Comparative Analysis of Irregular G+11 Storied RC Building With & Without Shear Walls at Different Locations using STAAD.Pro & SAP-2000

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Abstract - *In the past sufficient amount of research was conducted on Analysis of building with and without shear walls. However very little work is found related to Analysis of irregular high rise building with shear walls at different locations. It is relevant that high rise buildings are increasing day by day hence its study is necessary for development point of view. The present work contains the experimental investigation on reducing the size of the member to make structure economical and efficient by locating shear wall at varying places in irregular shape building. When shear walls are situated in advantageous positions in a building, they can be very efficient in resisting lateral loads originating from wind or earthquakes. All the G+11 (12 Storey) irregular High-rise structural buildings models were analysed with Equivalent Lateral Force Analysis, Modal Analysis, Time History and Response Spectrum analysis. These analyses are performed with few limitations of the both STAAD.Pro and SAP-2000 software's. The results that are obtained from the equivalent lateral force analysis, modal analysis, time history analysis and response spectrum analysis includes the max displacements, max moments and shears, mode shapes, time periods and frequencies, time history plots, base reactions for response spectrum case, and finally concrete design are represented for both the software's models.*

Key Words: High Rise Building, Shear Walls, STAAD.Pro, SAP-2000, Equivalent Lateral Force Analysis, Time History Analysis and Response Spectrum Analysis.

1. INTRODUCTION

The height of a building is subjective and can be described neither in terms of height nor number of storeys in absolute terms. But from the perspective of a structural engineer, the high-rise building can be characterized as one that is influenced by lateral forces due to wind, earthquakes or both. Reinforced concrete (RC) buildings usually have vertical plate-like RC walls known as Shear Walls, additionally to slabs, beams and columns. These walls typically begin at foundation level and square measure continuous throughout the building height as shown in fig [1]. Their thickness will be as low as 150mm, or as high as 400mm in high rise buildings. They are vertical components of the structure i.e. the horizontal force resisting system. They are made to counteract the result of lateral masses engaged on the structure.

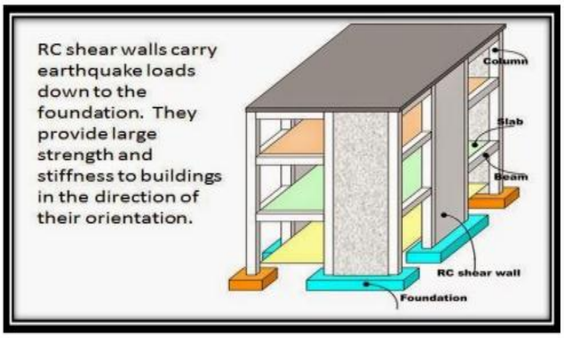


Fig.1 Building with Shear wall

Fig.2 Damage of building because of earthquake

The overwhelming success of buildings with shear walls in resisting robust earthquakes is summarized within the quote: “We cannot afford to make concrete buildings meant to resist severe earthquakes while not shear walls.” Mark Fintel, a noted consulting engineer in USA.

RC shear walls give massive strength and stiffness to buildings within the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces harm to structure and its contents. Since shear walls carry massive horizontal earthquake forces, the overturning effects on them are massive and the typical damage pattern is shown in fig [2]. Shear walls in buildings should be symmetrically located in decide to cut back ill-effects of twist in buildings. They may be placed symmetrically on one or each directions in arrange. Shear walls are more effective once situated on exterior perimeter of the building – such a layout will increase resistance of the building to twisting. Shear walls are easy to construct, because reinforcement detailing of walls is relatively straight-forward and therefore easily implemented at site. Shear walls are efficient, both in terms of construction cost and effectiveness in minimizing earthquake damage in structural and nonstructural elements.

1.1 Objective of the Study

- To study behavior of RC building (G+11) with and without shear walls at different locations like edges and corners of building.
- To study the behavior of G+11 storied RC building situated in earthquake zone III using equivalent lateral force analysis, modal analysis, time history analysis and response spectrum analysis.
- To measure the shear force and bending moment of these structures at numerous levels, relative to ground displacements in horizontal direction in both the STAAD.PRO & SAP-2000 software's.
- The study on Dynamic analysis discloses an effort to see the elemental natural frequency of various building's victimization Matrix methodology based mostly software packages, STAAD and SAP.

1.2 Methodology

For this study three models having the same plan configuration are taken with varying locations of shear walls in the model, these are modelled in two software's using STAAD.Pro and SAP-2000. Initially a bare frame model is developed and subjected to different load conditions and load combinations. Concrete design for bare frame models is done in both software's. The sections are finalised by using trails and error method, most economical sections are developed using these software's keeping the type of materials as constant in both software's. Fig.3 displays the flow chart of the models which are developed for this study.

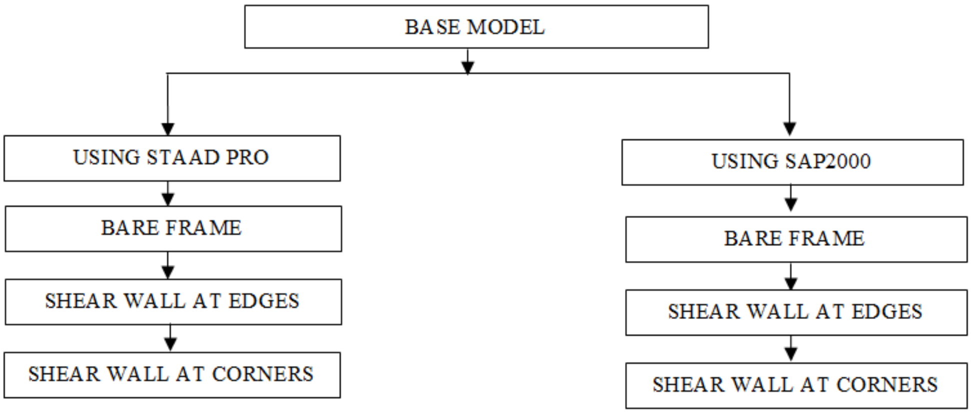


Fig.3 Model development flow chart

2. ANALYSIS & RESULTS

For all these models EQUIVALENT LATERAL FORCE analysis, MODAL analysis, TIME HISTORY and RESPONSE SPECTRUM analysis has been carried out. The type of time history analysis is direct nonlinear time history analysis, also known as Fast Nonlinear or FNA analysis. These analyses are performed with few limitations in both software's. By performing, following results are obtained, noted down & compared.

1. Max Storey displacements.
2. Max moment in the critical column of each Storey.
3. Max shear in the critical column of each Storey.
4. Mode shapes.
5. Time periods and frequencies.
6. Time vs. displacements plots from time history analysis.
7. Max base shears and moments at base from response spectrum analysis.

For the above analysis, the basic versions of STAAD.PRO and SAP-2000 are used, the following analysis are performed using individual software's.

2.1 Software Compatibility

S.no	Type Of Analysis/Command	STAAD.Pro	SAP-2000
1.	Equivalent Lateral Force Analysis	Yes	Yes
2.	Model Analysis	No	Yes
3.	Concrete Design	Yes	Yes
4.	Time History Analysis	No	Yes
5.	Response Spectrum Analysis	No	Yes

Table1. Analysis/Commands performed in software's

3. STRUCTURE MODELLING AND ANALYSIS

3.1 Structure Modelling

In this we will be discussing the development of the model in a step by step procedure in both the software's STAAD.Pro and SAP-2000, material data and section data, plan dimensions of all the models, Storey data of each model, location of shear walls in different models are represented.

S.No	Directions	No of bays/stories(no's)	Bay width/Storey height(m)
1.	X	9	5
2.	Y	9	5
3.	Z	12	3

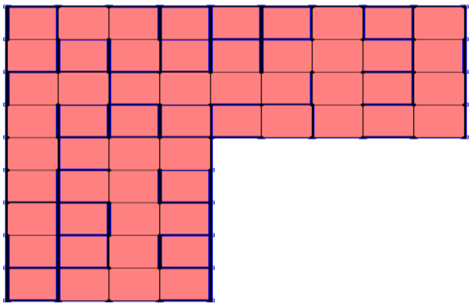
Table 2. Model dimensions

S.No	Section	Material Grade		Dimensions	
		Concrete	Rebar	STAAD Pro	SAP-2000
1	B1	M30	Fe500	0.45m X 0.30m	0.45m X 0.30m
2	C1	M30	Fe500	0.75m X 0.45m	0.65m X 0.35m
3	S1(Floor slab)	M30	Fe500	0.125m	0.125m
4	W1(Shear wall)	M30	Fe500	0.350m	0.350m

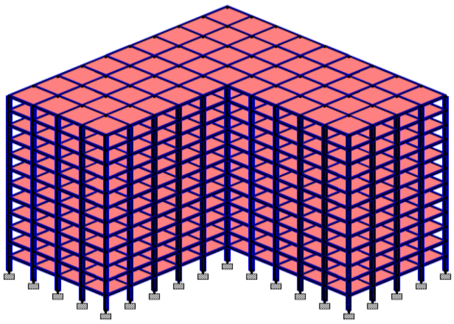
Table 3. Material & Section dimensions

Both the two software models are of same plan and Storey dimensions and the section materials, but differ in the property of column section. This is because of the concrete design as lower size sections are tending to fail in staad.pro.

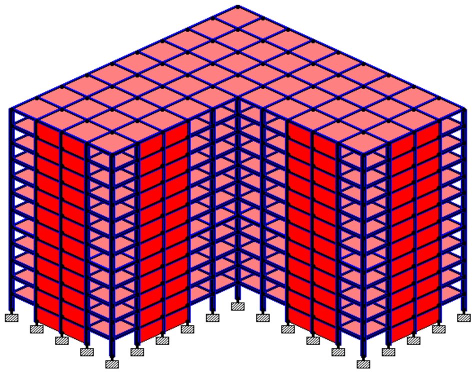
The following figs. 4 represent the plan and 3D views of all the models in STAAD.Pro.



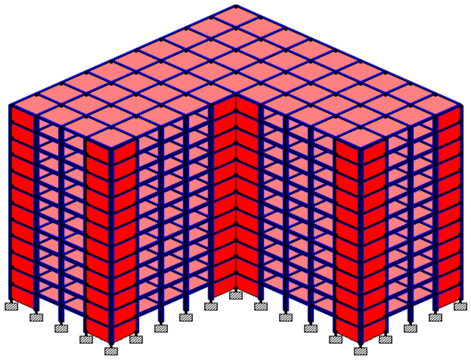
4.1. Typical floor plan



4.2. Bare frame without shear walls

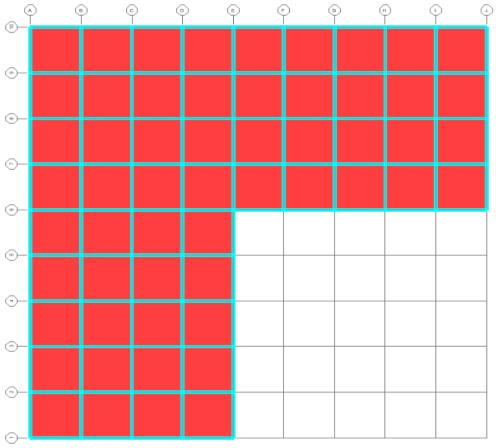


4.3. Model with Shear walls at edges

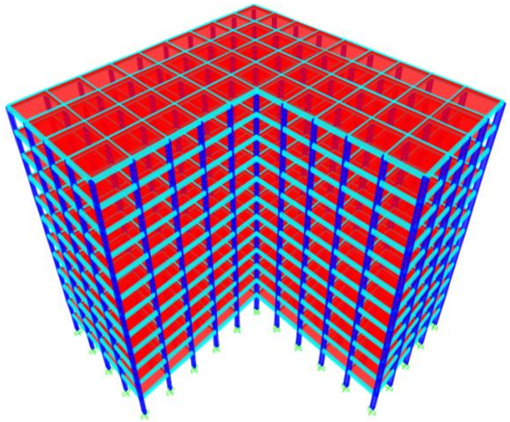


4.4. Model with Shear walls at corner

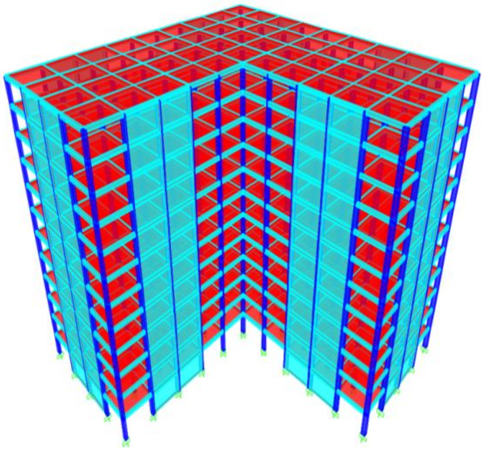
The following figs.5 represents the plan and 3D views of all the models in SAAP-2000



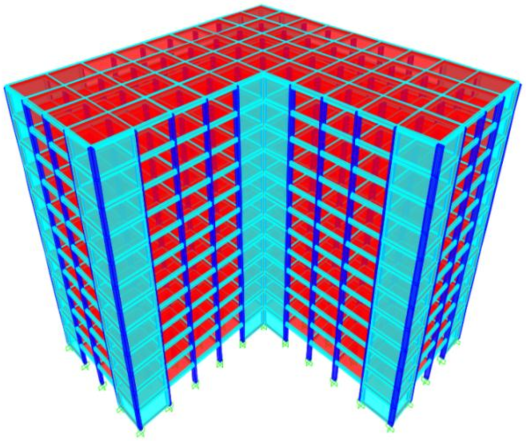
5.1. Typical floor plan



5.2. Bare frame without Shear walls



5.3. Model with Shear walls at edges



5.4. Model with Shear walls at corners

3.2 Structure Loading and Analysis

All the loads are calculated and generated in accordance with Indian standard codes IS 875 part-I for dead load calculations, Part II for live load calculations, Part III for Wind load calculations, IS 1893 for earthquake load and load combinations these are followed strictly for generation of loads.

The following are the loads and assigned for the structures in both the software's.

S. no	Load type	Assignment	Intensity
1	Dead load	Self-weight of the element	1
2		Wall load	10kN/m
3		Floor finish	1.5kN/m^2
4	Live load	Live load on slabs	2knN/m^2

Table 4. Loadings

S.no	Seismic Properties	Data
1	Zone factor	0.36
2	Response reduction factor	5
3	Importance factor	1
4	Soil type	Medium
5	Structure type	RC frame
6	Damping Ratio	5%

Table 5. Data of the earthquake properties which are assigned to the structure

S.no	Wind load parameters	Data
1	Wind Speed	50m/s
2	Terrain category	2
3	Importance factor	1
4	Risk coefficient	1
5	Topography factor	1

Table 6. wind load parameters

Height (m)	Wind pressure N/mm^2
36	1.49
33	2.94
30	2.90
27	2.83
24	2.75
21	2.68
18	2.61
15	2.55
12	2.41
9	2.32
6	2.32
3	2.32
0	1.16

Table 7. Wind loads

For the Time history function, koyna earthquake ground motion accelerogram data has been taken. The data consists of 1001 points of acceleration data with a time interval of 0.02 sec between each data point and has duration of 20 seconds. The below fig 7 shows the scaled representation of the data plot function with time on X-axis and acceleration on y-axis which has been used for analysis.

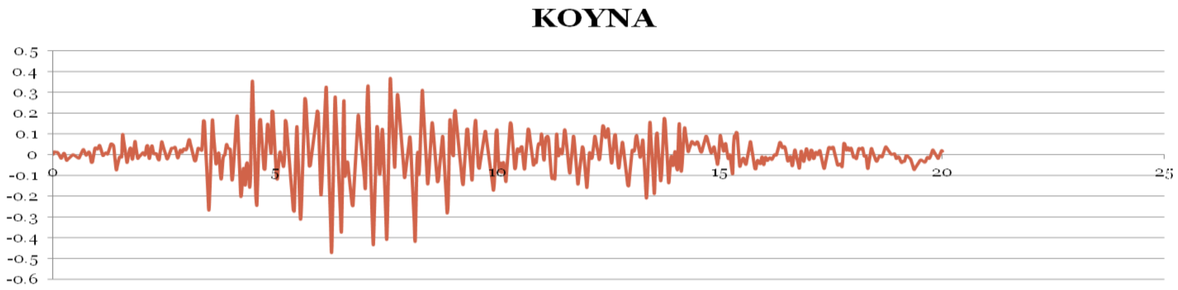


Fig 6. Koyna Accelerogram (Acceleration vs. Time graph)

For the response spectrum, the parameters which are taken for the earthquake load case, same parameters are considered for the development of response function.

4. RESULTS AND DISCUSSIONS

We will be discussing the results obtained from different analysis as mentioned in the previous chapters. From both the software's, we got max Storey displacements for the critical load case, modal time periods and frequencies for all the three models, max shears and moments in a typical column for a critical load case, mode shapes time history plot functions, max base shear and moments at supports for response spectrum load case, and concrete design outputs for all models in both the software's.

4.1 Storey Displacements

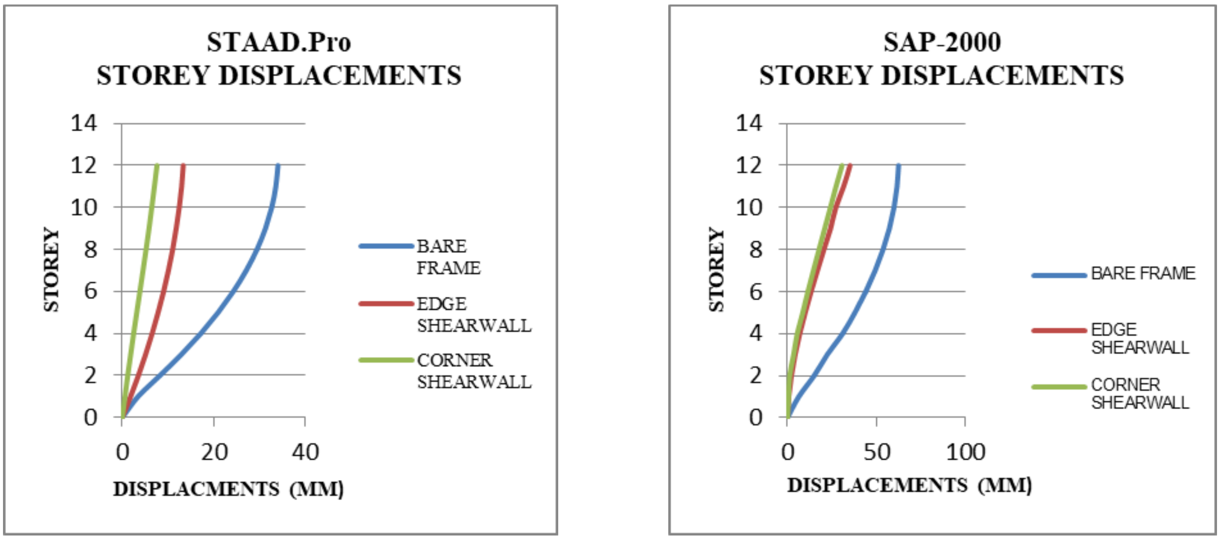


Fig 7. Storey displacements in STAAD.Pro

Fig 8. Storey displacements in SAP-2000

From the above two figures, it is observed that the displacements are maximum in the models which are not provided with shear walls. The displacements of models provided with shear walls are minimum.

When compared to both the software's, the displacements which are occurring in the SAP-2000 are higher than the STAAD.Pro software. In STAAD.Pro the displacements are less because of the increased size of columns which are done in order to pass the structure for concrete design.

4.2 Modal Time Periods and Frequencies

It is observed that the model with shear wall, time period has been decreased subsequently compared to the model without shear walls.

4.3 Column Shears

Both the models are analysed for the same set of loads and load combinations. Shear results for a typical column in each Storey for a critical load case / combination are selected and shear values are noted for each model in both the software's the following table displays the shear results for each model in both the software's.

From the below table [8] it is observed that the maximum shears are developed in the columns of models with of shear walls, where as the top Storey columns shears are generated more in the models having shear walls this is due to the presence of shear walls.

Storey no.	STAAD.Pro Shear (kN)			SAP-2000 Shear (kN)		
	Bare frame	Edge shear wall	Corner shear wall	Bare frame	Edge shear wall	Corner shear wall
Storey 12	19.85	82.63	67.52	53.63	126.32	179.56
Storey 11	25.07	67.45	52.14	62.45	86.65	124.75
Storey 10	33.19	62.13	52.64	80.00	94.75	132.8
Storey 9	41.0	61.33	51.23	92.63	93.68	127.31
Storey 8	48.71	61.12	48.65	102.78	92.52	122.13
Storey 7	56.18	55.96	45.98	108.67	89.61	115.45
Storey 6	63.47	50.87	42.89	112.38	84.56	105.63
Storey 5	70.55	45.25	37.61	114.46	76.73	93.35
Storey 4	77.38	38.86	31.29	115.52	66.82	79.46
Storey 3	83.88	30.31	24.49	113.78	53.45	62.76
Storey 2	90.17	20.19	17.52	110.46	36.56	41.55
Storey 1	92.28	13.56	17.23	100.71	22.62	25.82

Table 8. Shear results

4.4 Response Spectrum Base Reactions

The following are the base shears and moments generated at the base for all the three models in Response spectrum load case.

S.No	Model type	Base Shear (N)	Moment (N-m)
1	Bare Frame	347825.64	37716.69
2	Edge Shear wall	234687.72	11945.184
3	Corner Shear wall	267281.58	16772.463

Table 9. Response Spectrum Base Reactions

4.5 Column Moments

All the models are analysed for the same set of loads and load combinations. Moment results for a typical column in each Storey for a critical load case / combination are selected and moment values are noted for each model in both the software's. From the below table [10], it is observed that the maximum moments are developed in the columns of models with of shear walls, where as the top Storey columns moments are generated more in the models having shear walls this is due to the presence of shear walls.

The following table displays the moment results for each model in both the software's.

Storey no.	**STAAD.Pro Moment (kN-m)**			**SAP-2000 Moment (kN-m)**		
	Bare frame	**Edge shear wall**	**Corner shear wall**	**Bare frame**	**Edge shear wall**	**Corner shear wall**
Storey 12	22.22	108.23	88.12	100.13	309.32	221.96
Storey 11	31.99	94.45	78.53	108.15	191.61	132.35
Storey 10	43.75	94.52	78.76	134.86	200.23	144.53
Storey 9	55.51	91.78	76.46	149.46	192.56	140.75
Storey 8	66.94	91.45	72.56	161.56	184.86	140.63
Storey 7	78.16	81.56	68.78	169.32	173.76	136.56
Storey 6	89.12	75.78	62.63	174.75	159.86	129.82
Storey 5	99.84	66.65	55.89	175.85	142.65	119.49
Storey 4	110.431	56.35	46.76	173.23	122.75	105.68
Storey 3	121.754	44.53	36.48	172.98	97.86	87.37
Storey 2	140.19	30.27	24.63	181.23	66.56	62.86
Storey 1	191.11	21.47	24.89	223.46	50.12	51.17

Table 10. Moment results

4.6 Concrete Design

The following Table [11] represents the concrete design data for models developed in STAAD.Pro and Table [12] represents the concrete design data for models developed in SAP-2000. These are the outputs of the critical elements.

Model	**Element**	**Dimensions (mm)**	**Concrete grade**	**Rebar grade**	**Area of steel required (mm^2)**	**Reinforcement provided**
Bare frame	Column (C1)	750 x 430	M30	Fe500	8992	#18@25Ø
	Beam (B1)	450 x 300	M30	Fe500	858	#8@12Ø
Edge shear wall	Column (C1)	750 x 430	M30	Fe500	6785	#14@25Ø
	Beam (B1)	450 x 300	M30	Fe500	858	#8@12Ø
Corner shear wall	Column (C1)	750 x 430	M30	Fe500	6785	#14@25Ø
	Beam (B1)	450 x 300	M30	Fe500	858	#8@12Ø

Table 11. STAAD.Pro Concrete design output

Model	Element	Dimensions (mm)	Concrete grade	Rebar grade	Area of steel required (mm²)	Reinforcement provided
Bare frame	Column (C1)	650 x 350	M30	Fe500	13545	#18@320
	Beam (B1)	450 x 300	M30	Fe500	2053	#10@160
Edge shear wall	Column (C1)	650 x 350	M30	Fe500	11259	#14@320
	Beam (B1)	450 x 300	M30	Fe500	1598	#8@160
Corner shear wall	Column (C1)	650 x 350	M30	Fe500	11259	#14@320
	Beam (B1)	450 x 300	M30	Fe500	1598	#8@160

Table 12. SAP-2000 Concrete design output

5. CONCLUSIONS

In this work, a comparative analysis between two software's STAAD.Pro and SAP-2000 have been carried out in which three similar irregular models with varying locations of shear walls are analysed in each software, for carrying out the analysis and design basic versions of the both software's are taken, these basic versions are restricted to a set of available analysis and commands which are refereed in the Table [1] Analysis/Commands performed in software's. All the results from equivalent lateral force analysis, modal analysis, time history analysis, response spectrum analysis are obtained and finally concrete designs are portrayed in the results section. All these analysis are done with the standard loadings and design parameters confining to appropriate Indian codes.

In this chapter the conclusions are based on two criteria's, first is depending on the locations of shear walls in the models and the second is depending on the outputs from the two software's are incorporated.

1. Based on model configuration
2. Based on software's

5.1 Conclusions based on model configuration

From the results obtained from different analysis, the conclusions are drawn and listed below:

- By comparing all the models, the top storey displacements are decreased significantly with the incorporation of shear walls into the models.
- For Staad models, the percentage decrease of lateral displacement from bare frame to edge shear wall model is 61.51% and from edge shear wall to corner shear wall is 42.08% and the overall decrease of lateral displacement from bare frame to corner shear wall model is 77.70%. Whereas in SAP-2000 models, the percentage decrease of lateral displacement from bare frame to edge shear wall model is 43.69% and from edge shear wall to corner shear wall is 12.85% and the overall decrease of lateral displacement from bare frame to corner shear wall model is 50.93%. The lateral displacements are in the following order.

Corner shear wall < Edge shear wall < Bare frame model.

- There is a significant decrease in the bottom column shear and moment in the three models with the incorporation of shear wall this is because of the increased stiffness at the bottom of models which are having shear wall, this can be described by assuming the building as a cantilever projection, where the moments are high at fixed end and less at the free end.
- From the model analysis, it is concluded that the models with higher mass oscillation has less time period and vice-versa. The shear wall model has higher time period compared to bare frame models.
- From the time history analysis it is clear that the model with corner shear wall performs efficiently when compared to all the other models.

- From the concrete design taken from a critical column and beam, it is concluded that the models with shear wall require less area of steel than the bare frame model. This is due to reduced moments and shears in the structure, which is absorbed by the shear walls present in the model.

5.2 Conclusions based on model software's

From the different analysis performed and the restrictions in basic versions of the two software's STAAD.Pro and SAP-2000 the following conclusions are made:

- After the trial and error process for defining the most economical size of sections to pass for concrete design, the sections designed in Staad.pro are larger than the sap-2000 sections this is due to the minor change in factor of safety which the software's take by default.
- Both the software outputs are stable and safe, whereas the output from the sap-2000 is considered more economical over staad.pro.
- The complexity of modelling, loading and analysis is more in staad.pro. Whereas the same process is less complex and easy in sap-2000.
- The user interface and steps to follow differs a lot in both the software's, in staad.pro the interface and steps to be followed are archaic. Whereas in sap-2000 the interface is much modern flexible and efficient.
- Due to the change in section sizes in both models the models which are developed in sap-2000 are showing higher values of displacements, moments and shears when compared with the staad models.
- It is concluded that, due to the higher values of moment and shear in Sap-2000 models more amount of steel is required for the sections in those models.

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