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Optimized Design of a G+20 Storied Building Using ETABS

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ABSTRACT

In the present scenario of construction industry, the buildings that are being constructed are gaining significance, in general, those with best possible outcomes with reference to optimal sizing and reinforcing of the structural elements, mainly beam and column members in multi-bay and multi–storey RC structures. Optimal sizing incorporates optimal stiffness co-relation among structural members and results in cost savings over the typical state-of-the-practice design solutions. "Optimization" means making things the best.

The race towards new heights and architecture has not been without challenges. When the building increases in height, the stiffness of the structure becomes more important. Tall structures have continued to climb higher and higher facing strange loading effects and very high loading values due to dominating lateral loads. The design criteria for tall buildings are strength, serviceability, stability and human comfort. Thus the effects of lateral loads like wind loads, earthquake forces are attaining increasing importance and almost every designer is faced with the problem of providing adequate strength and stability against lateral loads.

Lateral load on tall buildings is most critical one to consider for the design. In order to observe the seismic effect and wind effect on tall building, a study on G + 20 storey's are taken for four different cases of structural system. The structural response due to lateral loads with load combinations is extracted. Effect of lateral load on moments, axial forces, shear force, base shear, maximum storey drift and tensile forces on structural system are studied

The present work was carried out on G + 20 storey commercial building with and without the provision of shear walls for the following structural systems:

- ***Only frame.***
- ***Frame with shear walls.***
- ***Frame with shear walls and shear core.***
- ***Frame with only shear core.***

1. NTRODUCTION

1.1GENERAL:

In modern civilization, tall buildings have rapidly developed worldwide. Tall buildings are symbols of civilized congested and populated society. It is certainly resemble of economic growth, the force and image of a civilization. A tremendous variety of architectural shapes and complex structural layouts are designed. New materials and structural models are built with unique structure with efficient performances as well established tall buildings.

1.2THE BASIC IDEA:

A structurein mechanics is defined by J.E. Gordon as "any assemblage of materials which is intended to sustain loads." Optimizationmeans making things the best. Thus, structural optimizationis the subject of making an assemblage of materials sustains loads in the best way .To fix ideas, think of a situation where a load isto be transmitted from a region in space to a fixed support as in Fig.1.1

1.3THE DESIGN PROCESS:

The goal of optimization is to find the best solution among a set of solutions using efficient quantitative methods. In this framework, a commercial building with G+20 stories is taken for analysis and design.

The objectives that are used as follows:

1. Function: A commercial building with G+20 stories is considered with four different models i.e.

- Only frame without any walls
- Frame with shear walls
- Frame with shear walls and shear core
- Frame with only shear core

1.4 SHEAR WALLS:

A shear wall (or bearing wall) is a wall that bears a load resting upon it by conducting its weight to a foundation structure. The materials most often used to construct shear walls in large buildings are concrete, block, or brick. Depending on the type of building and the number of stories, shear walls are gauged to the appropriate thickness to carry the weight above them. Without doing so, it is possible that an outer wall could become unstable if the load exceeds the strength of the material used, potentially leading to the collapse of the structure.

1.5 ADVANTAGES AND DISADVANTAGES OF TALL BUILDINGS:

ADVANTAGES OF TALL BUILDINGS:

- It provides large capacity
- Saving land
- Promote local economy

DISADVANTAGES OF TALL BUILDINGS:

- High Cost of Investment, Construction, Maintenance and operation
- Have negative effects on outdoor and indoor environment
- Huge pressure of urban, transport, consumption and drinking water.
- Destruction of the natural environment.
- Noise pollution.
- The fire-protection problem
- The fire spread quickly in high rise buildings.
- Evacuation difficulty during fire accidents.
- Poor fire resistance of steel structural system.

1.6OBJECTIVE:

The main objective of this study is to analyze and design of G+20 storey building with shear walls, shear core and only frame structural system by using ETABS software to get an optimized design.

The ETABS stands for extended 3D (Three-Dimensional) Analysis of Building Systems. This is based on the stiffness matrix and finite element based software. The analysis and design is done to satisfy all the checks as per Indian standards. Finally data base is prepared for various structural responses.

1.7SCOPE OF WORK:

The scope of the present thesis work is as follows

•The analysis is implemented for frame + shear walls, frame + shear core ,frame + shear walls + shear core and only frame structural system using ETABS to get an optimized design.

•The structural system is analyzed for both gravity and lateral loads (seismic and wind load).

- The development of high- rise buildings destroyed the harmony of the local cultural Landscape.

2. LITERATURE REVIEW

Cenek P. D., Wood J. H. (1990). Designing multi-storey buildings for windeffects Judgeford [N.Z.] The study is an exhaustive comparison of the wind forces obtained by Force coefficient based static analysis and Gust factor based dynamic analysis interpreting where which method should be used for better

James L. Beck, Eduardo Chan Earthquake Eng. Struct. Dyn. 28, 741 -761 (1999) “Multi-Criteria Optimal

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Structural Design under Uncertainty"This study is about a general framework for multi-criteria optimal design which is well suited for performance based design of structural systems operating in an uncertain dynamic environment. A decision theoretic approach is used which is based on aggregation of preference functions for the multiple, possibly conflicting, design criteria. This allows the designer to trade of these criteria in a controlled manner during the Optimization. Reliability-based design criteria are used to maintain user-specified levels of structural safety by properly taking into account the uncertainties in the modelling and seismic loads that a structure may experience during its lifetime.

3. ETABS PROJECT MODEL

3.1 ETABS INTRODUCTION:

The ETABS stands for extended 3D (Three-Dimensional) Analysis of Building Systems. This is based on the stiffness matrix and finite element based software. The analysis and design is done to satisfy all the checks as per Indian standards. Finally data base is prepared for various structural responses.

3.2Modelling using ETABS:

a) Open the ETABS Program

b) Check the units of the model in the drop-down box in the lower right-handcorner of the ETABS window, click the drop-down box to set units to kN-m

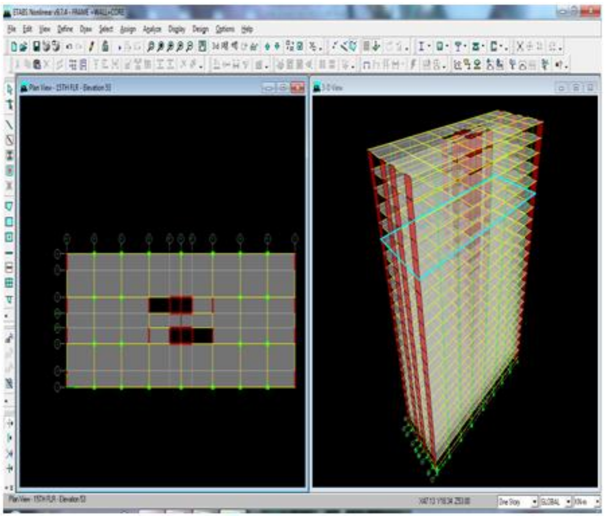


Figure 3.1 Plan View And 3D View

Time period is shown in figure 3.2 ETABS from Display > Show Mode Shape

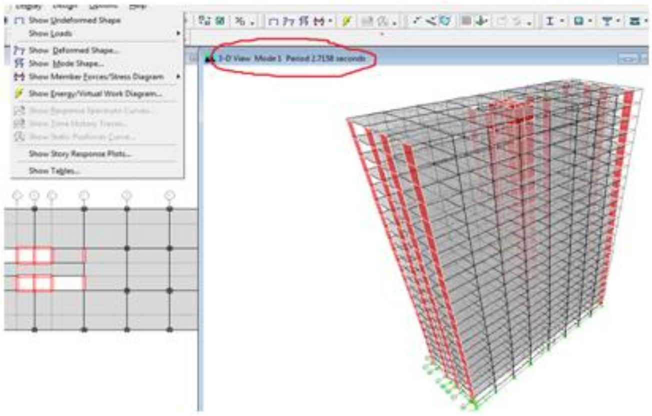


Figure 3.2 3DView Mode 1

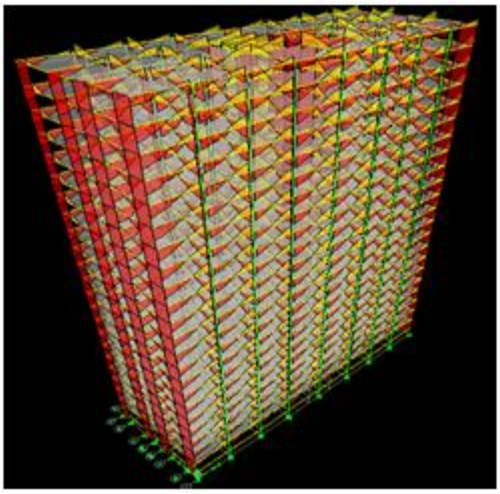
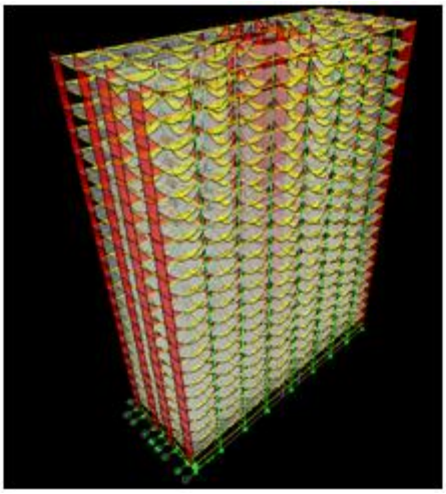


Figure 3.3Shear Force Diagram for D. LFigure



3.4Bending Moment Diagram for D.L

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4. ANALYSIS AND DESIGN

4.1INTRODUCTION:

The structure for only frame, frame with shear wall, frame with shear core and the frame with shear core and shear wall having G+ 20 storey's is analyzed for gravity and lateral loads.

4.2MODELING OF THE BUILDING USING E-TABS:

In this present study ground +20 storey building with shear wall, core and only frame is considered for analysis using ETABS. Various forces, displacements and moments have been worked out for different load combinations to achieve the optimized design.

TABLE: 4.1 MATERIAL PROPERTIES

Material name	Concrete
Type of material	Isotropic
Density	$25kN/m^3$
Modulus of elasticity	$5000\sqrt{fck}$
Poisson's ratio	0.2
Characteristic strength	M 30

TABLE: 4.2 ELEMENT PROPERTIES

Modeling cases	Element property	
	Beam section	Column section
(Model-1) Only frame	18"x27"	Foundation to 2^{nd} floor48"x48" 3^{rd} to 20^{th} floor 40"x40"
(Model-2) Frame with only shear wall	15"x24"	40"x40" for all the Floors.
(Model-3) Frame with only shear core	15"x24"	40"x40"for all the floors
(Model-4) Frame with shear wall and shear core	9"x21"	Foundation to 5^{th} floor 32"x32" 6^{th} to 20th floor 24"x24"

MODELLING FIGURES IN ETABS:

FRAME WITH SHEAR WALL AND SHEAR CORE

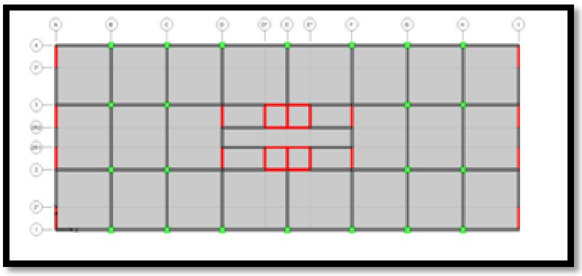

FIG: 4.2 TYPICAL FLOOR PLAN

ONLY FRAME

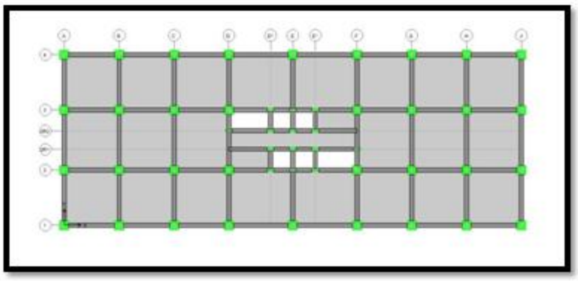

FIG: 4.3 TYPICAL FLOOR PLAN

FRAME WITH ONLY SHEAR CORE

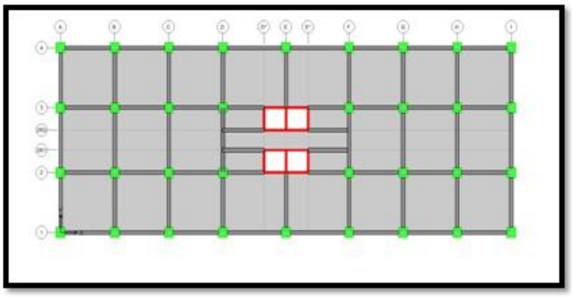

FIG: 4.4 TYPICAL FLOOR PLAN

FRAME WITH SHEAR WALLS

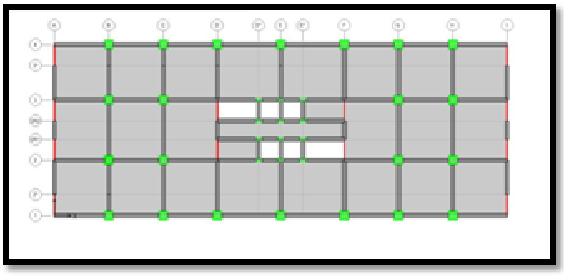

FIG: 4.5 TYPICAL FLOOR PLAN

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4.3 LOAD CASES AND LOAD COMBINATION

4.3 LOAD CASES AND LOAD COMBINATION

In this present study consider both gravity and lateral load cases. The load combinations as per the Indian standards are considered. The primary load cases and the load combinations are shown in table 4.3 and 4.4 respectively.

Table: 4.3 Primary load cases

LOAD CASE NUMBER	LOAD TYPE	LOAD CASE NUMBER	LOAD TYPE
1	Dead load (D.L)	6	EQ in Negative Y (EQNY)
2	Live load (L.L)	7	WIND in X (WX)
3	EQ in X (EqX)	8	WIND in Y (WY)
4	EQ in Y (EqY)	9	WIND in Negative X(WNX)
5	EQ Negative X (EqNX)	10	WIND in Negative Y(WNY)

Table: 4.4 Load combinations

COMBINATION NUMBER	LOAD COMBINATION	COMBINATION NUMBER	LOAD COMBINATION
COMB1	D.L+L.L	COMB14	0.9D.L+1.EQNX
COMB2	1.5(D.L+L.L)	COMB15	0.9D.L+1.5EQNY
COMB3	(D.L+ERELOAD)	COMB16	D.L+L.L+EQX
COMB4	1.5(D.L+EQX)	COMB17	D.L+L.L+EQY
COMB5	1.5(D.L+EQY)	COMB18	D.L+L.L+EQNX
COMB6	1.5(D.L+EQNX)	COMB19	D.L+L.L+EQNY
COMB7	1.5(D.L+EQNY)	COMB20	D.L+L.L+WX
COMB8	1.2(D.L+L.L+EQX)	COMB21	D.L+L.L+WY
COMB9	1.2(D.L+L.L+EQY)	COMB22	D.L+L.L+WNX
COMB10	1.2(D.L+L.L+EQNX)	COMB23	D.L+L.L+WNY
COMB11	1.2(D.L+L.L+EQNY)	COMB24	D.L+WX
COMB12	0.9D.L+1.5EQX	COMB25	D.L+WY
COMB13	0.9D.L+1.5EQY	COMB26	D.L+WNX
COMB27	D.L+WNY	COMB40	1.5(D.L+L.L+WX)
COMB28	1.5(D.L+WX)	COMB41	1.5(D.L+L.L+WY)
COMB29	1.5(D.L+WY)	COMB42	1.5(D.L+L.L+WNX)
COMB30	1.5(D.L+WNX)	COMB43	1.5(D.L+L.L+WNY)
COMB31	1.5(D.L+WNY)	COMB44	0.9(D.L+L.L)+1.5 WX
COMB32	1.2(D.L+L.L+WX)	COMB45	0.9(D.L+L.L)+1.5 WY
COMB33	1.2(D.L+L.L+WY)	COMB46	0.9(D.L+L.L)+1.5 WNX
COMB34	1.2(D.L+L.L+WNX)	COMB47	0.9(D.L+L.L)+1.5 WNY
COMB35	1.2(D.L+L.L+WNY)	COMB48	D.L+0.8(L.L+WX)
COMB36	1.5(D.L+L.L)+WX	COMB49	D.L+0.8(L.L+WY)
COMB37	1.5(D.L+L.L)+WY	COMB50	D.L+0.8(L.L+WNX)
COMB38	1.5(D.L+L.L)+WNX	COMB51	D.L+0.8(L.L+WNY)
COMB39	1.5(D.L+L.L)+WNY		

DIAPHRAGM ACTION:

The diaphragm action is used to transfer the lateral loads to the structural elements. While modeling the structure the diaphragm is created. It is denoted by id D1 in each storey. This id is used for entire structure.

Table 4.5 Modal time period and frequencies for frame+core

MODE NUMBER	TIME PERIOD (Sec)	FREQENCY (CYCLE/TIME)	CIRCULAR FREQENCY (RADIANS/Sec)
Mode-1	3.75154	0.26656	1.67483
Mode -2	3.44673	0.29013	1.82294
Mode -3	2.71833	0.36787	2.31142
Mode-4	1.09149	0.91618	5.75654
Mode-5	0.75585	1.32301	8.31270
Mode-6	0.50640	1.97474	12.40767
Mode-7	0.33480	2.98685	18.6694
Mode-8	0.22590	4.42670	27.81380

Table 4.6 Modal time period and frequencies for frame+shear walls

MODE NUMBER	TIME PERIOD (Sec)	FREQENCY (CYCLE/TIME)	CIRCULAR FREQENCY (RADIANS/Sec)
Mode-1	2.68724	0.37213	2.33815
Mode -2	2.28646	0.43736	2.74799
Mode -3	1.83238	0.54574	3.42897
Mode-4	0.86636	1.15426	7.25242
Mode-5	0.68764	1.45425	9.13729
Mode-6	0.48166	2.07616	13.04489
Mode-7	0.31099	3.21559	20.20414
Mode-8	0.25130	3.97937	25.00315

The mode shape of the entire structure with frame+shearwalls due to the lateral load (seismic and wind) are shown in Fig4.10.

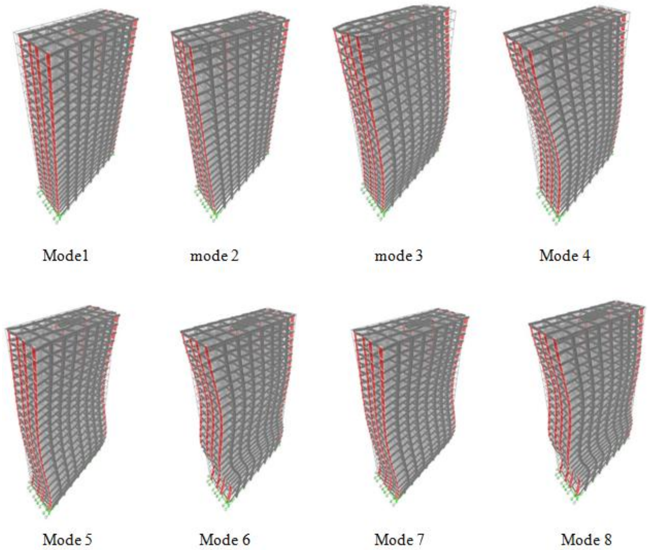

Table 4.7 Modal time period and frequencies for only frame

MODE NUMBER	TIME PERIOD (Sec)	FREQENCY (CYCLE/TIME)	CIRCULAR FREQENCY (RADIANS/Sec)
Mode-1	2.95499	0.33841	2.12630
Mode -2	2.64787	0.37766	2.37292
Mode -3	2.40450	0.41589	2.61310
Mode-4	0.93303	1.07178	6.73418
Mode-5	0.77303	1.29361	8.12796
Mode-6	0.50490	1.98057	12.44432
Mode-7	0.36981	2.70409	16.99032
Mode-8	0.26049	3.83885	27.12019

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The mode shape of the entire structure with only frame due to the lateral load (seismic and wind) are shown in Fig 4.11

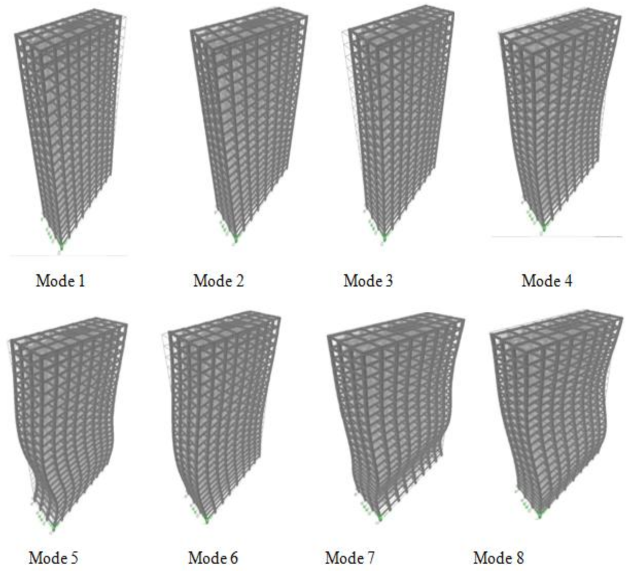
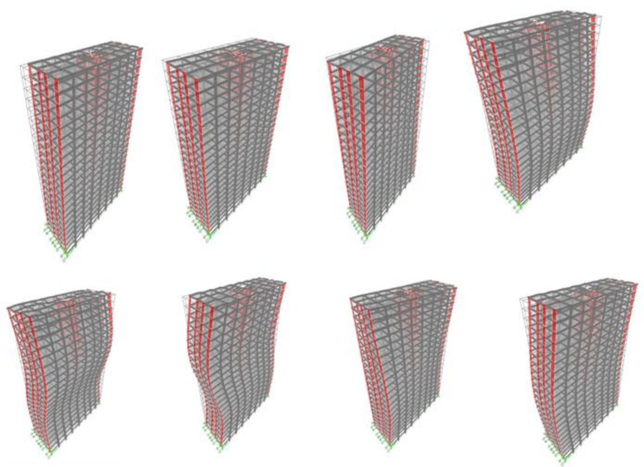


Table: 4.8 Modal time period and frequencies for Frame+shear walls+ shear core

The mode shape of the entire structure with Frame+shearwall+core due to the lateral load (seismic and wind) are shown in Fig 4.12

MODE NUMBER	TIME PERIOD (Sec)	FREQENCY (CYCLE/TIME)	CIRCULAR FREQENCY (RADIANS/Sec)
Mode-1	2.02696	0.49335	3.09981
Mode -2	2.01349	0.49665	3.12055
Mode -3	1.63053	0.61330	3.85346
Mode-4	0.58159	1.71941	10.80340
Mode-5	0.55567	1.79962	11.30734
Mode-6	0.49871	2.00519	12.59898
Mode-7	0.28445	3.51559	22.08913
Mode-8	0.26007	3.84512	24.15962



4.4 ANALYSIS AND RESULTS:

The present structural system is modeled and analyzed by using ETABS. For the analysis of gravity loads live load of the structure is considered 4 kN/m2. For the lateral load analysis (wind and earthquake) parameters are considered as per Indian code basis. The lateral load is transferred to the structural members through diaphragm action is considered.

4.5 ANALYSIS RESULTS AND DISCUSSION:

Model -1: Only Frame Structure
Model -2: Frame + shear core
Model -3: Frame + shear walls
Model -4: Frame + shear core + shear walls

1. Effect of axial force on four different models:

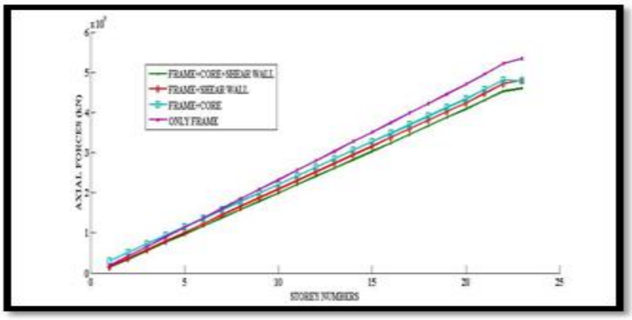


Fig: 4.13axial forces on four different models

The variation of moments with stories is linear .The maximum out of plane moment is in model-1.The difference in maximum out of plane moment when compared with model-1 and model-2 is 10% and model-1 and model-3 is 10.4% and model-1 and model-4 is 13.7%.

3. Effect of shear force on four different models:

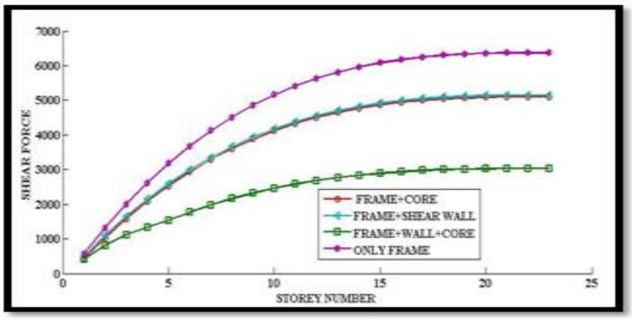


Fig: 4.15 shear force on models

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The variation of shear force with stories is non linear .The maximum shear force is in model-1.The difference in maximum shear force when compared with model-1 and model-2 is 20% and model-1 and model-3 is 19.5% and model-1 and model-4 is 27%.

4.Effect of storey lateral load on four different models:

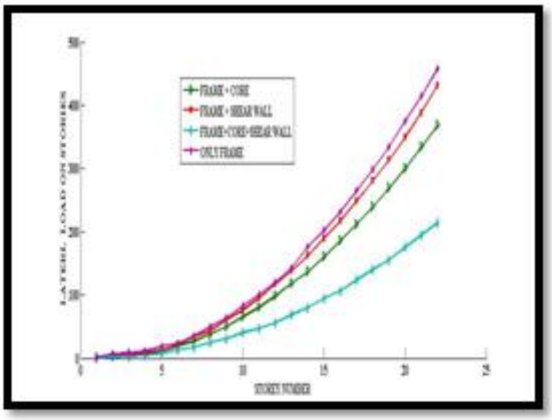

Fig: 4.16 storey lateral load on models

The variation of storey lateral load with stories is non linear. The maximum storey lateral load is in model-1.The difference in maximum storey lateral load when compared with model-1 and model-2 is 19.5% and model-1 and model-3 is 5.7% and model-1 and model-4 is 53%.

5.Effect of drift on four different models:

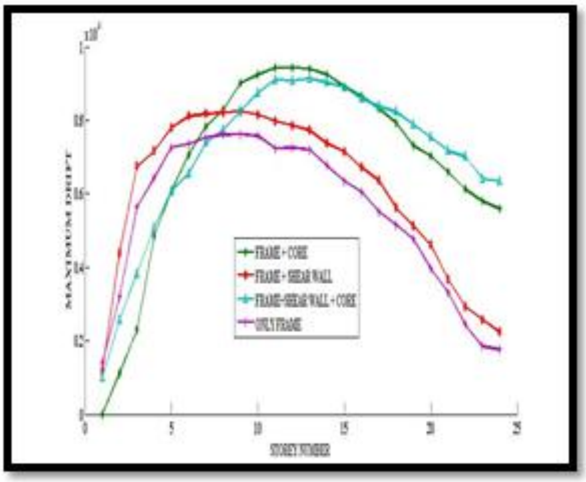

Fig: 4.17 Drifts on models

The variation of drifts with stories is non linear .the maximum drift is in model-1. The difference in maximum drift when compared with model-1 and model-2 is 2.5% and model-1 and model-3 is 44.1% and model-1 and model-4 is 63.2%

6. Effect of base shear on four different models:

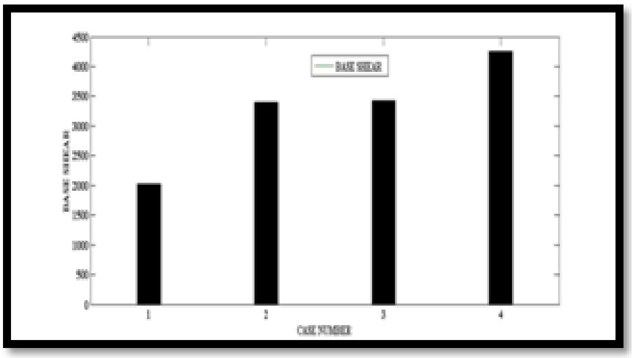

Fig: 4.18 base shear for four different models

From fig Case-1 is frame + shear wall +shear core
Case-2 is frame + shear core
Case-3 is frame + shear walls
Case-4 is only frame

The variation of base shear with stories is non linear. The maximum base shear is in model-1.The difference in maximum base shear when compared with model-1 and model-2 is 19.9% model-1 and model-3 is19.3% model-1 and model-4 is 52.4%

4.7 RESULTS AND SUMMARY:

In the present study, (G+20) storied R.C.C building in construction with only frame, frame with shear wall, frame with shear core and the frame with shear core and shear wall is analyzed for gravity and lateral loads. From the above results the following conclusions are arrived.

1. The variation of axial force with stories is linear. The maximum axial force is in model-1. The difference in maximum axial force when compared with model-1 and model-2 is 10% and model-1 and model-3 is 11% and model-1 and model-4 is 14%.

2. The variation of moments with stories is linear .The maximum out of plane moment is in model-1.The

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difference in maximum out of plane moment when compared with model-1 and model-2 is 10% and model-1 and model-3 is 10.4% and model-1 and model-4 is 13.7%.

3. The variation of shear force with stories is non linear .The maximum shear force is in model-1.The difference in maximum shear force when compared with model-1 and model-2 is 20% and model-1 and model-3 is 19.5% and model-1 and model-4 is 27%.

4. The variation of storey lateral load with stories is non linear. The maximum storey lateral load is in model-1.The difference in maximum storey lateral load when compared with model-1 and model-2 is 19.5% and model-1 and model-3 is 5.7% and model-1 and model-4 is 53%.

5. The variation of drifts with stories is non linear .the maximum drift is in model-1.The difference in maximum drift when compared with model-1 and model-2 is 2.5% and model-1 and model-3 is 44.1% and model-1 and model-4 is 63.2%

6. The variation of base shear with stories is non linear .The maximum base shear is in model-1.The difference in maximum base shear when compared with model-1 and model-2 is 19.9% model-1 and model-3 is19.3% model-1 and model-4 is 52.4%.

5. RESULTS AND CONCLUSIONS

In the present study, (G+20) storied R.C.C building in construction with only frame, frame with shear wall, frame with shear core and the frame with shear core and shear wall was analyzed for gravity and lateral loads. From the above results the following conclusions were arrived

1. The variation of axial force with stories is linear. The maximum axial force is in model-2 is 10% and model-1 and model-3 is 11% and model-1 and model-4 is 14%.

2. The variation of moments with stories is linear .The maximum out of plane moment is in model-1.The difference in maximum out of plane moment when compared with model-1 and model-2 is 10% and model-1 and model-3 is 10.4% and model-1 and model-4 is 13.7%.

3. The variation of shear force with stories is non linear .The maximum shear force is in model-1.The difference in maximum shear force when compared with model-1 and model-2 is 20% and model-1 and model-3 is 19.5% and model-1 and model-4 is 27%.

4. The variation of storey lateral load with stories is non linear. The maximum storey lateral load is in model-1.The difference in maximum storey lateral load when compared with model-1 and model-2 is 19.5% and model-1 and model-3 is 5.7% and model-1 and model-4 is 53%.

5. The variation of drifts with stories is non linear .the maximum drift is in model-1.The difference in maximum drift when compared with model-1 and model-2 is 2.5% and model-1 and model-3 is 44.1% and model-1 and model-4 is 63.2%

6. The variation of base shear with stories is non linear .The maximum base shear is in model-1.The difference in maximum base shear when compared with model-1 and model-2 is 19.9%model-1 andmodel-3 is19.3% model-1 and model-4 is 52.4%

TABLE: 4.19 CONCLUSIONS OF ELEMENT PROPERTIES

Modeling cases	Element property		Total Volume of concrete for beam, column, slab and footing	Total weight of steel for beam, column, slab and footing	% Reduction in R.C.C
	Beam section	Column section			
(Model-1) Only frame	18"x27"	Foundation to 2nd floor48"x48" 3rd to 20th floor 40"x40"	10275.6m^3	169403.2 kgs	100
(Model-2) Frame with only shear wall	15"x24"	40"x40" for all the Floors.	7772.68 m^3	109203.1 kgs	24.4
(Model-3) Frame with only shear core	15"x24"	40"x40"for all the floors	8315.42m^3	85523.2 kgs	19.1
(Model-4) Frame with shear wall and shear core	9"x21"	Foundation to 5th floor 32"x32" 6th to 20th floor 24"x24"	7010.42 m^3	105532.4 kgs	31.8

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CONCLUSIONS:

From the above results it is concluded that:

1. In only s.m.r.f (special moment resisting frame) (model-1), the cross sectional properties of beams and columns are high, and the axial forces, moments, shear force, tensile force, storey lateral load, drifts and base shear are maximum in this case.
2. By providing a ductile shear wall for the above s.m.r.f. (dual system: model-2) the cross sectional properties of beams and columns have been reduced marginally and also base shear and storey drifts are reduced. Axial forces, moments ,shear force are reduced when compared to model -1
3. By providing a ductile shear core in combination with s.m.r.f. (dual system: model -3) the cross sectional properties of beams and columns have been reduced marginally,(same as model-2 and model-3).but by providing shear core ,reduced axial forces and moments as obtained .
4. By providing a ductile shear walls and shear core for the s.m.r.f. of model-1 (dual system: model -4),the cross sectional properties are reduced when compared to s.m.r.f. (model-1).and also axial forces, moments, shear forces, tensile forces, storey lateral loads and base shear are reduced .
5. Volume of concrete in model -4 is very less when compared with model-1.by providing frame + shear walls +shear core we arrived an optimized design and also volume of concrete is optimized.

SCOPE FOR FURTHUR WORK:

In this experimental study the work was carried out on four different models with frame +shear walls, frame +shear core , frame + shear walls + shear core and only frame models to get an optimized design. The work can be further studied by as follows:

1. The same study can be done for different zones to get an optimized design
2. The same study can be done for precast elements to get an optimized design
3. The study can be further extended to stability scope for analysis

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