Optimized Design of G+ 20 Storied Building

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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 in particular. The concept of "best possible outcome" is called optimization. Optimization plays an important role in structural design, the very purpose of which is to find the best solutions from which a designer or a decision maker can derive a maximum benefit from the available resources. This paper presents the study and comparison of G+20 storey building with four different models to get an optimized design using ETABS software.
Keywords: Shear Walls, Shear core, Lateral Loads, Pier and Spandrels ETABS

I. INTRODUCTION

In modern civilization, tall buildings have rapidly developed worldwide. Tall buildings are symbols of civilized congested and populated society. It is certainty resemble of economic growth, the force and image of a civilization. A tremendous variety of architectural shapes and complex structural layouts are designed. The design strategies discussed here will contribute to only optimum design environments using the minimum amount of resources.

Optimization is the act of obtaining the best result under the given circumstances .In design construction and maintenance of any engineering system many technological and managerial decisions has to be taken at several stages. The ultimate goal of all such decisions is either to minimise the effort required or to maximize the desired benefit. Hence, optimization can be defined as the process of finding the conditions that gives the minimum or maximum value of a function, Where the function represents the effort required or the desired benefit.

Concrete shear walls provide a cost effective means to resist seismic lateral loads and thus they are frequently used as the primary lateral load resisting system in reinforced concrete buildings. Shear walls with high flexural stiffness typically assist with limiting inter storey drifts in buildings, consequently reducing structural and non structural damage during seismic events. With the added benefits of structural system, shear walls make an excellent choice for resisting lateral loads in concrete buildings.

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. The analysis and design is done to satisfy all the checks as per Indian standards. Finally data base is prepared for various structural responses.

Cenek P. D., Wood J. H. (1990). Designing multi- storey buildings for wind effects Judge ford [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 protection.

Hoenderkamp J. C. D. (2004) presented 'Shear wall with outrigger trusses on wall and column Foundations.

Structural Design of Tall and Special Buildings, 13(1) studied about graphical method to optimize the position of outriggers on shear walls with flexibility foundations. The Location of outriggers will cause a maximum deflection in lateral direction at the top of the building. The method can be used for preliminary design of high rise structures subjected to horizontal loading

Optimal Drift Design of Tall Reinforced Concrete Building Frameworks. Adv. In Structural Optimization, American Society of Civil Engineers studied performs an effective computer-based technique that incorporates pushover analysis together with numerical optimization procedures to automate the pushover drift performance design of reinforced concrete (RC) buildings.

O. Esmaili S. Epackachi M. Samadzad and S.R. Mirghaderi (2008) Studied structural aspects of one of the tallest RC buildings, located in the high seismic zone, with 56 stories. In this Tower, shear wall system with Irregular openings are utilized under both lateral and gravity loads, and may result some especial issues in the behaviour of structural elements such as shear walls, coupling beams and etc.

John Zils and John Viise studied the structural system of a high-rise building often has a more pronounced effect than a low-rise building on the total building cost and the architecture. As a result, those faced with an initial venture into tall building design need to be aware of low-rise design.

James L. Beck, Eduardo Chan presented 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.

Alberto Carpinteri .Mauro Corrado, Giuseppe lacidogna and sandro cammarano (2012) “studied about three- dimensional formulation to analyze the lateral loading distribution of external action of high rise buildings.

C. T. Ng and H. F. Lam (2005) “presented the feasibility in formulating the structural design problem as a minimization problem and solving it by numerical optimization algorithms. With the help of the numerical optimization algorithms, the trial-and-error design process can be carried out in a systematic and, even more important, automatic manner and the design process is formulated as the minimization of the total weight of the building under a series of constraints, which are designed to consider different design criteria.

II. MODELLING OF THE STRUCTURAL SYSTEM IN ETABS

In this present study Ground +20 storey commercial building is considered for four different models i.e. Only frame, frame with only shear walls, frame with only shear core and the frame with shear wall and shear core. The total plinth area of the structure is 925sqm.The modelling is done in ETABS as follows.

2.1 First the structure is defined by a material property, frame sections, slab and wall sections and then the structure is divided into distinct membrane and shell element.

2.2 The membrane element is used for slab sections and the shell element for wall sections as the shell element combines membrane and plate bending behavior, as shown in fig. It has six degrees of freedoms in each corner point. It is a simple quadrilateral shell element which has size of 24 x 24 stiffness matrix. The shell element is presented in Fig.1

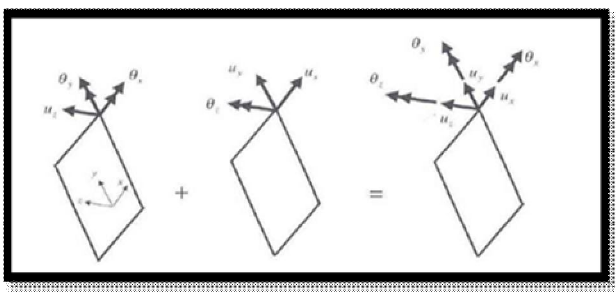


Fig.1 Shell Element used for Modelling

2.3 Grid lines are made for the x, y and z coordinates and the frame sections and wall sections are drawn from scratch.

2.4 Boundary conditions are assigned to the nodes wherever it is required. Boundary conditions are assigned at the bottom of the wall i.e., at ground level where restraints should be against all movements to imitate the behaviour of shear wall.

2.5. The material properties used in the models are shown in Table: 1

The element properties of the structural system are taken as follows:

Table: 1 Material Property

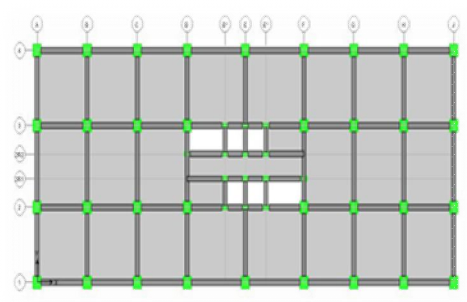
Material name	**Concrete**
Type of material	Isotropic
Density	$25kN/m^3$
Modulus of elasticity	$5000\sqrt{fck}$
Poisson’s ratio	0.2
Characteristic strength	M 30

Table: 2 Element Property

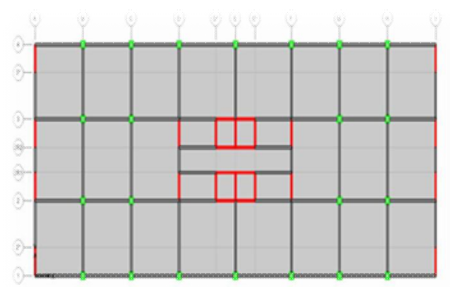
Modeling cases	Element property	
	Beam section	**Column section**
(Model-1)Only frame without any walls	18”x27”	Foundation to 2nd floor 48”x48” 3rd to 20th floor 40”x40”
(Model-2)Frame with only shear wall	15”x24”	40”x40” for all the Floors.
(Model-3)Frame with only shear core	15”x24”	40”x40”for all the floors
(Model-4)Frame with shear wall and shear core	9”x21”	Foundation to 5th floor 32”x32” 6th to 20th floor 24”x24”

III. BUILDING PLANS

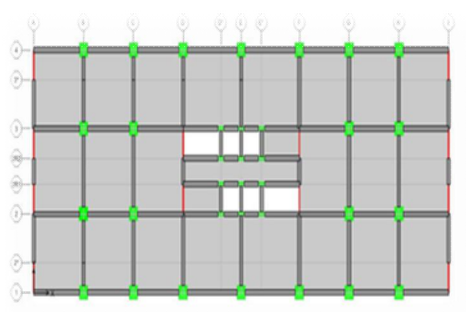
Four different types of structural framing considerations are considered for the study. The diagrammatic details are presented in Fig.2



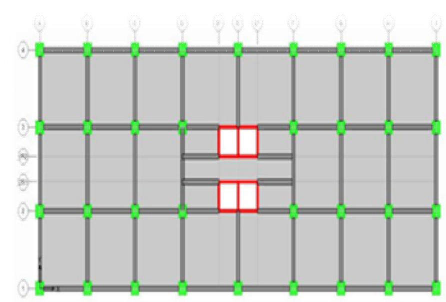
Normal Frame



Frame with Shear Core and Shear Wall



Frame with Sear Wall

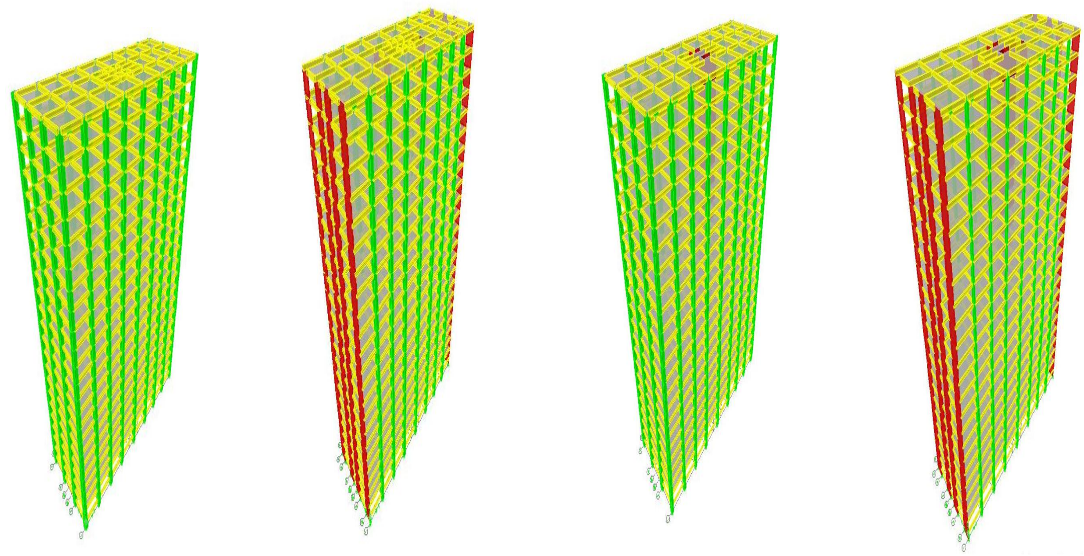


Frame with Shear Core

Fig.2 Building Configuration

IV. MODELS OF THE BUILDINGS IN ETABS

The models of the Buildings with different configurations modelled in ETABS is shown in figure.3



Model 1 Model 1 Model 1 Model 1

Fig.3 Model of the Building with different configurations

V. LOAD CONSIDERATION

While designing any building, different loads acting on it play a major role. An error in estimation of these loads can lead to the failure of the structure. Therefore, a careful study of loads that are acting on the structure becomes necessary. The loads in particular area must be selected properly and the worst combination of these loads must be evaluated. The dead load in a building should be comprised of the weight of all walls, partitions, floors, roof and should include the weight of all other permanent constructions in that building. Dead load for the design purpose is assessed from the code, IS 875:1987(Part I). Seismic design is done in accordance with IS: 1893:2002. This RC framed building is located in Seismic Zone III. The parameters used for analysis and designs are given below as per IS: 1893. (Part I). Siesmic and wind parameters are presented in Table. 3

Table: 3 Seismic and Wind Parameters

Seismic Coefficients IS: 1893-2000		**Wind Coefficients IS: 875-1987**	
Seismic Zone Factor	0.16	Wind speed (V_b)	50m/s
Soil Type	II	Terrain Category	II
Importance Factor (I)	1	Structure Class	C
Response Reduction (R)	5	Risk Coefficient k_1 factor	1
		Topography k_3 factor	1
		Windward coefficient	0.8
		Leeward coefficient	0.5

After the gravity and lateral load analysis is over , the parametric study is carried out for the optimized design of the structural system and responses like out-of-plane bending moments, axial compression load, maximum tensile force, maximum shear force, maximum storey drift, lateral load and storey shear are verified and The structural responses are tabulated and shown in the following graphs

VI. ANALYSIS RESULTS AND DISCUSSION:

The following structural configurations are considered for study.

Model 1: Only Frame Structure

Model 2: Frame + shear core

Model 3: Frame + shear walls

Model 4: Frame + shear core + shear walls

Four different models are tested for effect of the structural configuration on properties like axial force, Moments, Shear forces and story lateral loads. Fig.4 presents effect on axial force, Fig.5 presents effect on moments, Fig.6 presents effect on Moments and Fig.7 presents effect on lateral loads.

6. 1. Effect of axial force on four different models

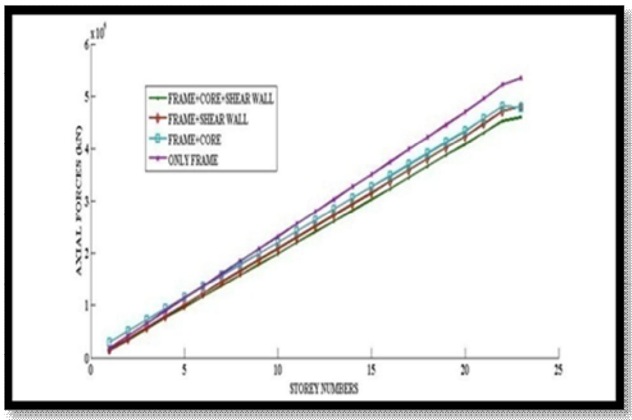


Fig.4 Axial Force on four models

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%.

6. 2. Effect of moments on four different models

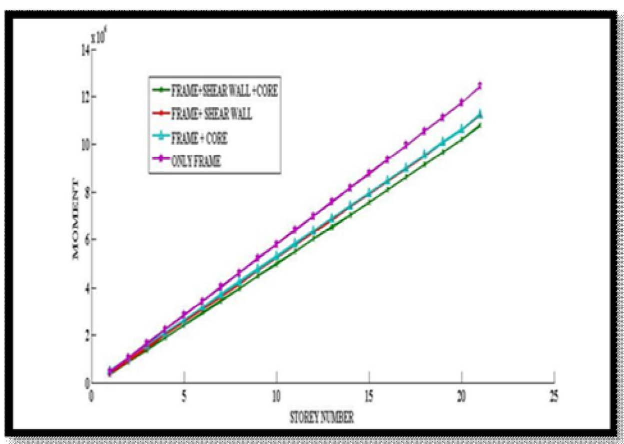


Fig.5 Out of plane moments on four models

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%.

6. 3. *Effect of shear force on four different models:*

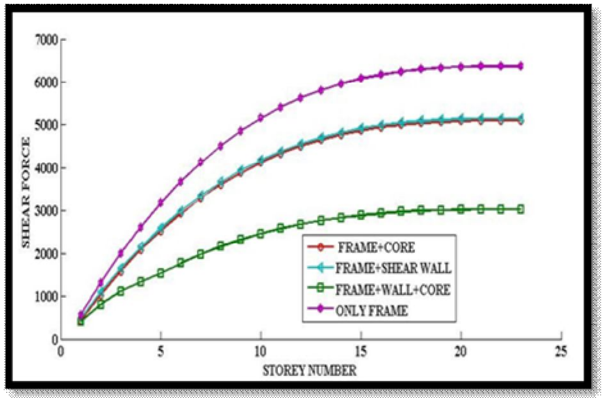


Fig.6 Shear Force on four models

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

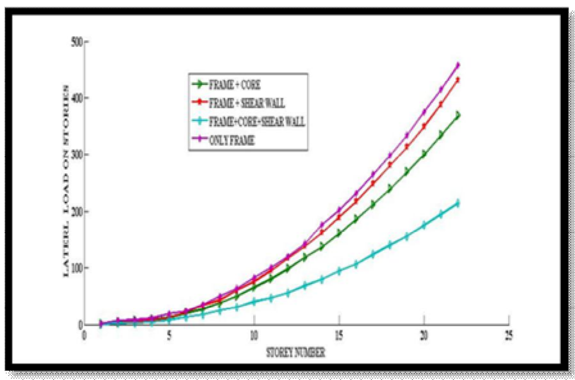


Fig.7 Storey Lateral Load on four models

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%.

6. 5. *Effect of drift on four different models:*

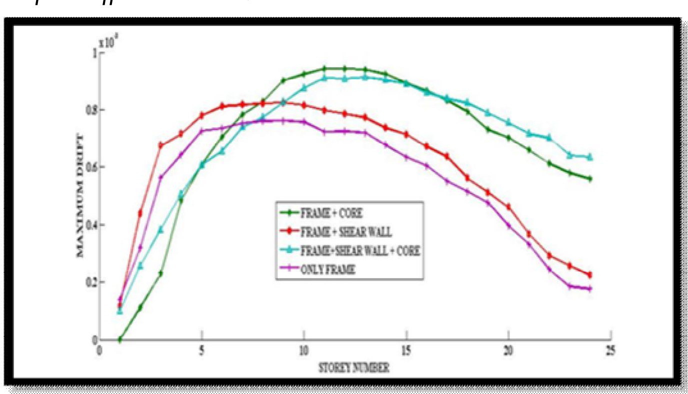


Fig.8 Drift on four models

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 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:

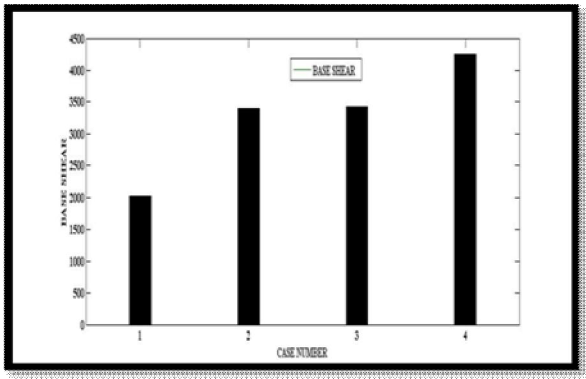


Fig.9 Base Shear in four models

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%

VII. 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 was 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 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%

VIII. 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.

Table: 4 Conclusions Of Element Properties

Modeling cases	**Element property**		**Total Volume of concrete for beam, column, slab and footing**	**% reduction in concrete**
	Beam section	**Column section**		
(Model-1) Only frame	18”x27”	Foundation to 2nd floor 48”x48” 3rd to 20th floor 40”x40”	10275.6m^3	100
(Model-2) Frame with only shear wall	15”x24”	40”x40” for all the Floors.	7772.68 m^3	24.4
(Model-3) Frame with only shear core	15”x24”	40”x40”for all the floors	8315.42m^3	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	31.8

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