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SIGNIFICANCE OF POSITION OF SHEAR WALL IN RC STRUCTURE UNDER SEISMIC LOADING

[1]AMMU WILSON, [2]Dr. CHETHAN K

[1].PG Student, Department of Civil Engineering, U.V.C.E, Bangalore University, Bengaluru

[2].Associate professor, Department of Civil Engineering, U.V.C.E , Bangalore University, Bengaluru

Abstract-*In modern high rise buildings, shear walls are generally used as a vertical structural element for resisting the lateral loads that is induced by the effect of wind and earthquakes. A shear wall may contain many openings due to the functional requirements such as doors and windows, which may largely affect the overall seismic response of the structure. This study is carried out on a G+9 storey RC framed building with different configurations of shear wall. The percentage of openings varies from 0% to 100% for all configurations of RC shear wall building. FE analysis such as Modal, Equivalent static and Response spectrum analysis are performed to obtain Natural frequency, Mode shapes, Base shear, Displacement, and Storey Drift. All the results acquired are tabulated, discussed and conclusions are drawn.*

Key Words:*Shear wall, Openings, FE Analysis*

1. INTRODUCTION

Shear walls are vertical elements of the horizontal force resisting system. Shear walls are constructed to counter the effects of lateral load acting on a structure. In residential construction, shear walls are straight external walls that typically form a box which provides all of the lateral support for the building. When shear walls are designed and constructed properly, and they will have the strength and stiffness to resist the horizontal forces. In building construction, a rigid vertical diaphragm capable of transferring lateral forces from exterior walls, floors, and roofs to the ground foundation in a direction parallel to their planes.

Shear walls should be provided along preferably both length and width. However, if they are provided along only one direction, a proper grid of beams and columns in the vertical plane (called a moment-resistant frame) must be provided along the other direction to resist strong earthquake effects. Door or window openings can be provided in shear walls, but their size must be small to ensure least interruption to force flow through walls. Moreover, openings should be symmetrically located.

2. METHODOLOGY

The methodology adopted for this dissertation is as follows:

- Detailed literature review to comprehend the previous work done and review the national and international codal provisions available on RC shear walls with and without openings.
- Validation of the models using the journal "Influence of openings in shear wall in high rise buildings by Harshal M. Banubakode and Bhushan H. Shinde, GH Raisoni college of engineering and management, Amaravathi, India.
- Design of RC shear wall using IS 456-2000, IS 1893(part-1)-2016 and SP-16.
- Generation of response spectrum for particular seismic zone as per IS 1893(Part-1):2016 code which is utilized for the analysis to be carried out on the RC shear wall structure.
- The modal analysis on RC Shear wall structure with and without openings is carried out to get Natural frequencies and Mode shapes using ETABS software.
- Equivalent static analysis are carried out on RC Shear wall structure with and without openings for Seismic zone V as per IS 1893(part-1)-2016 to get Base Shear and Response Spectrum analysis is carried out for the same to get Storey Displacement, Storey Drift.
- Comparison of the results obtained from the analysis with the permissible values of codes as per IS 1893-2016 with and without openings and drawing out detailed conclusions of the work.

3. DESCRIPTION OF MODELS

Notations of the models used for the analysis used for analysis is given in table 3.1

Table 3.1 Notations of the models used for the analysis

Bare Frame	BF
Core Shear wall	CW
Corner shear wall	CS
Corner shear wall + Core	CSC
Edge Shear wall+ Corner shear wall(1 bay)	CE1
Edge Shear wall+ Corner shear wall + Core(1 bay)	CE1C
Edge Shear wall(1 bay)	ES1
Edge Shear wall+ Core(1 bay)	ES1C

Edge Shear wall (3 bay)	ES3
Edge Shear wall+ Core (3 bay)	ES3C

3.1 Material properties

- Number of storey: G + 9
- Floor plan dimension: 30m x 30m
- Bay distance: 6m x 6m
- Floor height: 3.0 m
- Size of beam: (300x 450) mm
- Size of column: (600x 600) mm
- Depth of Slab: 150 mm
- Thickness of shear wall: 300mm
- Materials: M 40 concrete, Fe 415 steel

3.2 Preliminary load considerations

- Live load: 3 kN/m²
- Floor finish: 1.0 kN/m²
- Wall load (periphery): 13.248 kN/m

3.3 Seismic data

- Seismic Zone: II,III,IV,V
- Zone factor: (0.1),(0.16),(0.24),(0.36)
- Type of Soil: Medium (II)
- Importance Factor: 1.2
- Response Reduction Factor: 5
- Type of frame: RC buildings with Special moment resisting frame

4. MODELSUSED FOR FE ANALYSIS

All the models along with openings used for FE analysis are shown from fig 4.1 to fig 4.18

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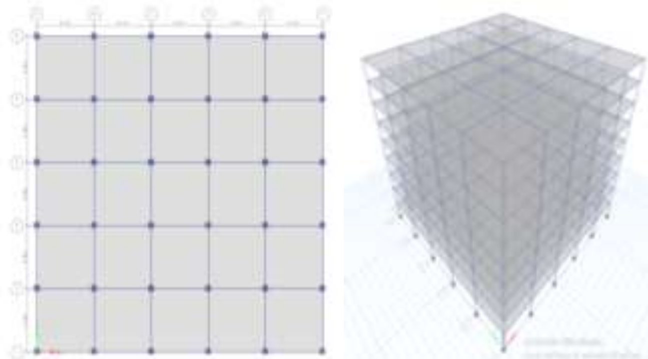

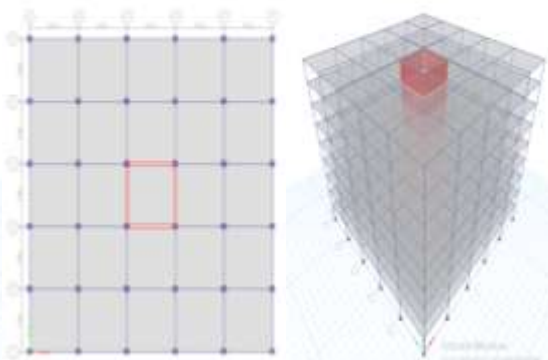

Fig 4.1: Bare Frame model**Fig 4.2:** Core Shear wall model

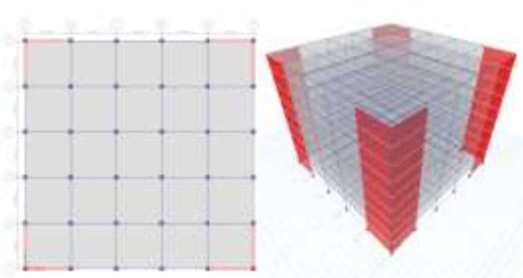

Fig 4.3: Corner Shear wall model

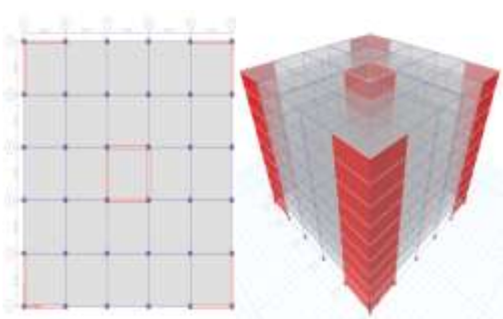

Fig 4.4: Corner Shear wall + Core model

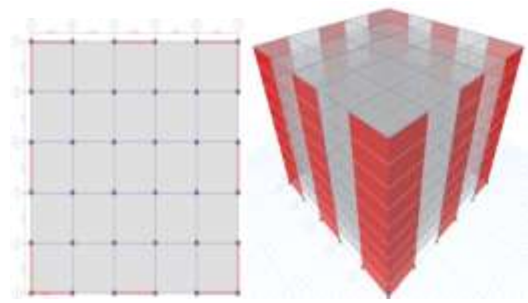

Fig 4.5: Edge Shear wall + Corner shear wall model

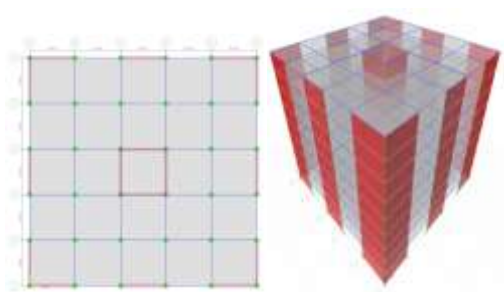

Fig 4.6: Edge Shear wall +Corner shear wall+ Core model

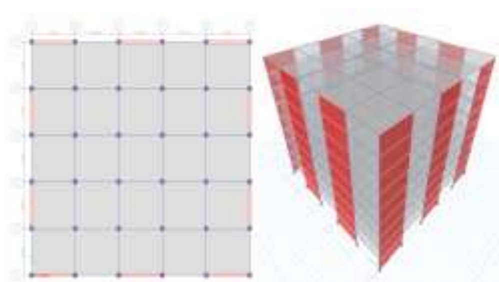

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Fig 4.7: Edge Shear wall (1 bay)

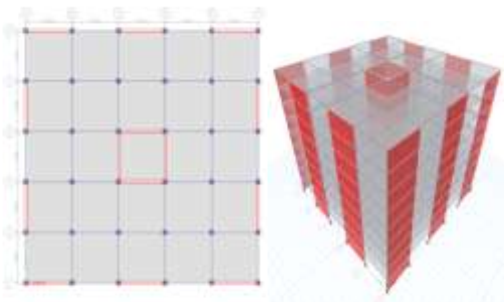


Fig 4.8: Edge Shear wall (1 bay) + Core model

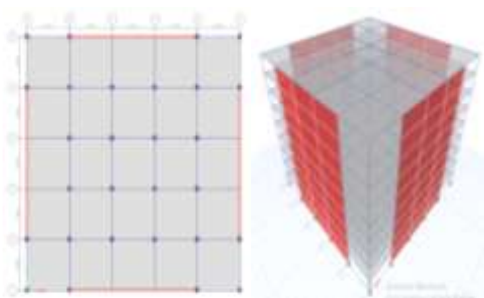


Fig 4.9: Edge Shear wall (3 bays)model

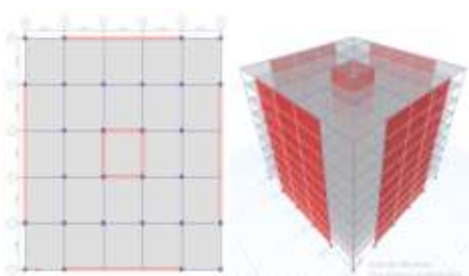


Fig 4.10: Edge Shear wall (3 bays) **+** Coremodel

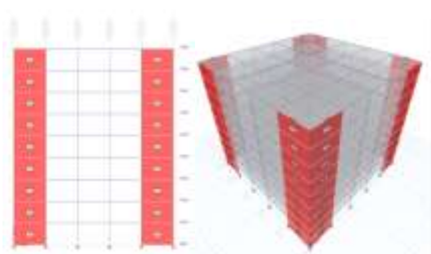


Fig 4.11: Corner Shear wall model with 5% Openings

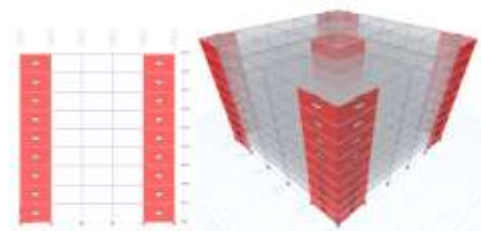


Fig 4.12: Corner Shear wall+ Core model with 5% Openings

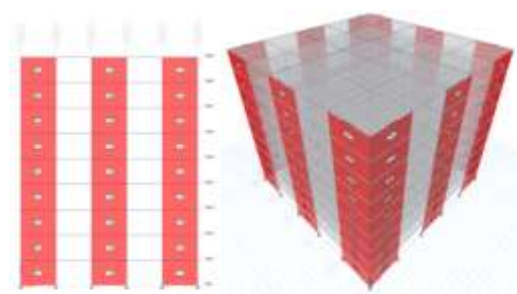


Fig 4.13: Edge shear wall + Corner Shear wall with 5% Openings

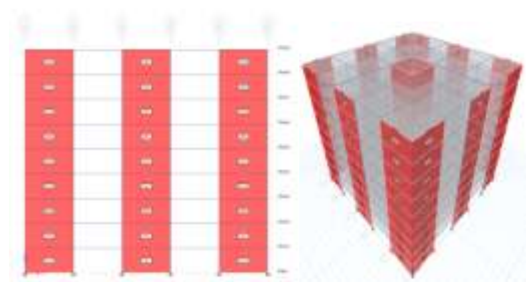


Fig 4.14: Edge shear wall +Corner Shear wall + Core model with 5% Openings

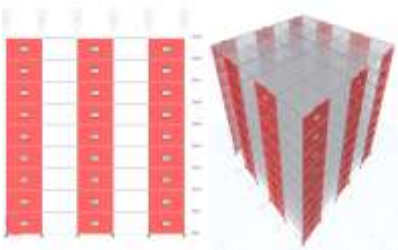


Fig 4.15: Edge shear wall (1 bays) with 5% Openings

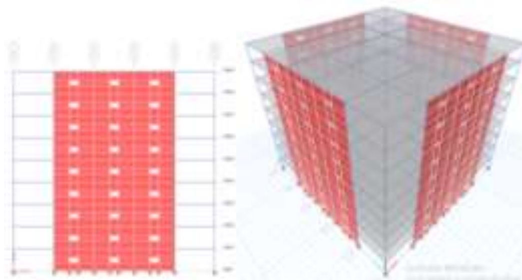


Fig 4.17: Edge shear wall (3 bays) with 5% Openings

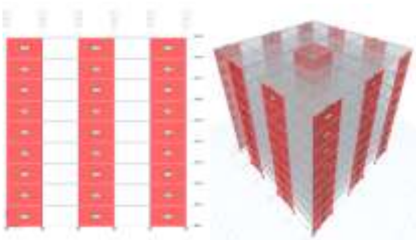


Fig 4.16: Edge shear wall (1 bays) + Core with 5% Openings

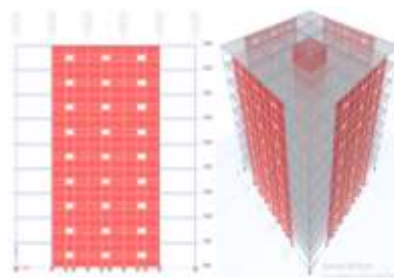


Fig 4.18: Edge shear wall (1 bays) +Core model with 5% openings

5. RESULTS

Shear walls are located at different positions such as Core, Edge, Edge + Core, Corner & Corner + Core in the RC structure along with openings in Shear walls varying from 0% to 100%. FE analysis including modal, Equivalent static and Response Spectrum analysis are performed and results such as Natural Frequencies, Modal shape Base Shear are obtained

5.1 Natural frequency

The results obtained from the modal analysis of models with and without opening is given in table 5.1 and 5.2 respectively

Table 5.1: Natural frequency of the models

NATURAL FREQUENCY(Hz)	
BF	0.643
CW	2.078
CS	2.617
CSC	2.833
CE1	2.583
CE1C	3.467
ES1	1.953
ES1C	2.759
ES3	4.422
ES3C	4.663
As per IS Code	2.028

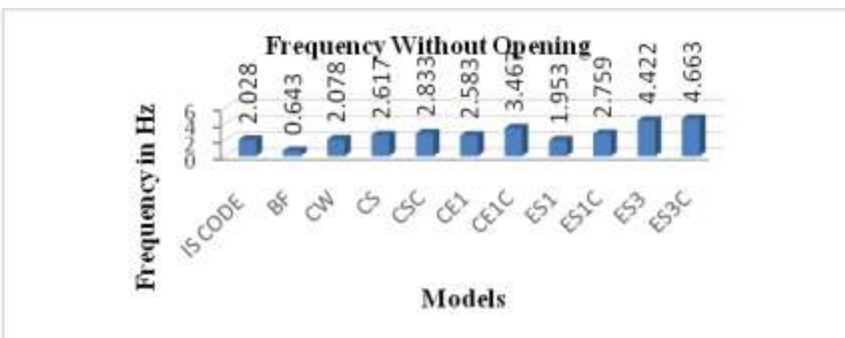
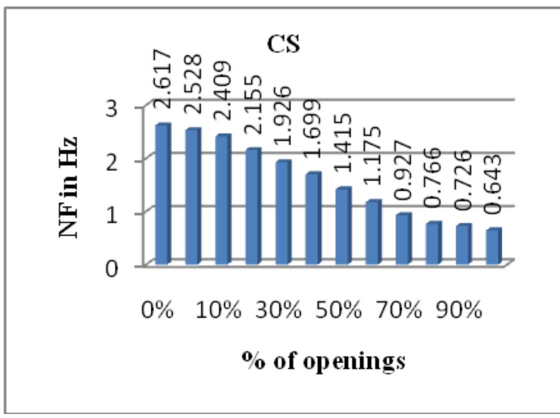


Fig 5.1:Natural frequency of the models

Table 5.2: Natural Frequency of the models with openings

NATURAL FREQUENCY(Hz)								
% Openings	CS	CSC	CE1	CE1C	ES1	ES1C	ES3	ES3C
0%	2.617	2.833	2.583	3.467	1.953	2.759	4.422	4.663

5%	2.528	2.833	2.584	3.25	1.954	2.739	4.245	4.512
10%	2.409	2.739	2.475	3.141	1.875	2.65	4.036	4.335
20%	2.155	2.624	2.357	3.01	1.783	2.546	3.639	4.013
30%	1.926	2.401	2.11	2.754	1.608	2.357	3.238	3.69
40%	1.699	2.206	1.885	2.53	1.43	2.167	2.855	3.402
50%	1.415	2.023	1.663	2.32	1.261	1.998	2.368	3.059
60%	1.175	1.807	1.385	2.072	1.046	1.797	1.953	2.787
70%	0.927	1.638	1.15	1.879	0.863	1.637	1.526	2.53
80%	0.766	1.479	0.907	1.697	0.674	1.486	1.246	2.38
90%	0.526	1.387	0.749	1.591	0.55	1.398	0.875	2.192
BF	0.643	0.643	0.643	0.643	0.643	0.643	0.643	0.643



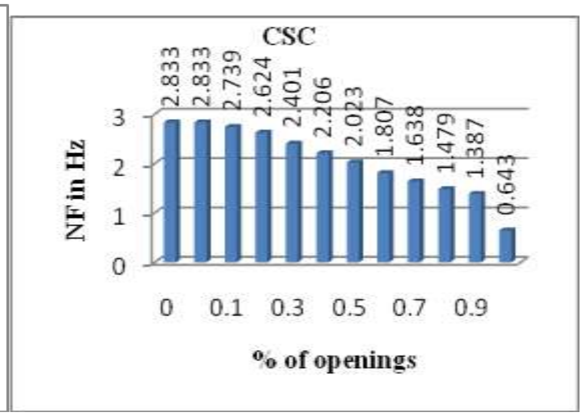
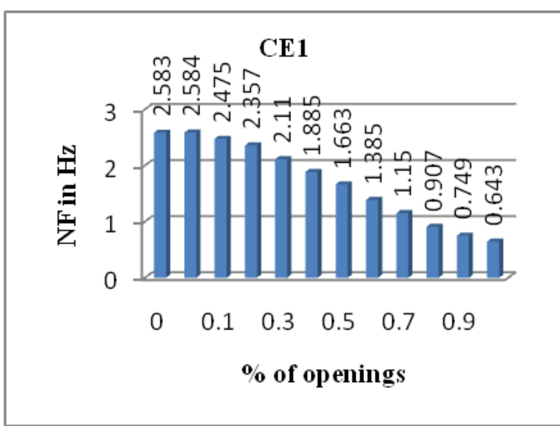


Fig 5.2: Natural frequency of CS with openings Fig 5.3: Natural frequency of CSC with openings



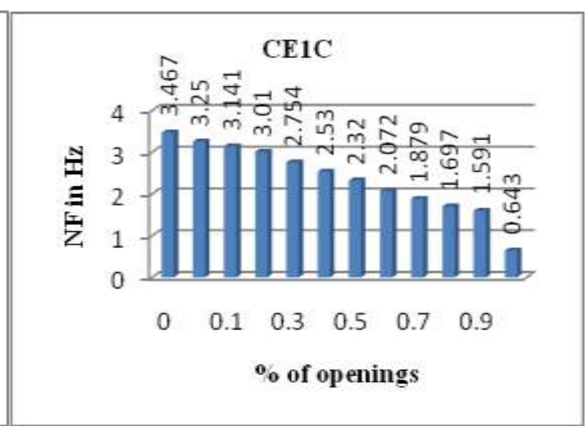
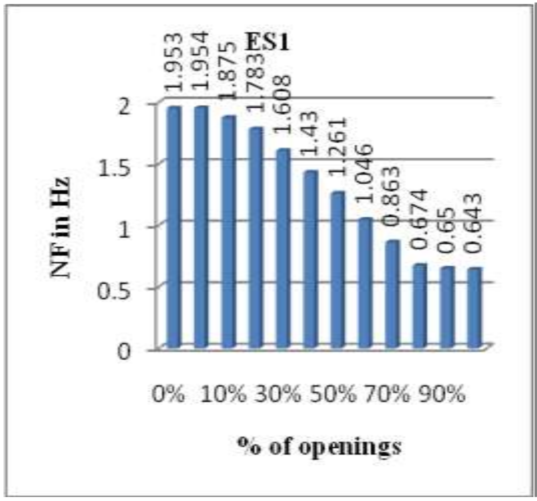


Fig 5.4: Natural frequency of CE1 with openings Fig 5.5: Natural frequency of CE1C with openings



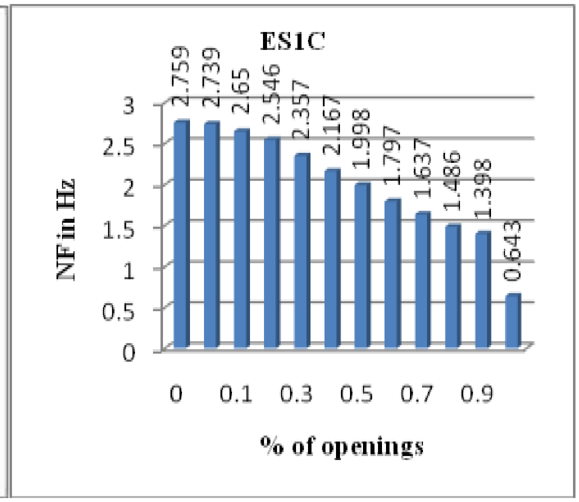
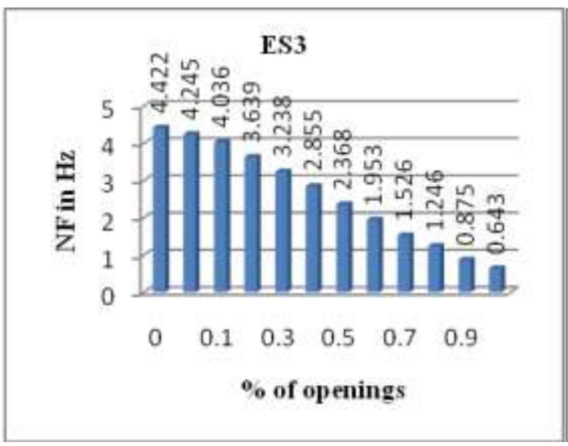


Fig 5.6: Natural frequency of ES1 with openings Fig 5.7: Natural frequency of ES1C with openings



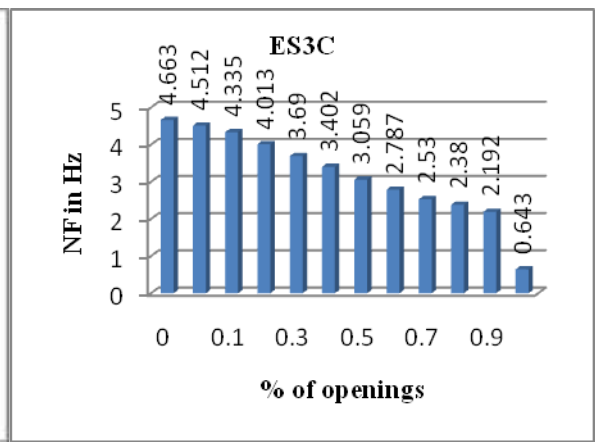


Fig 5.8: Natural frequency of ES3 with openings Fig 5.9: Natural frequency of ES3C with openings

Following are the discussion regarding the results of Natural Frequency

1. Natural Frequency obtained from IS 1893-2016 closely matches only with the Frequency obtained from Core shear wall model emphasize the shortfall of IS code
2. Natural frequency of ES1C, ES3C,CE1C and CSC is slightly greater than ES1,ES3,CE1 and CS respectively due to the stiffness offered by the core
3. Natural frequency of CW,CS,CSC,CE1,CE1C,ES1,ES1C,ES3,ES3C is 69% ,75% ,77% ,75% ,81% ,67% ,76% ,85% ,86%, greater than natural frequency of BF respectively
4. The increase in natural frequency between CS&CSC ,CE1&CE1C ,ES1&ES1C ,ES3&ES3C are 7%, 25%, 30%, 6% respectively

5. Due to the presence of core wall CSC,CE1C,ES1C & ES3C the reduction in natural frequency is small as the % of openings increases.
6. The increase in natural frequency between CS&CSC ,CE1&CE1C ,ES1&ES1C ,ES3&ES3C at 90% openings are 47%, 53%, 54%, 60% respectively
7. Natural frequency of ES1C, ES3C,CE1C and CSC at 90% openings is 53%,59%,54% & 70% greater than BF respectively

5.2 Base Shear

The results obtained from the equivalent static analysis of models with and without opening is given in table 5.3 and 5.4respectively

Table 5.3: Base shear of the models

Models	BASE SHEAR (kN)
BF	2423
CW	8380
CS	9156
CSC	9745
CE1	9763
CE1C	9984
ES1	9357
ES1C	9731
ES3	9298
ES3C	9731

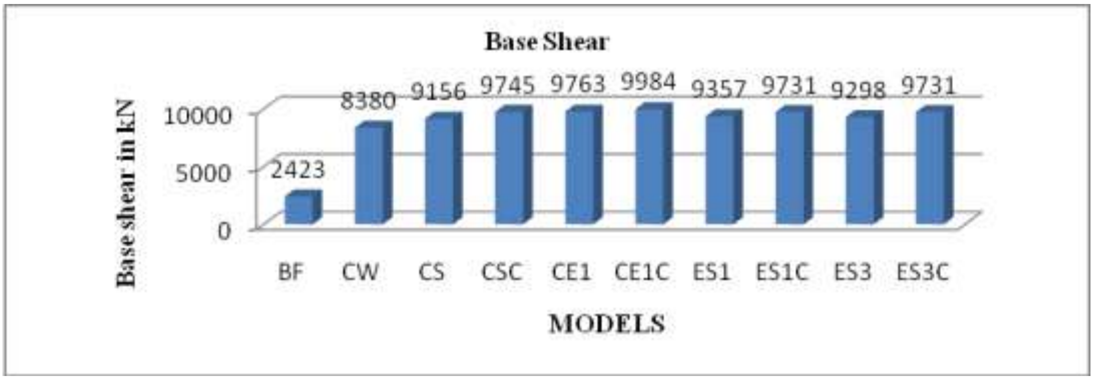
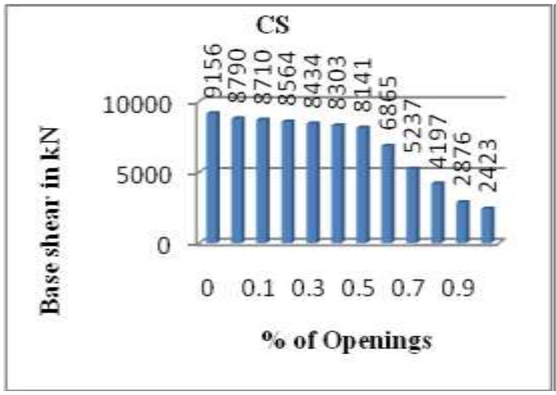


Fig 5.11: Base shear of the models

Table 5.3: Base shear of the models

% Openings	CS	CSC	CE1	CE1C	ES1	ES1C	ES3	ES3C
0%	9156	9745	9763	9984	9357	9731	9298	9731
5%	8790	9230	9230	9662	9290	9662	9230	9662
10%	8710	9145	9145	9578	9210	9578	9145	9578
20%	8564	8992	8992	9425	9063	9425	8992	9425
30%	8434	8856	8856	9289	8932	9289	8856	9289
40%	8303	8718	8718	9151	8799	9151	8718	9151
50%	8141	8548	8548	8980	8635	8980	8548	8980
60%	6865	7208	7208	8833	8493	8833	7208	8833
70%	5237	5499	5499	8674	8340	8674	5499	8674
80%	4197	4407	4407	8553	8224	8553	4407	8553
90%	2876	3020	3020	8155	7841	8155	3020	8155
BF	2423	2423	2423	2423	2423	2423	2423	2423



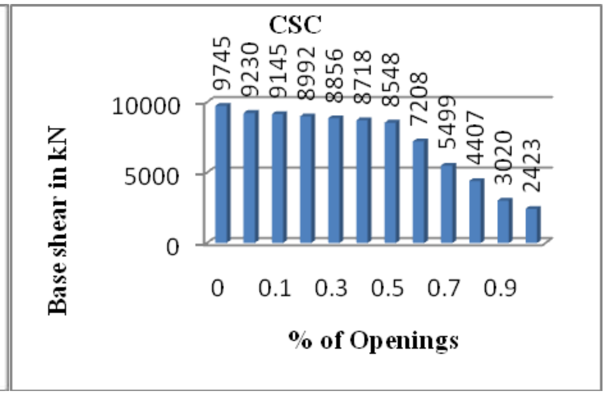
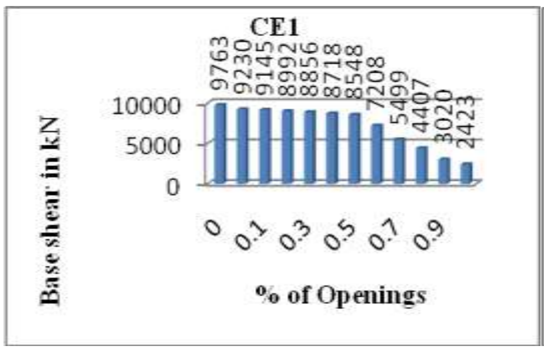


Fig 5.12: Base shear of CS with openings

Fig 5.13 : Base shear of CSC with openings



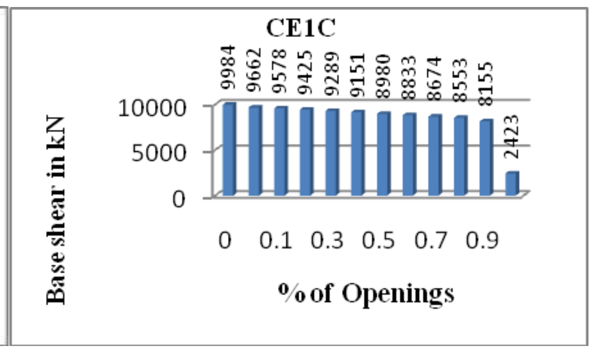
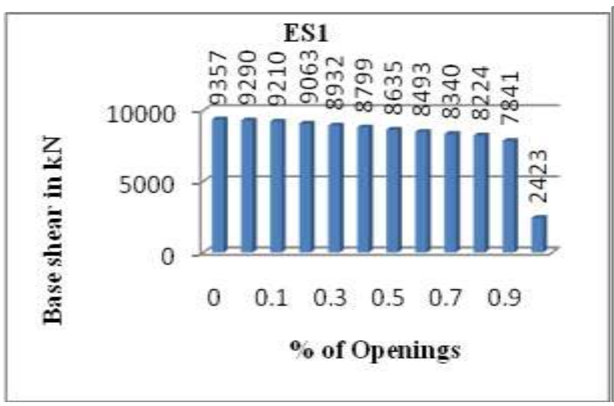


Fig 5.14: Base shear of CE1 with openings

Fig 5.15 : Base shear of CE1C with openings



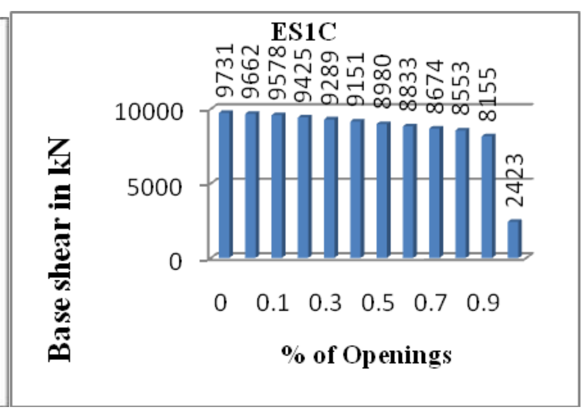


Fig 5.16: Base shear of ES1 with openings

Fig 5.17 : Base shear of ES1C with openings

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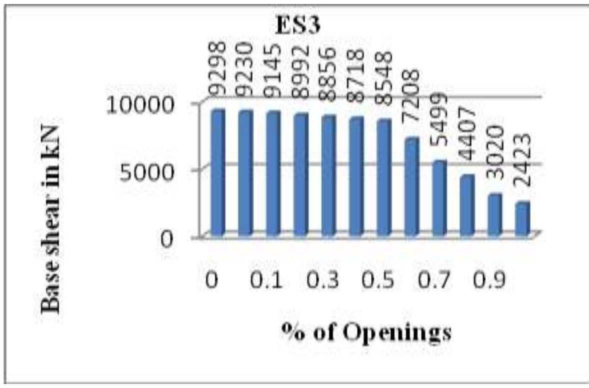

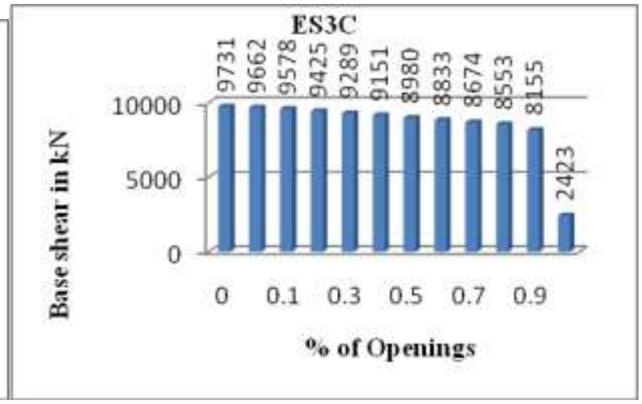

Fig 5.18: Base shear of ES3 with openings

Fig 5.19 : Base shear of ES3C with openings

Following are the discussion regarding the results of Base Shear

1. The value of base shear remains the same irrespective of the position of shear wall as base shear completely depends on the weight of the structure. The base shear value of CSC,CE1 & ES3 are almost similar and same pattern can be found in the base shear value of ES3C & CE1C
2. The base shear value of CSC, CE1C, ES1C & ES3C gradually decreases with increase in the % of openings compared to ES1, ES3, CE1 and CS highlighting the stiffness of core.
3. The base shear value of CE1C, ES1, ES1C and ES3C shows a sudden drop with increase in % of openings from 90% to 100% highlighting the reduction of mass of the RC structure.

6. CONCLUSION

1. Natural Frequency obtained from IS 1893-2016 closely matches only with the Frequency obtained from Core shear wall model emphasize the shortfall of IS code
2. Natural frequency of ES1C, ES3C,CE1C and CSC is slightly greater than ES1,ES3,CE1 and CS respectively due to the stiffness offered by the core
3. Natural frequency of CW,CS,CSC,CE1,CE1C,ES1,ES1C,ES3,ES3C is 69% ,75% ,77% ,75% ,81% ,67% ,76% ,85% ,86%, greater than natural frequency of BF respectively
4. The increase in natural frequency between CS&CSC ,CE1&CE1C ,ES1&ES1C ,ES3&ES3C are 7%, 25%, 30%, 6% respectively
5. Due to the presence of core wall CSC,CE1C,ES1C & ES3C the reduction in natural frequency is small as the % of openings increases.
6. The increase in natural frequency between CS&CSC ,CE1&CE1C ,ES1&ES1C ,ES3&ES3C at 90% openings are 47%, 53%, 54%, 60% respectively
7. Natural frequency of ES1C, ES3C,CE1C and CSC at 90% openings is 53%,59%,54% & 70% greater than BF respectively

8. The value of base shear remains the same irrespective of the position of shear wall as base shear completely depends on the weight of the structure. The base shear value of CSC,CE1 & ES3 are almost similar and same pattern can be found in the base shear value of ES3C & CE1C
9. The base shear value of CSC, CE1C, ES1C & ES3C gradually decreases with increase in the % of openings compared to ES1, ES3, CE1 and CS highlighting the stiffness of core.
10. The base shear value of CE1C, ES1, ES1C and ES3C shows a sudden drop with increase in % of openings from 90% to 100% highlighting the reduction of mass of the RC structure.

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