Seismic Analysis of Building with and Without Shear Wall for Building with RCC and Composite Column

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Abstract - Shear wall is a structural element which is provided for resisting horizontal forces (like wind force, earthquake force, etc) parallel to the plane of the wall and for supporting gravity loads simultaneously. These are basically flexural members which are generally provided in high rise buildings to avoid the total collapse of the building exposed to seismic forces. For seismic design of buildings, RC structural walls or shear walls are major earthquake resisting members which offer lateral load resistance by providing an efficient bracing system. The response of the buildings is dominated by the properties of seismic shear walls and so it becomes important to evaluate the seismic response of the shear walls appropriately. In this study, the effect of presence of shear walls in RCC and composite structures in being analysed on basis of storey displacement, storey drift, stiffness, lateral force and base shear for G+19 buildings. Effectiveness of shear wall is being studied with the help of four different models. Model 1 is RCC building without shear wall, Model 2 is RCC building with shear wall, Model 3 is building with composite columns having no shear wall and Model 4 is building with composite columns in presence of shear wall. The earthquake load is applied to a building in zone IV and the analysis is done using both static analysis method and response spectrum analysis method.

Keywords: ETAB 2017, RCC buildings, Building with steel-concrete composite columns, Seismic analysis, Shear wall.

I. INTRODUCTION
In recent time, a lot of effort is given to develop the structural control devices so that seismic impact in buildings can be reduced. One such practice is introduction of shear wall in the buildings. Shear walls are one of the best means to provide earthquake resistance in multi-storied building. Behaviour of building under earthquake load depends on how the weight, stiffness and strength are distributed in the horizontal and lateral direction. Shear walls are used in the building to reduce the effect of earthquake by improving the seismic response of buildings. It becomes important to ensure adequate lateral stiffness to resist lateral load. For high-rise buildings, beam and column sizes are very heavy and requirement of steel is large because of which there is a lot of congestion at the joints and making it difficult to vibrate concrete at the joints and also the displacement is quite heavy.

In India most of the buildings are low rise. So, RCC members are used widely as it is easy to construct and is economical. However with the growth of population there is increasing growth in high-rise buildings in metropolis. It is observed that the use of composite members over RCC members is much more effective and economical in high rise buildings. When a steel component like I-beam is attached to a concrete component like floor slab or bridge deck, a composite member is formed. In composite structures the high strength of the concrete in compression and high strength of the steel in tension are utilized in combination. Thus steel-concrete composite construction makes use of compressive strength of concrete and tensile strength of steel together to give more economical and effective structure. Such an advanced system is gaining recognition in high rise buildings.

In this paper effectiveness of shear wall in RCC building and building with composite columns have been studied with the help of four different models using Etabs in zone IV. The analysis is done by response spectrum analysis method and static analysis method. The models considered for the analysis are as follows: Model 1 is RCC building without shear wall, Model 2 is RCC building with shear wall, Model 3 is building with composite columns having no shear wall and Model 4 is building with composite columns in presence of shear wall.
Table 1: Building description

| Description                        | Details                  |
|------------------------------------|--------------------------|
| Building storey                     | G+19                     |
| Total height of building            | 60 m                     |
| Height of each storey               | 3.0 m                    |
| Beam size                          | 350mm x 700mm            |
| Column size                        | 600 mm X 600 mm          |
| Shear wall thickness                | 250 mm                   |
| Slab thickness                      | 225 mm                   |
| Thickness of external walls         | 230 mm                   |
| Thickness of internal walls         | 115                      |
| Live load                          | 3 KN/m²                  |
| Floor finish                       | 2 KN/m²                  |
| Grade of Concrete                   | M30                      |
| Grade of reinforcing Steel          | HYS 415                  |
| Grade of Steel                      | Fe 250                   |
| Density of Concrete                 | 25 KN/m³                 |
| Zone                               | IV                       |
| Importance factor                   | 1.2                      |
| Soil condition                      | Medium soil              |
| Response reduction factor           | 5.0                      |
| Damping ratio                       | 5%                       |
III. RESULTS AND DISCUSSIONS

Equivalent static method and response spectrum method is used to analyse the results of all four models. Loads are calculated and distributed as per IS 1893:2016 and results obtained is compared as per following parameters.

3.1 STATIC ANALYSIS OF G+19 BUILDINGS

1. Lateral Displacement- From the observed results it was found that building with composite column in presence of shear wall showed minimum displacement. Also it is observed that the building on introduction of shear wall reduced displacement in the building substantially.

| STOREY | RCC (mm) | RCC WITH SHEAR WALL (mm) | COMPOSITE (mm) | COMPOSITE WITH SHEAR WALL (mm) |
|--------|----------|-------------------------|----------------|-------------------------------|
| 1      | 6.562    | 1.427                   | 4.123          | 1.154                         |
| 2      | 17.534   | 4.305                   | 12.168         | 3.458                         |
| 3      | 29.419   | 8.29                    | 21.505         | 6.599                         |
| 4      | 41.539   | 13.165                  | 31.266         | 10.43                         |
| 5      | 53.728   | 18.744                  | 41.146         | 14.814                        |
| 6      | 65.909   | 24.868                  | 51.019         | 19.637                        |
| 7      | 78.016   | 31.398                  | 60.809         | 24.794                        |
| 8      | 89.979   | 38.211                  | 70.457         | 30.192                        |
| 9      | 101.723  | 45.199                  | 79.902         | 35.748                        |
| 10     | 113.168  | 52.261                  | 89.078         | 41.386                        |
| 11     | 124.227  | 59.311                  | 97.917         | 47.037                        |
| 12     | 134.808  | 66.271                  | 106.344        | 52.638                        |
| 13     | 144.813  | 73.071                  | 114.28         | 58.157                        |
| 14     | 154.139  | 79.655                  | 121.64         | 63.486                        |
| 15     | 162.678  | 85.977                  | 128.336        | 68.647                        |
| 16     | 170.318  | 92.002                  | 134.274        | 73.591                        |
| 17     | 176.943  | 97.714                  | 139.363        | 78.302                        |
| 18     | 182.435  | 103.115                 | 143.517        | 82.774                        |
| 19     | 186.693  | 108.234                 | 146.69         | 87.029                        |
| 20     | 189.744  | 113.06                  | 148.965        | 91.014                        |

![Displacement graph](image)

Fig 5: Comparison of storey displacement

2. Storey Drift- Decrease in storey drift was observed in presence of shear wall in both building with RCC column as well as building with Composite column. Maximum drift was observed in RCC building without shear wall.

| STOREY | RCC (mm) | RCC WITH SHEAR WALL (mm) | COMPOSITE (mm) | COMPOSITE WITH SHEAR WALL (mm) |
|--------|----------|-------------------------|----------------|-------------------------------|
| 1      | 6.562    | 1.427                   | 4.123          | 1.154                         |
| 2      | 10.972   | 2.879                   | 8.045          | 2.304                         |
| 3      | 11.885   | 3.985                   | 9.337          | 3.141                         |
| 4      | 12.12    | 4.875                   | 9.761          | 3.83                          |
| 5      | 12.189   | 5.579                   | 9.88           | 4.385                         |
| 6      | 12.181   | 6.124                   | 9.872          | 4.823                         |
| 7      | 12.107   | 6.53                    | 9.791          | 5.157                         |
| 8      | 11.963   | 6.814                   | 9.648          | 5.398                         |
3. **Stiffness** - It is observed that building with composite column having shear wall has maximum stiffness and RCC building without shear wall shows minimum stiffness as evident from the graph below.

![Drift(mm)](image)

### Table 4: Stiffness

| STOREY | RCC (K/N/m) | RCC WITH SHEAR WALL (K/N/m) | COMPOSITE (K/N/m) | COMPOSITE WITH SHEAR WALL (K/N/m) |
|--------|-------------|------------------------------|-------------------|-----------------------------------|
| Base   | 0           | 0                            | 0                 | 0                                 |
| 1      | 12688.30    | 60586.1579                   | 2062814.746       | 7645688.716                      |
| 2      | 75860.79    | 3000926.082                  | 1056867.359       | 3827626.858                      |
| 3      | 69931.18    | 2164984.441                  | 909535.751        | 2803316.998                      |
| 4      | 683496.6    | 1764036.19                   | 867034.373        | 2291679.015                      |
| 5      | 675719.4    | 1532494.518                  | 851613.092        | 1996302.486                      |
| 6      | 670043.4    | 1383341.694                  | 844533.12         | 1793098.3                       |
| 7      | 665269      | 1280102.383                  | 840342.895        | 1654623.847                      |
| 8      | 661009      | 1204476.322                  | 837254.968        | 1551727.315                      |
| 9      | 657014.2    | 1146030.216                  | 834587.182        | 1471074.498                      |
| 10     | 653038.4    | 1098099.278                  | 831982.827        | 1404090.936                      |
| 11     | 648797.8    | 1055899.696                  | 829154.648        | 1344609.27                       |
| 12     | 643937.4    | 1015525.479                  | 825762.217        | 1287617.095                      |
| 13     | 637982.4    | 973324.746                   | 821441.032        | 1278487.908                      |
| 14     | 630252.7    | 925436.317                   | 815506.837        | 1162426.33                       |
| 15     | 619704      | 867387.251                   | 806971.279        | 1084005.722                      |
| 16     | 604599.5    | 793723.815                   | 794013.26         | 986762.678                      |
| 17     | 581758.1    | 697717.153                   | 772848.449        | 862871.81                       |
| 18     | 544364.9    | 571451.642                   | 734022.261        | 703273.343                      |
| 19     | 474687.1    | 405781.908                   | 649120.953        | 497137.915                      |
| 20     | 308690.8    | 197581.503                   | 419907.19         | 242734.859                      |
3.2 RESPONSE SPECTRUM ANALYSIS OF G+19 BUILDINGS

1. Lateral displacement - It is observed that displacement is reduced substantially in presence of shear wall. Building with composite column in presence of shear wall showed minimum displacement while the RCC building without shear wall showed maximum displacement.

Table 6: Lateral displacement by response spectrum

| STOREY | RCC (mm) | RCC WITH SHEAR WALL (mm) | COMPOSITE (mm) | COMPOSITE WITH SHEAR WALL (mm) |
|--------|----------|--------------------------|----------------|-------------------------------|
| 1      | 4.295    | 0.835                    | 2.682          | 0.678                         |
| 2      | 11.3     | 2.413                    | 7.815          | 1.947                         |
| 3      | 18.614   | 4.509                    | 13.597         | 3.601                         |
| 4      | 25.759   | 6.984                    | 19.422         | 5.546                         |
| 5      | 32.64    | 9.725                    | 25.084         | 7.699                         |
| 6      | 39.241   | 12.64                    | 30.519         | 9.993                         |
| 7      | 45.563   | 15.659                   | 35.711         | 12.376                        |
| 8      | 51.605   | 18.726                   | 40.653         | 14.805                        |
| 9      | 57.358   | 21.798                   | 45.341         | 17.25                         |
| 10     | 62.811   | 24.844                   | 49.767         | 19.686                        |
| 11     | 67.948   | 27.842                   | 53.918         | 22.095                        |
| 12     | 72.752   | 30.774                   | 57.781         | 24.464                        |
| 13     | 77.205   | 33.627                   | 61.341         | 26.782                        |
| 14     | 81.289   | 36.393                   | 64.584         | 29.042                        |
| 15     | 84.985   | 39.062                   | 67.495         | 31.235                        |
| 16     | 88.27    | 41.63                    | 70.056         | 33.356                        |
| 17     | 91.115   | 44.092                   | 72.244         | 35.399                        |
| 18     | 93.486   | 46.45                    | 74.034         | 37.362                        |
| 19     | 95.346   | 48.713                   | 75.414         | 39.251                        |
| 20     | 96.714   | 50.871                   | 76.423         | 41.038                        |
Fig 10: Comparison of displacement by response spectrum method

2. **Lateral drift** - There is decrease in drift in building with composite column than building with RCC column. Building with composite column in presence of shear wall showed minimum drift among all the four models

| STOREY | RCC (mm) | RCC WITH SHEAR WALL (mm) | COMPOSITE (mm) | COMPOSITE WITH SHEAR WALL (mm) |
|--------|----------|--------------------------|----------------|---------------------------------|
| 1      | 4.295    | 0.835                    | 2.682          | 0.678                           |
| 2      | 7.015    | 1.581                    | 5.136          | 1.271                           |
| 3      | 7.355    | 2.103                    | 5.801          | 1.66                            |
| 4      | 7.243    | 2.49                     | 5.874          | 1.956                           |
| 5      | 7.659    | 2.766                    | 5.764          | 2.173                           |
| 6      | 6.87     | 2.957                    | 5.605          | 2.327                           |
| 7      | 6.683    | 3.082                    | 5.435          | 2.433                           |
| 8      | 6.483    | 3.158                    | 5.299          | 2.501                           |
| 9      | 6.269    | 3.197                    | 5.07           | 2.543                           |
| 10     | 6.033    | 3.209                    | 4.865          | 2.564                           |
| 11     | 5.777    | 3.202                    | 4.641          | 2.569                           |
| 12     | 5.505    | 3.177                    | 4.404          | 2.561                           |
| 13     | 5.214    | 3.137                    | 4.155          | 2.539                           |
| 14     | 4.904    | 3.081                    | 3.891          | 2.503                           |
| 15     | 4.567    | 3.007                    | 3.606          | 2.452                           |
| 16     | 4.18     | 2.913                    | 3.28           | 2.383                           |
| 17     | 3.717    | 2.801                    | 2.891          | 2.297                           |
| 18     | 3.146    | 2.673                    | 2.42           | 2.097                           |
| 19     | 2.436    | 2.141                    | 1.865          | 1.592                           |
| 20     | 1.665    | 1.286                    | 1.304          | 0.95                            |
4. **Stiffness** - It is observed that building with composite column having shear wall has maximum stiffness and RCC building without shear wall shows minimum stiffness as evident from the graph below.

Table 7: Lateral drift by response spectrum

| STOREY | RCC (KН/m) | RCC WITH SHEAR WALL (KН/m) | COMPOSITE (KН/m) | COMPOSITE WITH SHEAR WALL (KН/m) |
|--------|------------|-----------------------------|------------------|-----------------------------------|
| Base   | 0          | 0                           | 0                | 0                                 |
| 1      | 1292503    | 6903487.031                 | 2114177.636      | 8671133.005                      |
| 2      | 774342.8   | 3580772.778                 | 1084590.899      | 4557050.78                       |
| 3      | 714501.7   | 2602323.877                 | 931641.314       | 3380857.809                      |
| 4      | 697616.7   | 2180287.83                  | 885008.033       | 2744738.727                      |
| 5      | 690112.3   | 1790395.946                 | 868738.96        | 2341520.377                      |
| 6      | 684098.4   | 1576977.717                 | 860705.989       | 2056837.42                       |
| 7      | 679372.2   | 1422627.942                 | 857024.369       | 1845012.295                      |
| 8      | 674405.3   | 1307964.745                 | 853859.368       | 1683578.05                       |
| 9      | 670043.8   | 1223756.894                 | 851149.968       | 1562652.152                      |
| 10     | 665350.3   | 1163540.138                 | 848342.788       | 1475294.03                       |
| 11     | 660542.6   | 1122271.362                 | 844653.719       | 1415875.442                      |
| 12     | 656247     | 1096152.405                 | 841706.512       | 1378940.327                      |
| 13     | 651791.5   | 1079304.053                 | 839213.043       | 1355954.249                      |
| 14     | 647886.4   | 1065735.302                 | 837528.542       | 1337481.054                      |
| 15     | 645048.4   | 1049662.173                 | 83233.66         | 1313068.196                      |
| 16     | 641406.4   | 1018441.574                 | 839112.705       | 1268493.341                      |
| 17     | 635356.8   | 960599.353                  | 836997.76        | 1186967.922                      |
| 18     | 622575.9   | 855676.38                   | 826986.996       | 1046213.631                      |
| 19     | 580528.6   | 670223.997                  | 776934.689       | 806723.924                       |
| 20     | 412496.8   | 361815.448                  | 546004.379       | 430153.909                       |

Fig 11: Comparison of drift by response spectrum method
IV. CONCLUSION

- From all the above analysis, it is observed that for high rise building of 20 storey, building with composite column is more efficient. It is observed that displacement and drift is reduced substantially and stiffness of the building increases in presence of shear walls. Hence it is concluded that composite column building with shear wall counter seismic force more as compared to other models.

- In case of RCC framed structure the lateral displacement is very high. It is observed that in presence of shear wall the displacement at top reduces by approx 40% in case of static analysis and 47% in case of response spectrum analysis in both RCC and composite column buildings. Also the building with composite column reduces the displacement by approx 20% as compared to RCC building.

- Hence the composite column building in presence of shear wall counters the seismic effect more efficiently.

- Storey-drift is the relative displacement, it means the drift of one level relative to the level below. It is observed that the drift at top is reduced by 13% in presence of shear wall in case of static analysis and 23% in case of response spectrum analysis.

- Building with composite columns reduces the drift by approx 25% compared to RCC column buildings.

- The stiffness of the building is more in case of composite column compared to RCC column building. The shear wall in the building makes the building increases the stiffness of the building.

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Fig 12: Comparison of stiffness by response spectrum method