8	125.62	132.13

BENDING MOMENT IN COLUMN OF G+7 BUILDING		
Floor	Old Code	New Code
1	28.4	23.92
2	118.03	127.4
3	84.85	89.42
4	68.49	74.83
5	48.08	45.12
6	61.96	62.95
7	61.77	59.49
8	70.62	71.8

% OF STEEL IN COLUMN OF G+7 BUILDING		
Floor	Old Code	New Code
1	1.45	1.78
2	0.83	0.83
3	0.83	0.83
4	0.83	0.83
5	1.47	1.85
6	1.41	1.58
7	1.41	1.58
8	1.32	1.41

DISPLACEMENT IN COLUMN OF G+7 BUILDING		
Floor	Old Code	New Code
1	5.673	6.622
2	16.483	18.56
3	28.551	30.943
4	40.757	42.501
5	56.254	56.161
6	71.197	69.005
7	82.265	78.628
8	88.554	84.234

SHEAR FORCES IN BEAMS OF G+7 BUILDING		
BEAM NO.	Old Code	New Code
1006	169.339	177.152
1017	168.244	175.544
1028	168.243	175.576
1039	168.157	175.495
1050	170.736	178.617

BENDING MOMENT IN BEAMS OF G+7 BUILDING		
BEAM NO.	Old Code	New Code
1006	286.421	310.295
1017	282.726	304.607
1028	282.768	304.754
1039	282.726	304.607
1050	286.421	310.295

TOTAL QUANTITES OF G+7 BUILDING		
MATERIAL	Old Code	New Code
Concrete	557.3	555.5
Steel	77.59	95.54

C. Results of Staad.Pro for G+10 building:

The values of axial force, bending moment and percentage of steel in columns are taken from the critical load cases / load combination for which the column had been designed in Staad.Pro. Therefore, the critical load case / load combination may vary for columns in same building as well.

The results collected for G+10 building which was designed for seismic Zone 4 are represented as under:

AXIAL FORCES IN COLUMN OF G+10 BUILDING		
Floor	Old Code	New Code
1	413.84	379.44
2	380.3	346.78
3	332.58	302.29
4	278.89	254.71
5	221.55	206.57
6	174.73	167.63
7	128.06	128.95
8	85.37	92.95
9	654.91	489.81
10	381.84	402.11
11	124.59	133.59

BENDING MOMENT IN COLUMN OF G+10 BUILDING		
Floor	Old Code	New Code
1	356.21	417.34
2	205.34	219.67
3	136.88	141.19
4	109.45	112.85
5	130.65	135.44
6	81.57	88.04
7	60.21	72.81
8	43.85	63.17
9	60.57	47.6
10	63.4	61.84
11	72.85	74

% OF STEEL IN COLUMN OF G+10 BUILDING		
Floor	Old Code	New Code
1	0.81	0.81
2	0.81	0.81
3	0.81	0.81
4	0.81	0.81
5	0.83	0.83
6	0.83	0.83
7	0.83	0.83
8	0.83	0.83
9	1.32	1.47
10	1.32	1.58
11	1.32	1.47

DISPLACEMENT IN COLUMN OF G+10 BUILDING		
Floor	Old Code	New Code
1	2.961	3.399
2	9.338	10.416
3	17.173	18.604
4	25.736	27.032
5	36.901	37.284
6	49.178	47.973
7	60.889	57.882
8	71.549	66.679

9	83.296	76.304
10	92.759	84.38
11	98.185	89.339

SHEAR FORCES IN BEAMS OF G+10 BUILDING		
BEAM NO.	Old Code	New Code
1006	169.104	175.683
1017	168.275	174.495
1028	168.222	174.474
1039	168.121	174.439
1050	167.76	174.514

BENDING MOMENT IN BEAMS OF G+10 BUILDING		
BEAM NO.	Old Code	New Code
1006	280.616	300.55
1017	278.068	296.722
1028	277.951	296.679
1039	278.068	296.722
1050	280.616	300.55

TOTAL QUANTITES OF G+10 BUILDING		
MATERIAL	Old Code	New Code
Concrete	962	961.1
Steel	102.61	127.80

IV. CONCLUSION

Total 6 different models were analyzed and designed in STAAD.Pro with static and dynamic seismic analysis in Zone IV as per IS: 1893-2002 and IS: 1893-2016 and results were recorded for this paper. Inferences, which were drawn from the recorded results of the study, are represented in this chapter.

A. Inferences Drawn for G+3 building are:

- Maximum Axial Force, Bending Moment and percentage of steel in columns obtained from IS 1893:2016 is 1.018, 1.150 and 1.233 times higher than the maximum Axial Force, Bending Moment and percentage of steel obtained from IS 1893:2002 respectively.
- Maximum Displacement in columns obtained from IS 1893:2016 is 1.130 times higher than the maximum Displacement obtained from IS 1893:2002.
- Maximum Shear Force and Bending Moment in beams obtained from IS 1893:2016 is 1.04 and 1.04 times higher than the maximum Shear Force and Bending Moment obtained from IS 1893:2002 respectively.
- Total quantity of concrete is same for both the codes but total quantity of steel obtained from IS 1893:2016 is 1.15 times higher than the total quantity of steel obtained from IS 1893:2002.

B. Inferences Drawn for G+7 building are:

- Maximum Axial Force, Bending Moment and percentage of steel in columns obtained from IS 1893:2016 is 1.052, 1.093 and 1.259 times higher than the maximum Axial Force, Bending Moment and percentage of steel obtained from IS 1893:2002 respectively.
- Maximum Displacement in columns obtained from IS 1893:2016 is 1.167 times higher than the maximum Displacement obtained from IS 1893:2002.
- Maximum Shear Force and Bending Moment in beams obtained from IS 1893:2016 is 1.05 and 1.08 times higher than the maximum Shear Force and Bending Moment obtained from IS 1893:2002 respectively.
- Total quantity of concrete is same for both the codes but total quantity of steel obtained from IS 1893:2016 is 1.23 times higher than the total quantity of steel obtained from IS 1893:2002.

C. Inferences Drawn for G+10 building are:

- Maximum Axial Force, Bending Moment and percentage of steel in columns obtained from IS 1893:2016 is 1.089, 1.441 and 1.197 times higher than the maximum Axial Force, Bending Moment and percentage of steel obtained from IS 1893:2002 respectively.

- Maximum Displacement in columns obtained from IS 1893:2016 is 1.148 times higher than the maximum Displacement obtained from IS 1893:2002.
- Maximum Shear Force and Bending Moment in beams obtained from IS 1893:2016 is 1.04 and 1.07 times higher than the maximum Shear Force and Bending Moment obtained from IS 1893:2002 respectively.
- Total quantity of concrete is same for both the codes but total quantity of steel obtained from IS 1893:2016 is 1.25 times higher than the total quantity of steel obtained from IS 1893:2002.

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