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# "A COMPARATIVE STUDY OF STATIC ANALYSIS (AS PER IS:1893-2002) & DYNAMIC ANALYSIS (AS PER IS: 1893-2016) FOR ZONE V"

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***Abstract***

***With the introduction of new seismic codes IS; 1893-2016, new design criteria and guidelines were also introduced. There were many changes but the major change was that according to previous code IS: 1893-2002, majority of the buildings (low-rise and medium-rise buildings) should be design by static seismic analysis but as per IS: 1893-2016, almost all the building must be designed by dynamic seismic analysis except from the building in zone II having height less than 15 m. Therefore, in order to understand the concept of static and dynamic seismic analysis on low-rise building and medium-rise building, this study was taken. During this study, different structural members and parameter shall be considered for their behavior subjected to afore-mentioned design analysis and comparison shall be made. Cost analysis shall also be done.***

***Keywords: Storey, Static Analysis, Dynamic Analysis, Zone V and Seismic effects***

## 1. Introduction

Depending upon the site and loads, different design methods are implemented with which any structural designer designs its structural. Designer concerns only two things: one is stability and second is durability. All the structural members should possess enough strength once the designing part is over so that they can easily resist all the loads acting on it [1-2]. As stability and durability are the basic requirements of any structure but economy is also as important as these two factors. For this, some design criteria and guidelines are provided by Indian Standard Codes. The application of afore-mentioned methods for seismic design can vary with the type of structure, location and total height of the building. Previously, according to IS: 1893-2002, dynamic analysis was done for the buildings greater than 40 m, but it, according to new code (revision 2016) all the buildings shall be analyzed with dynamic method expect for buildings in zone II having total height less than 15m. The deficiency in seismic analysis while designing any type of structure will always create risk to infrastructure and lives [3-4].

[5-6] Many changes and improvement in the Earthquake resistant design of structure is done in past recent years. It results in the changes in the Indian seismic code IS 1893 which is revised and drafted in year 2016, after a time elapsed of nearly 14 years. In this paper we represents the seismic load assessment for multistory building as per IS: 1893-2002 and IS:

1893-2016 recommendations. Considering and analyzing the four storey RC framed multistorey building.

It is concluded that such study is done on individual RC framed building structure which is designed using earlier code. To predict the seismic vulnerability of building structure and to check due to revisions and changes in the IS codal provisions the structure is safe or unsafe.

### 3.1. Objective Of Study

1. To compare the new seismic code with respect to old seismic code in order to fully understand the concept of new design criteria and guidelines provided in it.
2. To study the behavior of different structural components for their different structural parameters when the buildings are designed with new seismic code and old seismic code for seismic zone V.
3. Lateral sway of different storey buildings shall be compared when the buildings are designed with new seismic code and old seismic code for seismic zone V.
4. Cost analysis shall also be performed for the buildings designed with IS: 1893-2002 and IS: 1893-2016.

### 3.2. Research Methodology

#### 3.2.1. Modelling Structures by Using Staad.pro:

Design software Staad.pro was used for modelling various structures. In order to carry this step, total 3 models were prepared with old seismic code and 3 models were prepared with new seismic code.

**Table 1. Models Prepared for Present Study.**

| Type | Storey | Earthquake Design Code | Seismic Analysis Method | Total Height (m) |
|---|---|---|---|---|
| Type A | 4 storey Buiding | IS: 1893-2002 | Equivalent Static Method | 14.4 |
| Type B | 8 storey Buiding | IS: 1893-2002 | Equivalent Static Method | 28.8 |
| Type C | 11 storey Buiding | IS: 1893-2002 | Equivalent Static Method | 39.6 |
| Type D | 4 storey Buiding | IS: 1893-2016 | Dynamic Method | 14.4 |
| Type E | 8 storey Buiding | IS: 1893-2016 | Dynamic Method | 28.8 |
| Type F | 11 storey Buiding | IS: 1893-2016 | Dynamic Method | 39.6 |

Other parameters of modelling are being represented in the table given below:

- Height of each storey = 3.6 m
- No. of bays in X-direction = 6
- No. of bays in Z-direction = 6
- Panel of each bay = 6 m x 5 m

## 4. Results

#### 4.2.1. Results of Staad.Pro for 4 Storey building:

The values of structural parameters such as axial force (kN) and bending moment (kN-m) for the columns of 4 storey building are being represented in table 6 and table 7 respectively.

**Table 2 AXIAL FORCES (KN) IN COLUMN**

| Floor | Old Code (Type A) | New Code (Type D) |
|---|---|---|
| 1 | 327.84 | 289.01 |
| 2 | 879.67 | 489.57 |
| 3 | 490.23 | 500.44 |
| 4 | 160.67 | 164.13 |

**Table 3. BENDING MOMENT (KN-M) IN COLUMN**

| Floor | Old Code (Type A) | New Code (Type D) |
|---|---|---|
| 1 | 420.76 | 589.49 |
| 2 | 272.77 | 309.48 |
| 3 | 263.02 | 305.07 |
| 4 | 190.67 | 200.52 |

Table 3 shows the % steel and it can be clearly seen that the new code (Type D building) value is more than the value of old code (Type A building) and the maximum ratio (new code value/ old code value) comes out to be 1.60.

Whereas, table 4 represents the displacement (mm) of column. Due to dynamic seismic analysis, it was observed that the maximum displacement value is 1.16 times higher than the value obtained from static seismic analysis.

**Table 4. % OF STEEL IN COLUMN**

| Floor | Old Code (Type A) | New Code (Type D) |
|---|---|---|
| 1 | 1.19 | 1.9 |
| 2 | 0.8 | 0.821 |
| 3 | 0.8 | 0.821 |
| 4 | 0.8 | 0.82 |

**Table 5. DISPLACEMENT (MM) IN COLUMN**

| Floor | Old Code (Type A) | New Code (Type D) |
|---|---|---|
| 1 | 6.307 | 8.128 |
| 2 | 17.227 | 21.38 |
| 3 | 27.24 | 32.573 |
| 4 | 33.949 | 39.54 |

Table 6 and 7 shows the beam result i.e. values of shear force and bending moment respectively. From the table given below, it was concluded that type D building (new code) produces more value than type A building (old code), approximately 1.07 times higher.

**Table 6. SHEAR FORCE (KN) IN BEAM**

| Floor | Old Code (Type A) | New Code (Type D) |
|---|---|---|
| 1 | 140.28 | 147.37 |
| 2 | 137.3 | 145.4 |
| 3 | 137.38 | 145.35 |
| 4 | 137.38 | 145.35 |
| 5 | 137.3 | 145.4 |

**Table 7. BENDING MOMENT (KN-M) IN BEAM**

| Floor | Old Code (Type A) | New Code (Type D) |
|---|---|---|
| 1 | 155.32 | 162.61 |
| 2 | 149.01 | 159.772 |
| 3 | 149.01 | 159.772 |
| 4 | 149.01 | 159.772 |
| 5 | 149.01 | 159.772 |

As per the results of staad post-processing, the total quantity of concrete in cumec and steel in tonnes are being represent in the table given below.

**Table 8. Total Quantity for 4 Storey Building**

| | Concrete ($m^3$) | Steel (tonnes) |
|---|---|---|
| Old Code (Type A) | 545.10 | 49.11 |
| New Code (Type D) | 545.10 | 59.04 |

For the purpose of cost analysis, following prevailing rates were taken in this study:

- Rate of Concrete: Rs. 5000/cumec
- Rate of Steel Reinforcement: Rs. 40/Kg.

After cost analysis, the cost of the concrete and steel is being represented in figure 10. Therefore, the total cost of 4 storied building comes out to be Rs. 53.82 lakhs for type D building and Rs. 49.35 lakhs for Type A building.

**Table 9. Cost Analysis for 4 Storey Building**

| | Concrete Cost (lakhs) | Steel Cost (lakhs) | Total Cost(lakhs) |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Old Code (Type A) | 27.26 | 22.10 | 49.35 |
| New Code (Type D) | 27.26 | 26.57 | 53.82 |

### 4.2.2. Results of Staad.Pro for G+7 building:

The values of structural parameters such as axial force (kN) and bending moment (kN-m) for the columns of 8 storey building are being represented in table 14 and table 15 respectively.

**Table 10. AXIAL FORCES (KN) IN COLUMN**

| Floor | Old Code (Type B) | New Code (Type E) |
|---|---|---|
| 1 | 488.15 | 719.21 |
| 2 | 2670.98 | 2583.29 |
| 3 | 2199.8 | 2122.61 |
| 4 | 1718.28 | 1662.74 |
| 5 | 1176.75 | 383.74 |
| 6 | 800.75 | 562.82 |
| 7 | 468.32 | 461.24 |
| 8 | 153.37 | 150.2 |

**Table 11. BENDING MOMENT (KN-M) IN COLUMN**

| Floor | Old Code (Type B) | New Code (Type E) |
|---|---|---|
| 1 | 16.29 | 741.81 |
| 2 | 82.37 | 82.27 |
| 3 | 71.99 | 71.84 |
| 4 | 84.15 | 83.9 |
| 5 | 422.68 | 373.8 |
| 6 | 246.62 | 249.07 |
| 7 | 266.37 | 264.58 |
| 8 | 175.5 | 164.89 |

Table 11 shows the % steel and it can be clearly seen that the new code (Type E building) value is more than the value of old code (Type B building) and the maximum ratio (new code value/ old code value) comes out to be 1.07.

Whereas, table 12 represents the displacement (mm) of column. Due to dynamic seismic analysis, it was observed that the maximum displacement value is 0.84 times the value obtained from static seismic analysis.

**Table 12. % OF STEEL IN COLUMN**

| Floor | Old Code (Type B) | New Code (Type E) |
|---|---|---|
| 1 | 1.01 | 0.99 |
| 2 | 0.8 | 0.85 |
| 3 | 0.8 | 0.85 |
| 4 | 0.8 | 0.85 |
| 5 | 0.96 | 1.1 |
| 6 | 0.83 | 0.89 |
| 7 | 0.83 | 0.89 |
| 8 | 0.83 | 0.89 |

**Table 13. DISPLACEMENT (MM) IN COLUMN**

| Floor | Old Code (Type B) | New Code (Type E) |
|---|---|---|
| 1 | 3.305 | 3.771 |
| 2 | 9.589 | 10.571 |
| 3 | 16.742 | 17.622 |
| 4 | 24.36 | 24.282 |
| 5 | 37.212 | 34.207 |
| 6 | 53.045 | 46.473 |
| 7 | 63.31 | 56.818 |
| 8 | 75.268 | 63.564 |

Table 13 and 14 shows the beam result i.e. values of shear force and bending moment respectively. From the Table, it was concluded that type E building (new code) produces more value than type B building (old code), approximately 1.1 times higher.

**Table 14. Shear Force (Kn) In Beam**

| Beam | Old Code (Type B) | New Code (Type E) |
|---|---|---|
| 1 | 148.64 | 154.9 |
| 2 | 141.52 | 152.05 |
| 3 | 141.52 | 152.05 |

| | | |
|---|---|---|
| 4 | 141.52 | 152.05 |
| 5 | 141.52 | 152.05 |

**Table 15. BENDING MOMENT (KN-M) IN BEAM**

| Beam | Old Code (Type B) | New Code (Type E) |
|---|---|---|
| 1 | 155.42 | 172.86 |
| 2 | 151.01 | 168.32 |
| 3 | 151.01 | 168.32 |
| 4 | 151.01 | 168.32 |
| 5 | 151.01 | 168.32 |

As per the results of staad post-processing, the total quantity of concrete in cumec and steel in tonnes are being represent in the table given below.

**Table 16. Total Quantity for 8 Storey Building**

| | Concrete ($m^3$) | Steel (tonnes) |
|---|---|---|
| Old Code (Type B) | 1368.20 | 115.77 |
| New Code (Type E) | 1368.20 | 137.74 |

For the purpose of cost analysis, following prevailing rates were taken in this study:

- Rate of Concrete: Rs. 5000/cumec
- Rate of Steel Reinforcement: Rs. 40/Kg.

The cost of concrete and steel is being represented in table 15. Therefore, the total cost of 8 storied building comes out to be Rs. 130.40 lakhs for Type E building and Rs. 120.51 lakhs for Type B building.

**Table 17. Cost Analysis for 8 Storey Building**

| | Concrete Cost (lakhs) | Steel Cost (lakhs) | Total Cost(lakhs) |
|---|---|---|---|
| Old Code (Type B) | 68.41 | 52.10 | 120.51 |
| New Code (Type E) | 68.41 | 61.99 | 130.40 |

### 4.2.3. Results of Staad.Pro for G+10 building:

The values of structural parameters such as axial force (kN) and bending moment (kN-m) for the columns of 11 storey building are being represented in table 22 and table 23 respectively.

**Table 18. AXIAL FORCES (KN) IN COLUMN**

| Floor | Old Code (Type C) | New Code (Type F) |
|---|---|---|
| 1 | 4873.65 | 1018.24 |
| 2 | 4378.21 | 4308.42 |
| 3 | 3835.73 | 3767.66 |
| 4 | 3276.51 | 3219.11 |
| 5 | 2707.53 | 2670.11 |
| 6 | 2222.25 | 2205.06 |
| 7 | 1738.4 | 1741.92 |
| 8 | 1266.21 | 310.24 |
| 9 | 786.21 | 512.67 |
| 10 | 441.8 | 461.56 |
| 11 | 143.64 | 152.19 |

**Table 19. BENDING MOMENT (KN-M) IN COLUMN**

| Floor | Old Code (Type C) | New Code (Type F) |
|---|---|---|
| 1 | 28.75 | 1012.59 |
| 2 | 90.24 | 90.11 |
| 3 | 80.82 | 80.59 |
| 4 | 92.85 | 92.5 |
| 5 | 68.54 | 68.25 |
| 6 | 85.89 | 85.51 |
| 7 | 82.12 | 81.7 |
| 8 | 97.72 | 59.21 |
| 9 | 234.5 | 260.85 |
| 10 | 189.82 | 214.26 |
| 11 | 131.21 | 156.46 |

Table 19 shows the % steel and it can be clearly seen that the new code (Type F building) value is more than the value of old code (Type C building) and the maximum ratio (new code value/ old code value) comes out to be 1.30.

Whereas, Table 20 represents the displacement (mm) of column. Due to dynamic seismic analysis, it was observed that the maximum displacement value is 0.9 times than the value obtained from static seismic analysis.

**Table 20. % OF STEEL IN COLUMN**

| Floor | Old Code (Type C) | New Code (Type F) |
|---|---|---|
| 1 | 1.24 | 1.38 |
| 2 | 0.85 | 0.85 |
| 3 | 0.85 | 0.85 |
| 4 | 0.85 | 0.85 |
| 5 | 0.85 | 0.99 |
| 6 | 0.83 | 0.83 |
| 7 | 0.83 | 0.83 |
| 8 | 0.83 | 0.83 |
| 9 | 1.34 | 1.787 |
| 10 | 1.34 | 1.564 |
| 11 | 1.12 | 1.34 |

**Table 21. DISPLACEMENT (MM) IN COLUMN**

| Floor | Old Code (Type C) | New Code (Type F) |
|---|---|---|
| 1 | 2.317 | 2.676 |
| 2 | 6.969 | 7.897 |
| 3 | 12.461 | 13.783 |
| 4 | 18.292 | 19.693 |
| 5 | 25.267 | 26.303 |
| 6 | 32.63 | 32.914 |
| 7 | 39.594 | 38.914 |
| 8 | 45.938 | 44.22 |
| 9 | 56.913 | 53.281 |

| | | |
|---|---|---|
| 10 | 66.476 | 61.729 |
| 11 | 71.632 | 66.573 |

Table 21 and 22 shows the beam result i.e. values of shear force and bending moment respectively. From the Table, it was concluded that type F building (new code) produces more value than type C building (old code), approximately 1.07 higher.

**Table 22. SHEAR FORCE (KN) IN BEAM**

| Beam | Old Code (Type C) | New Code (Type F) |
|---|---|---|
| 1 | 159.32 | 165.81 |
| 2 | 155.27 | 164.2 |
| 3 | 155.27 | 164 |
| 4 | 155.27 | 164 |
| 5 | 155.27 | 164 |

**Table 23. BENDING MOMENT (KN-M) IN BEAM**

| Beam | Old Code (Type C) | New Code (Type F) |
|---|---|---|
| 1 | 165.25 | 181.4 |
| 2 | 161.11 | 178.45 |
| 3 | 161.24 | 178.4 |
| 4 | 161.09 | 178.38 |
| 5 | 160.98 | 178.43 |

As per the results of staad post-processing, the total quantity of concrete in cumec and steel in tonnes are being represent in the table given below.

**Table 24. Total Quantity for 11 Storey Building**

| | Concrete ($m^3$) | Steel (tonnes) |
|---|---|---|
| Old Code (Type C) | 2425.20 | 164.66 |
| New Code (Type F) | 2425.20 | 189.51 |

For the purpose of cost analysis, following prevailing rates were taken in this study:

- Rate of Concrete: Rs. 5000/cumec
- Rate of Steel Reinforcement: Rs. 40/Kg.

After cost analysis, the cost of the concrete and steel is being represented in figure 20. Therefore, the total cost of 11 storied building comes out to be Rs. 206.54 lakhs for type F building and Rs. 195.36 lakhs for Type C building.

**Table 25. Cost Analysis for 11 Storey Building**

| | Concrete Cost (lakhs) | Steel Cost (lakhs) | Total Cost(lakhs) |
|---|---|---|---|
| Old Code (Type C) | 121.26 | 74.10 | 195.36 |
| New Code (Type F) | 121.26 | 85.28 | 206.54 |

## 5.1. CONCLUSIONS

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

### 5.1.1. 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.
- Maximum quanitiy of concrete is same for both the codes but maximum quantity of steel obtained from IS 1893:2016 is 1.15 times higher than the maximum quantity of steel obtained from IS 1893:2002.

### 5.1.2. 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.
- Maximum quanitiy of concrete is same for both the codes but maximum quantity of steel obtained from IS 1893:2016 is 1.23 times higher than the maximum quantity of steel obtained from IS 1893:2002.

### 5.1.3. 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.
- Maximum quanitiy of concrete is same for both the codes but maximum quantity of steel obtained from IS 1893:2016 is 1.25 times higher than the maximum quantity of steel obtained from IS 1893:2002.

## 5.2. LIMITATIONS AND FUTURE SCOPE

(i) The building taken in present study was analyzed and designed for seismic Zone-V only. Different seismic zone can be taken in new research study as the results may vary once the zone is changed.
(ii) Only STAAD.Pro software was used for the present study. Different software like e-tabs can be used in new research program because with the change of software, results of same study may vary.
(iii) Symmetrical and assumed structures were taken for this study. Therefore, assymetrical and original constructed buildings can be used for new study under same concept as this.
(iv) Only regular building (in plan and elevation) was considered for this study. Therefore, irregular structure can also be taken in new study as it may have different results.

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