Comparison of Modelling Strategies of R.C Walls for Seismic Analysis

Syed Hamim Jeelani¹, Salim Akhtar², Lingeshwaran. N¹, Durga Chaitanya Kumar Jagarapu¹, M A Mohammed Aslam³, Babu Nallusamy³, Syed Shams Rizvi³

¹Assistant Professor, Department of Civil Engineering, Koneru Lakshmaiah Education Foundation (Deemed to be University), Guntur - 522502, Andhra Pradesh, India
²Department of Geology, University of Delhi, Delhi 110007, India
³Department of Geology, Central University of Karnataka, Kalaburagi - 585367, Karnataka, India

Abstract Reinforced concrete walls are being widely adopted as lateral load resisting systems for high rise structures. The current practice among design engineers for modelling of such walls is by idealizing the same as ‘wide’ columns, which is uncertain from safety as well as economy point of view. The most efficient modelling strategy of RC walls involves use of shell elements. Such an approach can be computationally much intensive, especially from a seismic analysis perspective. The present study utilizes an equivalent strut approach for modelling RC walls. The modelling strategy is demonstrated on a G + 15 storey residential apartment located in Calicut city. The proposed methodology will be compared with the traditional ‘wide’ column method as well as the one with shell element discretization. Comparison of modal properties such as frequencies and vibration modes from the various models are initially made to assess the model accuracy. Various seismic analyses viz. Equivalent static approach, Response spectrum approach and the assessment the storey shear, inter storey drifts as well as computation times using various models were performed using time history analysis. From preliminary results, it is understood that the modelling strategy could serve as an efficient alternative to more robust and computationally demanding scheme involving use of shell elements.

Keywords: Seismic analysis, Response Spectra, Time history analysis, Storey drift, Base shear

1.0 Introduction
The tremendous pace of urbanization of rural areas and ever-increasing population in urban areas has necessitated the increase in the construction of multi-storeyed buildings in order to optimize accommodation in vertical direction and there by minimize the space in horizontal direction [1]. Highrise buildings can be effectively used to meet the requirements of modern society and solve the problem of limitation of construction site resources [2].

2.0 Literature
2.1 Loads Considered
Structural loads or actions are forces, deformations or accelerations applied to a structure or its components. Loads cause stresses, deformations and displacements in structures
2.2 Moment Resisting Frames
Moment resistant frame consists of columns and beams. The lateral stiffness of a moment resisting frame depends on the bending toughness of the columns and beams [3]. The advantage of moment resisting frame is that allows freedom of planning and easy fitting of doors and windows. It is economical only for buildings up to about 25 stories. Above 25 stories the relatively high flexibility of the frame calls for uneconomically large members in order to control the drift and displacements [4].

2.3 Shear Walls
Continuous concrete vertical wall serves both architecturally as partitions and structurally to carry gravity and lateral loads. Their very high in plane stiffness and strength makes them ideal for tall buildings. In a shear wall structure, such walls are accountable for the lateral load resistance of the building [5]. They act as vertical cantilevers through separate planar walls and as non-planar assemblies of connected walls around elevator, stair and service shafts. As they are stiffer horizontally than rigid frames, shear wall structures can be economical up to about 35 stories.

3.0 Seismic Analysis Methods
There are three methods of force based seismic design of buildings
- Equivalent Static Analysis.
- Response Spectrum Analysis.
- Time History Analysis.

4.0 Preliminary Dimensioning
The architectural drawings of G + 15 storied structures proposed to be constructed in Calicut city shown in Figure 1(a), Figure 1(b), Figure 1(c),

Fig. 1(a). Ground Floor Plan.
Fig. 1(b). Typical 1st - 15th Floor Plan.

Fig. 1(c). Terrace Floor Plan.

5.0 Shear wall Modelling in Staad
The GUI interconnects with the STAAD analysis appliance through the STD contribution file. That input file is a text file consisting of a series of commands which are executed sequentially, the modelling of structure is shown in Figure 2.
5.1 Modal Analysis
This is the method of defining the integral dynamic features of a arrangement in systems of natural frequencies, damping aspects and mode shapes, and by means of them to articulate a model for its behaviour.

6.0 Procedure of Modal Analysis in Staad
- For modal or free vibration analysis, loadings are defined and assigned to members in all three directions.
- A load case is created which include self-weight, dead load of 15.44 kN/m² on floors and 6.24 kN/m² roof are defined in x, y, z directions with factor of 1.
- Modal analysis command is given after assigning the dead loads.
- Finally, analysis is performed and results obtained are associated for the three models.

6.1 Analysis Results (Fundamental)
The free vibration captured by the model using Shell Elements is treated to be exact. So, this is kept as a reference for assessment with other two models [6]. The fundamental mode captured is Torsion and fundamental frequency and time period obtained is 0.709 Hz and 1.410 s respectively. The fundamental mode predicted by the model using Wide Column analogy is Sway in x direction. The structure is stiffer in this case. As the wide column method incorrectly captures the stiffness distribution, the fundamental mode itself is changed. So, the mode prediction is not advisable. The fundamental mode predicted by model using equivalent struts is Torsion, the same as model 3. Frequency values and time period is very much nearer to that obtained in case of model 3 [7]. Equivalent strut model appears much superior to the wide column modelling strategy. In case of wide column analogy, if the mode shape is discarded stiffness of model is very much greater than other ones. The storey shear attracted by model is much higher as the model 1 is much stiffer, which is reflected by higher frequency. Hence the design using such an approach result in uneconomical sections. Though accurate, the time needed for Eigen value calculation in case of model 3 is greater [8]. It is 9.2 times and 7.2 times greater than that of model 1 and 2 respectively, much prohibiting the Time History Analysis of this model. And the mode, frequencies and time periods of three models are displayed in the Table 1 and modal frequencies are represented in the Table 2.

Fig. 2. Modelling of Structure
The details of modal analysis results of building model, developed using various modelling strategies conferred prior was represented in this chapter [9]. It is experimental modelling strategy involving use of equivalent struts for modelling RC walls success in capturing the major vibration manners of the structure which infect were predicted through the modelling technique involving use of shell elements for RC walls. Flexural torsional mode with 65 % mass participation happens to be the fundamental mode predicted by both the proposed approach as well as the more exact model by means of shell elements [10]. The wide column modelling strategy which is followed by most design offices fails to capture this mode, which predicts the fundamental mode to be lateral sway. Hence, it can be concluded that the currently followed strategy of modelling RC walls as wide columns fails to capture the seismic design forces correctly, details of which will be explored in subsequent chapters using various seismic analysis methodologies such as equal static analysis, response spectrum analysis as well as time history analysis.

### 7.0 Procedure of Equivalent Static Analysis in Staad

- **IS 1893:2002** seismic definitions are defined by providing seismic parameters given in seismic load parameters are Zone factor is 0.1, Response Reduction factor is 5, Importance factor is 1.5, Type of soil strata is 2.
- Seismic loadings are provided under the seismic definition which include self-weight and floor load consisting of floor dead load of 15.44 kN and roof dead load of 6.24 kN; and live include of 0.625 kN (only 25% of floor live load considered for seismic analysis a/c to IS 1893:2002 cl.7.3.1).
- Load cases are defined starting with seismic loading in x direction followed by seismic loading z direction by adding self-weight with a factor of 1 [11].
- Two more load cases are added which include dead and live loading. Dead load consists of 15.44 kN as floor load and roof load of 6.24 kN. Live load consists of 2.5 kN at floor and 1.5 kN at roof.
- Auto combination for IS code is generated considering the load cases.
- Finally, analysis is performed for the seismic definition provided.
- The analysis results obtained are connected for the models considering global comparison by base shear and elemental comparison by column shear and storey drift values.
The frequency of Model 1, Model 2, and Model 3 is obtained as 0.9Hz, 0.6Hz, and 0.7Hz respectively in the modal analysis of structure. As the frequency of the structure increases, stiffness increases provided mass is constant. A structure with more stiffness attracts baser shear. Theoretically, the base shear engrossed by model 1 must be greater and that by model 2 essentially be the least. But the obtained results mirror that model 2 has attracted the maximum base shear than others which is opposing the result.

7.1 Comparison of Elemental Shear
The models are equated in the elemental level. Three Columns are selected whose position is shown in Figure 3. Shear acting on these columns are compared so as to obtain an elementary level of evaluation of various models [12].

![Fig. 3. Position of Selected Columns](image)

At the top storey columns comparison of shear in X- direction shown in the Table 3, comparison of shear in Z - direction shown in the Table 4, at bottom storey column comparison of shear in X- direction shown in the Table 5, comparison of shear in Z - direction shown in the Table 6.

| Table 3: Comparison of shear in x direction |
|-----------------|-----------------|-----------------|
| SI.NO | Model 1 | Model 2 | Model 3 |
| Column 1 | 4.47 KN | 3.53 KN | 3.60 KN |
| Column 2 | 4.63 KN | 3.48 KN | 3.49 KN |
| Column 3 | 4.63 KN | 3.48 KN | 3.49 KN |

| Table 4: Comparison of shear in z direction |
|-----------------|-----------------|-----------------|
| SI.NO | Model 1 | Model 2 | Model 3 |
| Column 1 | 4.37 KN | 4.18 KN | 4.16 KN |
| Column 2 | 4.37 KN | 4.18 KN | 4.16 KN |
| Column 3 | 4.57 KN | 4.25 KN | 4.19 KN |
Table 5: Comparison of shear in x direction (Bottom storey)

| SI.NO | Model 1     | Model 2     | Model 3     |
|-------|-------------|-------------|-------------|
| Column 1 | 237.96 KN   | 137.56 KN   | 125.98 KN   |
| Column 2 | 220.64 KN   | 129.88 KN   | 121.72 KN   |
| Column 3 | 232.20 KN   | 129.88 KN   | 121.72 KN   |

Table 6: Comparison of shear in z direction (Bottom storey)

| SI.NO | Model 1     | Model 2     | Model 3     |
|-------|-------------|-------------|-------------|
| Column 1 | 105.82 KN   | 119.68 KN   | 111.76 KN   |
| Column 2 | 187.65 KN   | 115.00 KN   | 4.16 KN     |
| Column 3 | 185.73 KN   | 119.67 KN   | 4.19 KN     |

Comparation the values of both top storey and bottom storey columns it is understood that the Wide Column model appeals stiffer than the accurate shell element model, it is reflected by the improved shear attracted by it. It is seen that the Equivalent Strut model attracts shear similar to the shear attracted by the Shell Element model.

7.2 Comparison of Storey Drift

Storey drift of these three models is compared. The wide column model has not captured the lateral stiffness properly, that is reflected by the higher levels of storey drift and since the drift is higher it is attracting more shear. Comparison of storey drift in x direction shown in the Figure 4. In z direction, model 2 underestimated the stiffness i.e., it didn’t capture the shears of RC walls in that direction properly. Therefore, it is concluded that the strut width chosen here based on the proposal by Priestly is not sufficient. Hence, it is anticipated to choose a better strut that can detect stiffness properly. In this case the result obtained is entirely contradictory with that obtained in case of storey drift along x axis. On later examination it was deduced that the Equivalent Static Analysis is not valid in case of the analysis of Irregular structures whose fundamental mode is Torsion, Comparison of storey drift in z direction shown in the Figure 5.

Fig. 4. Comparison of storey drift in x direction

Fig. 5. Comparison of storey drift in z direction

The building under consideration is an irregular one with fundamental mode torsion. Hence it can be concluded that the Equivalent Static Analysis is not reliable in case of such structures.

7.3 Comparison of Computational Time

The time required for the equivalent static analysis of model 1, model 2 and model 3 are 70 s, 107 s and 1433 s respectively i.e., the equivalent strut model requires 1.5 times and shell element model requires 20.5 times the computational time required for the wide column model.
8. Response Spectra Analysis in STAAD PRO

In the calculation of structural response (whether modal analysis or otherwise), the structure should be so represented by means of an analytical or computational model that reasonable and rational results can be obtained by its behaviour. When response spectrum method is used with modal analysis procedure, at least 3 modes of response of the structure should be considered except in those cases where it can be expressed qualitatively that either third mode or the second mode produces negligible response. The model maxima should be joined using the square root of the sum of the squares of the individual model values. In this method the building is considered as a flexible structure with lumped masses concentrated at floor levels, with each mass having one degree of freedom that of lateral displacement in the direction under consideration. The procedure is

- IS 1893:2002 seismic definitions are defined by providing seismic parameters.
- Seismic loadings are provided under the seismic definition which include self-weight and floor load comprising of floor dead load of 15.44 kN and roof dead load of 6.24 kN; and live include of 0.625 kN (only 25% of floor live load considered for seismic analysis a/c to IS 1893:2002 cl.7.3.1).
- Dead loads of 15.44 kN and 6.24 kN are added in load case 1.
- Loadings defined in seismic definitions are assigned in x, y and z directions with a factor of 1 load case 2.
- Response spectrum definitions for IS 1893:2002 are also provided in load case 2 in x and z directions with a factor (Z/2) (I/R) through a damping factor of 0.05.
- After analysis it should be checked whether base shear (VB) from response spectrum is less than base shear (Vb) calculated using empirical formula for fundamental time period. If so a multiplication factor of Vb/VB applied on response spectrum definition factor and the analysis is repeated till factor becomes 1.
- Response spectrum factor = (Z/2) (I/R) = (0.16/2) (1/3) = 0.0257
- Corrected factor = 0.0257 x 1.1089 = 0.03
- The analysis results obtained are compared for the three models considering global comparison by base shear and elemental comparison by column shear and storey drift values.

8.1 Response Spectrum Analysis Results of the Structure (Comparison of base shear)
The models are compared in the global level, Comparison of base shear shown in the Table 7

| Table 7: Comparison of Base shear |
|----------------------------------|
| Model | Model 1 | Model 2 | Model 3 |
| X/Z | X/Z | X/Z | X/Z |
| Base Shear | 3745.76 | 4332.72 | 3749.78 | 3749.56 | 4185.61 | 2545.86 |

It is observed that in the x direction, the base shear attracted by the wide column and equivalent strut model are alike and varies a bit from the precise shell element model. But in z direction, both the model 1 and model 2 attracts much greater shear than the model 3.

8.2 Comparison of peak storey shears
The three models are compared in the storey level and the comparison of peak storey in the X direction shown in the Table 8

| Table 8: Comparison of Peak Storey Shear in the X direction |
|-------------------------------------------------------------|
| Floor | Model 1 | Model 2 | Model 3 |
| 16 | 285.55 | 162.81 | 4185.61 |
| 15 | 799.77 | 504.84 | 627.77 |
The storey shear attracted by the wide column model and equivalent strut model are similar. In the wide column model, the top storeys attract more shear i.e., more than that attracted by the shell element model. But the bottom storeys attract lesser shear. The equivalent strut model attracts lesser than the shell element model. The shear involved is comparable to the standard model in the top storeys but deviates clearly in the bottom storey’s comparison of peak storey in the Z direction shown in the Table 9.

Table 9: Comparison of Peak Storey Shear in the Z direction

| Floor | Model 1 (kN) | Model 2 (kN) | Model 3 (kN) |
|-------|--------------|--------------|--------------|
| 16    | 288.54       | 233.79       | 186.63       |
| 15    | 816.93       | 654.16       | 528.35       |
| 14    | 1273.41      | 978.21       | 794.58       |
| 13    | 1658.70      | 1226.08      | 1002.29      |
| 12    | 1980.29      | 1421.35      | 1177.46      |
| 11    | 2250.67      | 1582.68      | 1329.88      |
| 10    | 2492.69      | 1725.82      | 1458.74      |
| 9     | 2722.64      | 1864.55      | 1571.74      |
| 8     | 2942.53      | 2011.50      | 1673.66      |
| 7     | 3156.39      | 2174.75      | 1778.85      |
| 6     | 3365.22      | 2359.56      | 1890.93      |
| 5     | 3567.47      | 2572.97      | 2009.35      |
| 4     | 3758.05      | 2823.42      | 2130.20      |
| 3     | 3930.05      | 3065.78      | 2245.55      |
| 2     | 4075.69      | 3307.13      | 2354.49      |
| 1     | 4192.49      | 3521.08      | 2454.54      |
| 0     | 4265.13      | 3665.97      | 2499.39      |
| -1    | 4332.72      | 3748.68      | 2544.85      |
| Support | 4332.72  | 3749.56      | 2545.86      |

In the z direction, both the wide column model and shell element model attracts greater shear than the standard shell element model. All three models attract similar shear in the above storeys but deviates...
towards the bottom storeys. The wide column model attracts much more shear than the equivalent strut model.

### 8.3 Comparison of elemental shear

The shear attracted by the columns are compared by selecting 3 columns whose positions are marked in the Figure 6.

![Figure 6: Position of selected columns](image)

The high storey contrast of shear in X direction shown in the Table 10, high storey contrast of shear in Z direction shown in the Table 11.

| Model  | Column 1 | Column 2 | Column 3 |
|--------|----------|----------|----------|
|        | 4.47 KN  | 3.54 KN  | 5.36 KN  |
|        | 4.82 KN  | 2.92 KN  | 3.96 KN  |
|        | 4.82 KN  | 2.29 KN  | 3.96 KN  |

**Table 10: Top storey comparison of Shear in x direction**

| Model  | Column 1 | Column 2 | Column 3 |
|--------|----------|----------|----------|
|        | 13.75 KN | 4.87 KN  | 7.63 KN  |
|        | 14.00 KN | 2.63 KN  | 2.85 KN  |
|        | 14.00 KN | 2.63 KN  | 2.85 KN  |

**Table 11: Top storey Comparison of Shear in z direction**

The bottom storey comparison of shear in X direction shown in the Table 12, bottom storey comparison of shear in Z direction shown in the Table 13.

| Model  | Column 1 | Column 2 | Column 3 |
|--------|----------|----------|----------|
|        | 135.91 KN| 115.69 KN| 128.94 KN|
|        | 136.92 KN| 130.13 KN| 126.16 KN|
|        | 136.92 KN| 130.13 KN| 126.16 KN|
### Table 13: Bottom storey comparison of Shear in z direction

|        | Model 1   | Model 2   | Model 3   |
|--------|-----------|-----------|-----------|
| Column 1 | 135.79 KN | 154.62 KN | 187.26 KN |
| Column 2 | 112.48 KN | 192.61 KN | 155.01 KN |
| Column 3 | 112.49 KN | 192.61 KN | 154.52 KN |

In the top storey columns, the shear attracted by the wide column model is similar to that attracted by the shell element model. But in the bottom storey columns, the shears attracted by the equivalent strut model and the shell element model are similar.

#### 8.4 Comparison of Storey Drift

The contrast of storey drift in X direction shown in the Table 14

### Table 14: Comparison of Storey drift in x direction

| Floor | Model 1 | Model 2 | Model 3 |
|-------|---------|---------|---------|
| 16    | 13.704  | 9.557   | 9.652   |
| 15    | 13.220  | 8.924   | 9.209   |
| 14    | 12.592  | 8.264   | 8.679   |
| 13    | 11.814  | 7.588   | 8.109   |
| 12    | 10.900  | 6.908   | 7.505   |
| 11    | 9.891   | 6.237   | 6.875   |
| 10    | 8.834   | 5.588   | 6.225   |
| 9     | 8.060   | 4.970   | 5.653   |
| 8     | 7.269   | 4.39    | 5.072   |
| 7     | 6.454   | 3.856   | 4.489   |
| 6     | 5.608   | 3.359   | 3.906   |
| 5     | 4.736   | 2.893   | 3.327   |
| 4     | 3.920   | 2.451   | 2.773   |
| 3     | 3.090   | 2.020   | 2.230   |
| 2     | 2.256   | 1.593   | 1.702   |
| 1     | 1.436   | 1.161   | 1.193   |
| 0     | 0.203   | 0.726   | 0.712   |
| -1    | 0.149   | 0.281   | 0.209   |

The model 2 captures stiffness similar to model 3 and so their storey drift is similar. In this case model 1 does not captures stiffness properly which is reflected as lesser storey drift. The storey drift exhibited
by the equivalent strut model and the shell element model are similar, whereas the storey drift in the wide column model is more.
The contrast of storey drift in Z direction shown in the Table 15

| Floor | Model 1 | Model 2 | Model 3 |
|-------|---------|---------|---------|
| 16    | 13.395  | 18.243  | 17.477  |
| 15    | 12.727  | 17.516  | 16.884  |
| 14    | 11.992  | 16.692  | 16.124  |
| 13    | 11.201  | 15.798  | 15.249  |
| 12    | 10.366  | 14.834  | 14.285  |
| 11    | 9.501   | 13.820  | 13.255  |
| 10    | 8.620   | 12.774  | 12.183  |
| 9     | 7.798   | 11.715  | 11.262  |
| 8     | 6.968   | 10.646  | 10.316  |
| 7     | 6.137   | 9.520   | 9.343   |
| 6     | 5.319   | 8.489   | 8.340   |
| 5     | 4.505   | 7.397   | 7.305   |
| 4     | 3.728   | 6.304   | 6.269   |
| 3     | 2.927   | 5.190   | 5.202   |
| 2     | 2.263   | 4.059   | 4.108   |
| 1     | 1.592   | 2.918   | 2.990   |
| 0     | 0.973   | 1.784   | 1.869   |
| -1    | 0.403   | 0.659   | 0.770   |

The model 2 captures stiffness similar to model 3 and so their storey drift is similar. In this case model 1 does not captures stiffness properly which is reflected as lesser storey drift. The storey drifts of the equivalent strut model and the shell element model are similar whereas that of the wide column model is lesser.

8.5 Comparison of Computational Time
The time required for wide column model, equivalent strut model and shell element model is 137 s, 170 s and 3375 s respectively i.e., the equivalent strut model requires 1.24 times and shell element model requires 24.64 times larger effort than the wide column model.
9.0 CONCLUSIONS

A simplified modelling strategy for reinforced concrete walls for seismic analysis i.e. the modelling of RC walls as equivalent struts was attempted. Efficiency of the model has been compared with that of more precise solution using shell element. The contrast is done for three analysis methods. The three methods are the most widely used seismic analysis strategies, Equivalent Static Analysis, Response Spectra Analysis and Time History Analysis. The methodology is demonstrated on a G+15 residential apartment building. From the free vibration analysis, it was understood that the fundamental mode is Torsion. The wide column model used by most design officers failed even to capture the correct mode. The equivalent strut model captured the correct mode and mode shapes. The equivalent static analysis was steered and the contradictory results obtained proved that this analysis method doesn’t imply for irregular buildings and to the buildings whose fundamental mode is torsion. The response spectra and time history analysis were held and the results were compared with that of more correct solution using shell element in time history analysis. The results reflected that the equivalent strut model applied as a simplified modelling strategy for RC walls. But this doesn’t capture lateral stiffness properly in some cases. It can be concluded that the corresponding strut width calculated using Priestley’s formula, which is commonly used is not appropriate. A new equivalent strut width has to be proposed and it possess the ability to capture the free vibrational characteristics of the structure more accurately. It can be done as a future work and is beyond the scope of present study. Manual design of shear wall was done through the analysis results obtained from STAAD PRO using provisions of IS 13920: 1993. The beams and columns were designed using STAAD.

10.0 References

1. Om Prakash Mahato, M. Anil Kumar, “Study on Effect of Geometry on RC Multistory Building Under Seismic Load” International Journal of Recent Technology and Engineering (IJRTE), ISSN: 2277-3878, Volume-7, Issue-6C2, April 2019.

2. Mohammad Tasleema, M. Anil Kumar, J. Leon Raj, “Evaluation of Shear Strength of Deep Beams using Artificial Neural Networks” International Journal of Recent Technology and Engineering (IJRTE), ISSN: 2277-3878, Volume-7, Issue-6C2, April 2019.

3. Fayaz, S. K., Kishore, I. S., Chowdary, C. M., & Brahmachari, K. J. (2019). Numerical analysis of cold formed steel compression members based on buckling profile under eccentric loading. International Journal of Recent Technology and Engineering, 7(6C2), 42–48.

4. Md. Rafi, P., & Chari, K. J. B. (2019). 5D applications of BIM in construction management. International Journal of Recent Technology and Engineering, 7(6C2), 97–101.

5. Naresh, M. V, & Chari, K. J. B. (2019). Study on static and dynamic analysis of multi-storied building in seismic zones. International Journal of Recent Technology and Engineering, 7(6C2), 154–159.

6. E.V.V.S.N.Sai Kausik, I. Siva Kishore, N. Sandeep Kumar, Ch. Mallika Chowdary, (April 2019) “Behavior of circular CFST columns with central wood piece under biaxial loading”, International journal of recent technology and engineering (IJRTE), Volume-7, Issue-6C2, Pages 220-224.
7. Sk. Fayaz, I. Siva Kishore, Ch. Mallika Chowdary, K.J. Brahmachari, (April 2019) “Numerical analysis of cold formed steel compression members based on buckling profile under eccentric loading”, International journal of recent technology and engineering (IJRTE), Volume-7, Issue-6C2, Pages 42-48.

8. V. V. L. Dinesh sai, N. Lingeshwaran, Experimental Investigation on Reinforced Masonry walls under axial load, International Journal of Recent Technology and Engineering, Volume 7(6C2), 225 (2019). DOI: F10630476C219.

9. Harihara Venkata Nagasai, P. Bhargav reddy, V. Rama Krishna Kolli, N. Lingeshwaran, Comparison between seismic and non-seismic analysis of Multi storey building, International Journal of Recent Technology and Engineering, Volume 6(6C2), DOI: F11240476C219.

10. Venugopal, S. & Kumar, K.D. & Singh, S. &Nagarathinam, Lingeshwaran. (2017). Analysis and design of a (G+4) building. International Journal of Civil Engineering and Technology. 8. 260-266.

11. Girish, N &Nagarathinam, Lingeshwaran. (2018). A Comparative Study of Flat Slabs Using Different Shear Reinforcement Parameters. International Journal of Engineering & Technology. 7. 321. 10.14419/ijet.v7i2.20.16725.

12. Kumar, K. S., Lingeshwaran, N., & Jeelani, S. H. (2020). Analysis of residential building with STAAD. Pro & ETABS. Materials Today: Proceedings, 33, 1221-1228.