OPTIMIZATION OF STRUCTURAL MEMBERS IN RCC STRUCTURE USING E-TABS

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Abstract- *More than half of our country falls under active seismic zone and considerable destruction has been caused in India by earthquakes. A good knowledge of seismicity is essential for assessment of seismic hazard especially for a developing country like India where destruction and deaths due to earthquakes are at several order. The cost of the material required in structural system for a multistoried building makes 40-50% of the overall cost of a typical RCC structure. For the analysis and design of a RCC structure, there are many software available in the market such as STAAD-Pro, ETABS, SAP, ANSYS etc. Among all the available softwares the chosen software, ETABS has many advantages over its counterparts such as accurate analysis result, optimized design output, better user interface and availability of more number of Indian and International codes. In the present study we are aiming to optimize the size of structural components using ETABS. The analysis and design has been done for G+9, G+11 RCC structure for seismic zone III and V. The loading and all other relevant considerations are made for office building. Based on the output obtained from the detailed analysis, the quantity and cost models are prepared. These models have the direct applicability in the construction field giving the most economic cost and safe design.*

***Keywords-* E-TABS, Optimization, Quantity modelling, Cost modelling , RCC structure**

I. INTRODUCTION

1.1 OVERVIEW

The current development trend of India shows that majority of the construction works involves the use of cement concrete and/or reinforced cement concrete [1]. The reason of this may be the availability of the construction material like fine and coarse aggregate locally, and also the cheap unskilled labor. In the current construction practice in India, building modeling is relatively young field seeking to establish as a worthy scientific enterprise [2]. For the small scale construction people are yet consult the design engineers. This is mainly because they are unaware about the fact that construction on due consult of professionals can make their structure safer and more economic [3]. We cannot ignore the fact that various professionals involved in the construction field such as architects, design engineers, cost engineers, quantity surveyors and others work independently [4]. Each of them has their own approach and customs and their unique thumb rules. This leads to misunderstanding from office to field. Hence there exist lots of challenges to be dealt in this area.

Optimization is the process of making or using something as effectively as possible. For a particular structure, optimization may be done in various ways, optimization of space and utility by proper planning, optimization of material using the most efficient section, optimization of construction time by the best choice of construction technique, etc. [5]. Optimization should not just be a cost function instead a structure should be optimized functionally for its proper utility [6]. For a structural engineer or a designer the most important job is to make the most efficient structure, with minimum construction cost and maximum utility. The cost optimization not only reduces the overall costs in comparison to the classical design approach, it also offers a detailed insight into the structure of all relevant manufacturing, material, construction and utility costs [6].

A structure may look strong from outside but it may not perform as expected during adverse conditions. This has been seen in the past experience like earthquake of Bhuj 2001 [8]. Hence a model is necessary to be designed well for various seismic conditions as well as construction needs proper supervision. The development of FEM based analysis and design software has facilitated the structural engineers and designers to develop various structural optimization techniques [9]. Due to such developments optimization of structure has become a widespread reality. However even in case of optimal structural design, there exist some limitations that hinder their application in the engineering practice [10]. Realistic structural design optimization should consider real structural properties, multiple load cases, and constraints representing all ultimate and serviceability limit state design rules [11]. For better design and efficiency of high rise buildings with respect to different perspectives such as structural, services, functional performance, etc., new and innovative structural plan geometry/configurations have been adopted such as Y shaped, star shaped, tubular, etc [12]. In the best case the design following the provisions of Indian Codes with advance references of international codes are the one best reliable.

The detailed structural analysis and design of building gives more accurate quantity requirement of the RCC multistoried building. The cost variation with the same plan with different number of stroyes, and different seismic zone is being considered. The variation of number of storied to be considered are G+9, G+11, G+13 and G+15 i.e. 10 storey, 12 storey, 14 storey and 16 storey. The seismic zones to be considered are zone III and zone V. Hence design and analysis of 8 buildings is done using E-

TABS. The loading parameter for an office building with infill brick masonry is considered. Along with the basic load, seismic load and wind load is also be taken into account while analysis of the structure.

II. LITERATURE REVIEW

Shweta A. Wagh, et.al. (2014) the author highlighted the point that use of steel in construction industry in very low in India to that of other developing countries. With the current construction trend there is a great potential in increase in steel demand for construction. In the present work author has made a comparative study of RCC structure with concrete- steel composite for G+12, G+16, G+20 and G+24 story buildings situated in seismic zone II and wind speed of 44m/s. for the modeling of composite and concretesteel composite structure, author has used STAAD-Pro and the result has been compared. The comparison parameters included cost, axial force, bending moment and shear force in beam and column.

Aniket Sijaria, et.al. (2014) in this particular paper the author has included the analysis, cost comparison, design and planning of the G+5 industrial building. The material used is concrete-steel composite and the floor height considered is 3.658 m. ETABS is used for analysis and design of the structure. Seismic consideration is taken as per the Indian Standards provision. The result shows that composite building is cheaper than RCC. The rate of construction is faster hence improves the economy of the building further.

Anish N. Shah, et.al. (2013) the author has done the modeling, design and analysis of G+15 storey office building using STAAD-Pro. The building was situated in seismic zone IV and wind speed of 39m/s was acting.

Mahbuba Begum, et.al. (2013) the author has conducted a cost analysis in the concretesteel composite structure in Bangladesh. The author highlights the convenient method of construction of RCC and is popularity. Due to its low performance during earthquake, concrete-steel composite material is gaining popularity in the present days. For mid-rise and high buildings RCC doesn't show economic advantage thus concrete-steel composite is to be preferred in such cases. The author further concludes that for the storey greater than G+15, composite structure proves to be economic.

A.M. Mwafy, et.al. (2012) this paper studies the impact of increasing material strength on seismic performance and cost-effectiveness of high-rise buildings. Five 60-story reinforced concrete buildings with varying concrete strengths, ranging from 45 to 110 MPa, are designed and detailed to fine accuracy keeping almost equal periods of vibration. Detailed fiber-based simulation models are developed to assess the seismic response of the reference structures using inelastic pushover and incremental dynamic analyses (IDAs) under the effect of 20 input ground motions. It is concluded that a considerable saving in construction cost and gain in useable area are attained with increasing concrete strength. The seismic response of high-strength tall structures is not inferior, but may be safer at high ground motion intensity levels, than that of normal strength materials. This paper also summarizes a systematic seismic assessment study and provides practical recommendations to understand the reliability and cost effectiveness of high-rise buildings in earthquake-prone areas.

III. PROPOSED METHODOLOGY

3.1 MODELLING CONSIDERATION

3.1.1 DEFINING GRID SPACING AND STOREY HEIGHT

The structural modelling, analysis and design is done using E-TABS software. Initially, the model grid spacing and storey heights are defined.

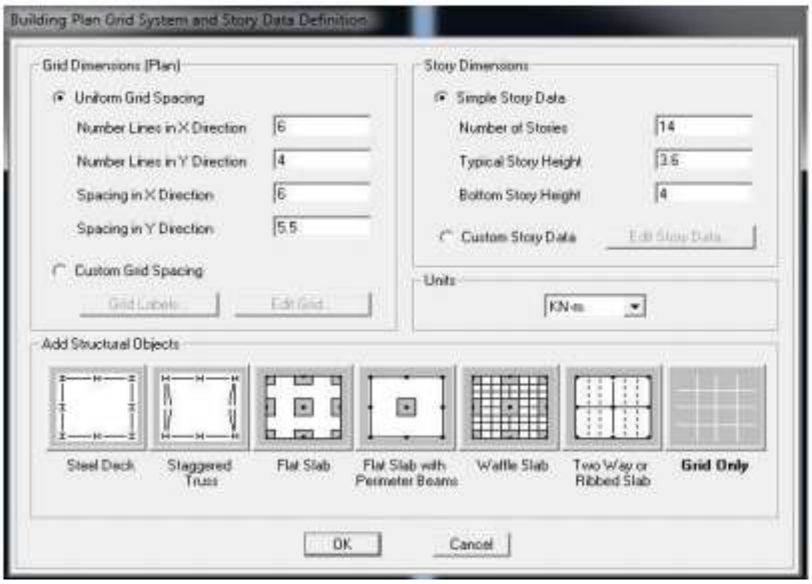


Figure 3. 1: Defining Grid Spacing and Storey Height

3.1.2 DEFINING MATERIAL PROPERTIES

The various materials to be used in the design such as steel and concrete are defined in this step. For this design the materials defined are steel grade Fe 500, and concrete grade of M25, M30 and M35.

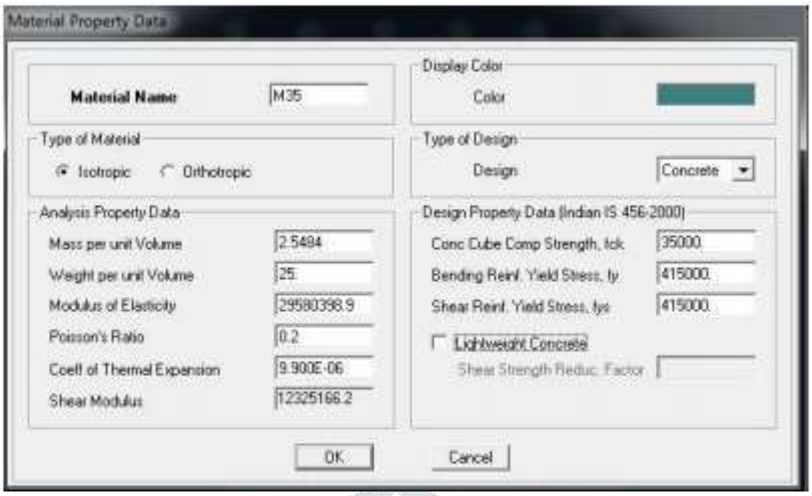


Figure 3. 2: Defining Material Properties

3.1.3 DEFINING FRAME SECTIONS AND SLAB

Once the materials are defined we use these materials and define various sections. The structural sections to be defined are beams, columns and slabs. For all the building in the present work we use slab of thickness 120 mm. For the optimal design the beam and column dimensions are to be varied starting from the least possible dimension. We have started with the minimum permissible dimension as per IS 456:2000 and gone up to the maximum requirement taking into site feasibility into consideration.

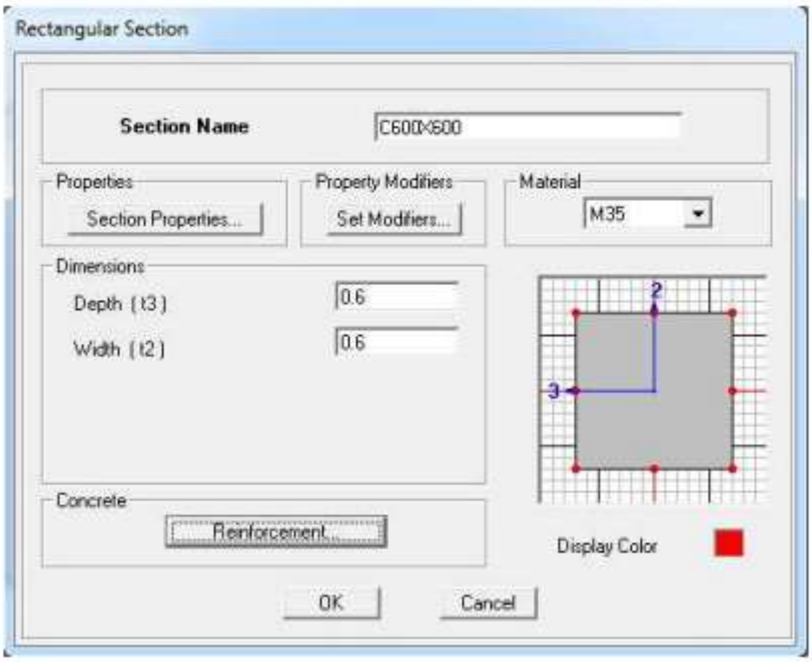


Figure 3. 3: Defining Frame Sections

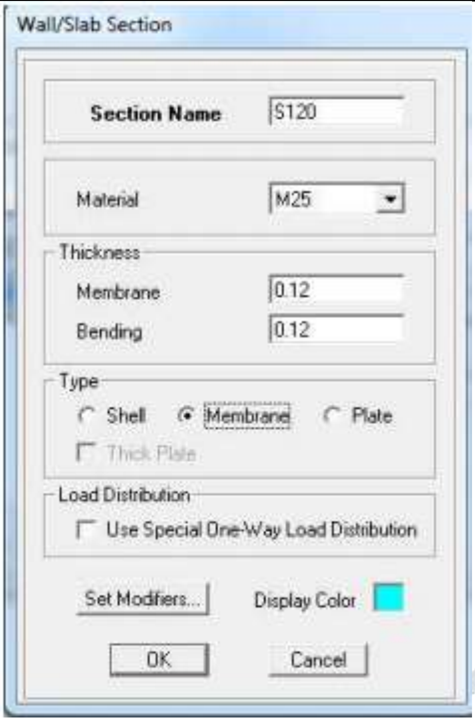


Figure 3. 4: Defining Slab

3.1.4 DEFINING STATIC LOAD CASES

Various static loading patterns are to be defined as per the type of loads acting on the structure. In the present works the various load cases defined are shown in figure below.

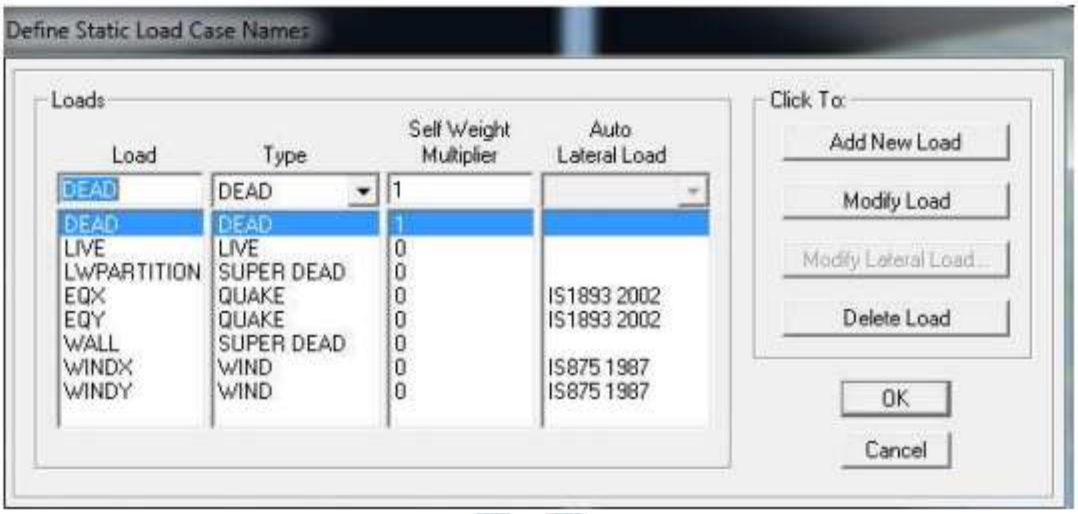


Figure 3. 5: Defining Static Load Cases

Dead load includes the self-weight of the material. This is automatically calculated knowing the section dimensions and materials properties. The unit-weight of the materials is taken with account of IS 875 (Part-I):1987.

Live load is taken with account of IS 875 (Part-II):1987 for an office building. This live load includes floor finishing of 40 mm and ceiling plaster of 6mm. Live load at terrace also includes top finishing of 150 mm.

Lightweight partition is the additional load taken into account which is expected to get induced in the office floor due to the partitions of cabin etc.

Wall Load are frame line loads that are induced due to brick masonry.
There are three category of wall load:
i. Exterior wall: 230 mm thick wall with 15 mm plaster on both sides.
ii. Interior wall: 115 mm thick wall with 15 mm plaster on both sides.
iii. Parapet: 230 mm thick wall with 15 mm plaster on both sides up to a height of 0.9 m.

Quack load that is mentioned is the earthquake load acting both is direction X as well as direction Y. Both are to be mentioned separately and details are to be given as per IS 1893 (Part-I) 2002.

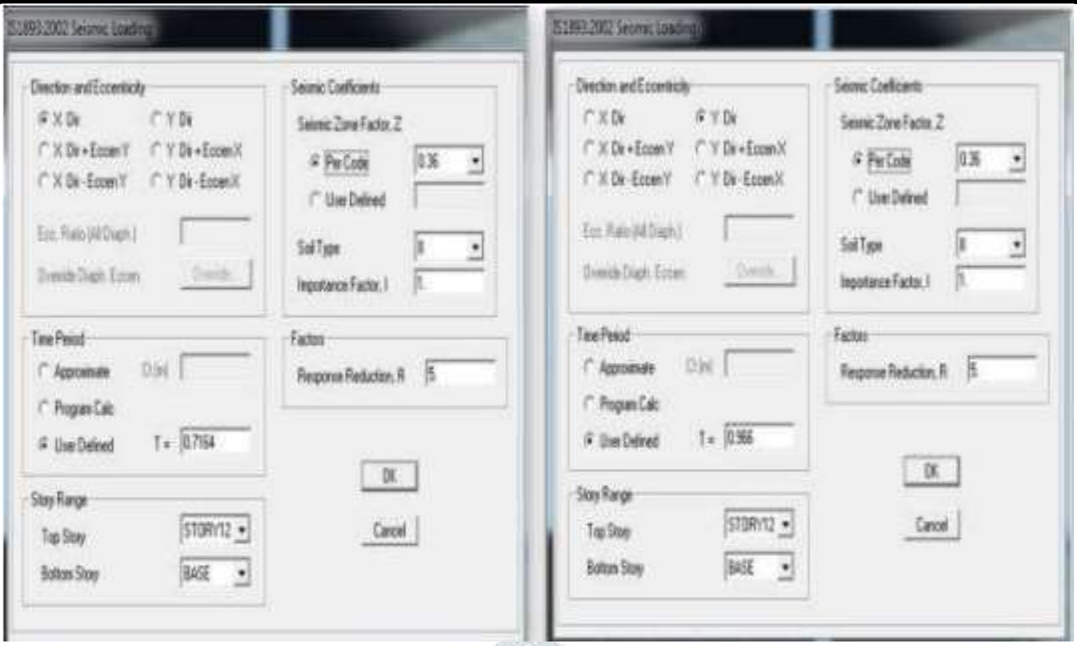


Figure 3. 6: Defining Earthquake loads

Wind Load acting on the building is taken assuming the building is located at Punjab whose average wind speed is 47 m/s. Other coefficients are taken as per IS 875 (Part-III): 1987. The wind load is computed for both directions i.e. Direction X and direction Y.

Figure 3. 7: Defining Wind loads

3.2 SPECIAL PARAMETERS IN MODELLING

Some specials parameters are applied to the model to satisfy provisions of code and the practical behaviour of the building. Basically they are: support restraints and assigning of rigid diaphragms in slabs. In base storey plan (first storey) all support points are selected and restraints are applied for translation and rotation in all the three axes.

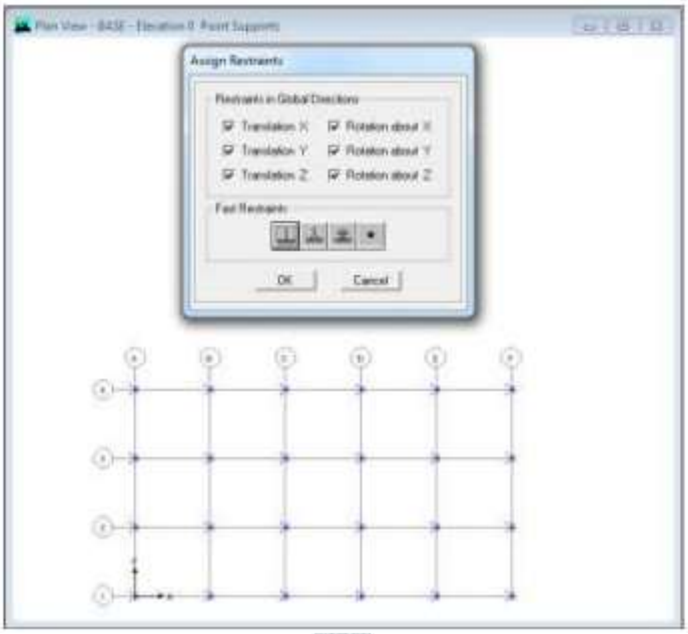


Figure 3.8: Restrained Support Condition

Slabs at all the storey levels are modelled as membrane and rigid diaphragms are assigned to them. Assigning the rigid diaphragms allows the frame and slabs act rigid which is practically true.

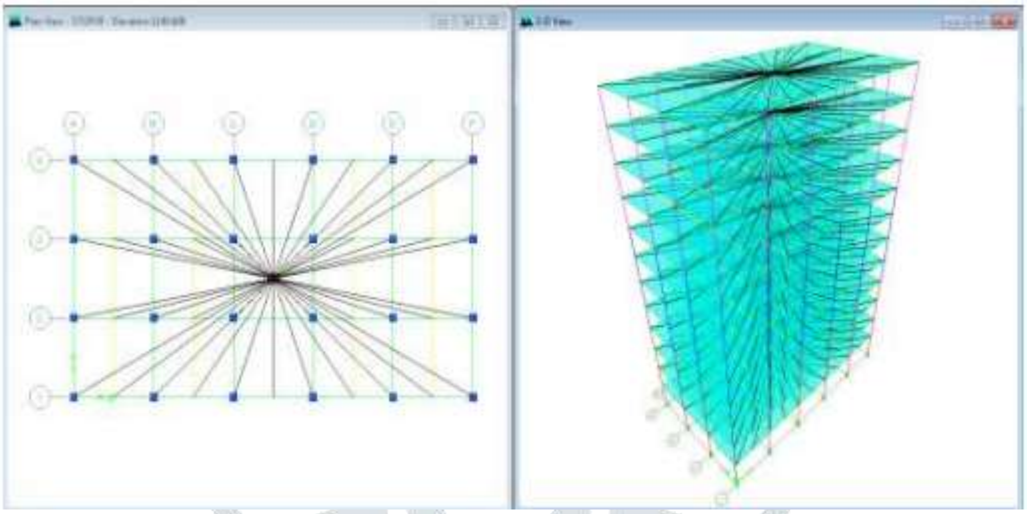
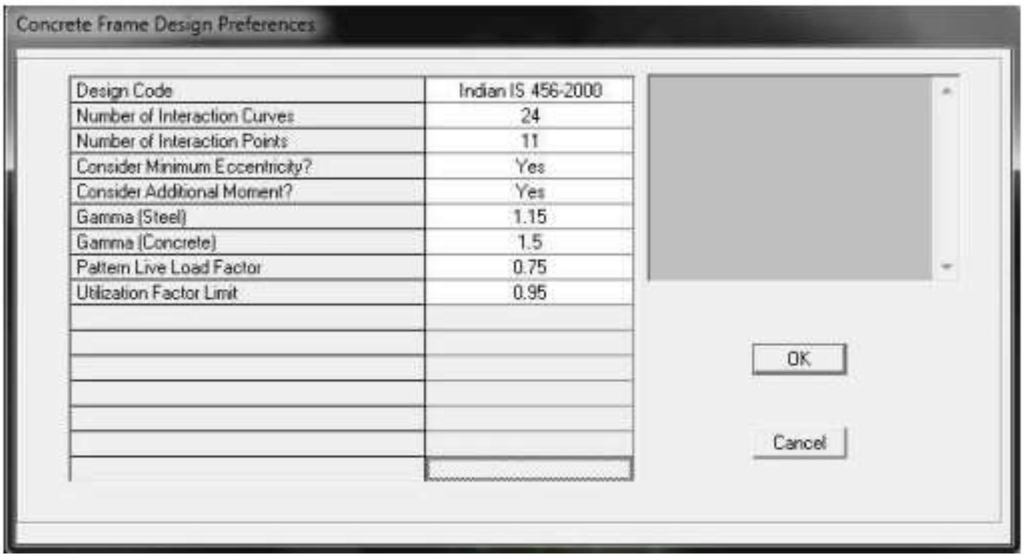


Figure 3.9: Defining Rigid Diaphragm

3.3 DESIGN PARAMETERS

The required design load combinations are set and the concrete frame and shear wall design are done as per IS 456:2000.



Design Code	Indian IS 456-2000
Number of Interaction Curves	24
Number of Interaction Points	11
Consider Minimum Eccentricity?	Yes
Consider Additional Moment?	Yes
Gamma (Steel)	1.15
Gamma (Concrete)	1.5
Pattern Live Load Factor	0.75
Utilization Factor Limit	0.95

Figure 3.10: Concrete Frame Design Preferences in ETABS

The design outputs are given graphically and in tabular form by ETABS. For the concrete frame design we have various design outputs as given below.

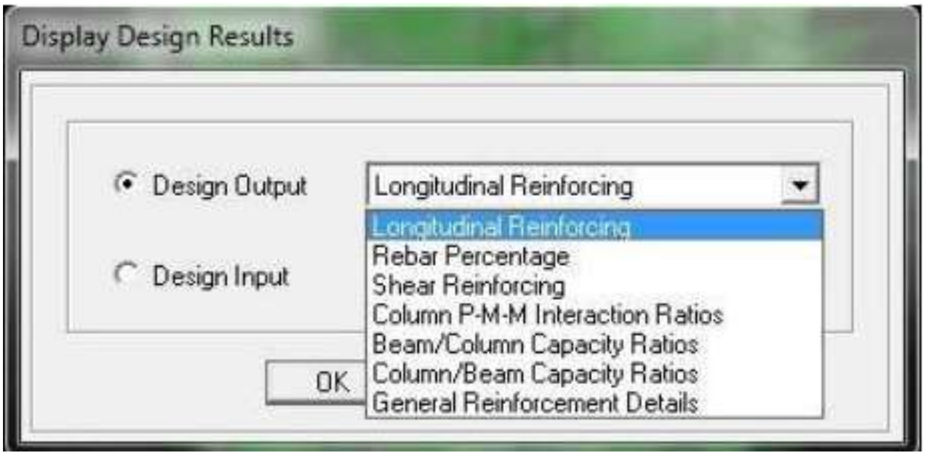


Figure 3.11:Concrete Frame Design Output Options

3.4 CALCULATION OF SEISMIC FORCES AND COEFFICIENTS

1. FOR 10 STOREY BUILDING

COVERED FLOOR AREA CALCULATION C/C -
Grid Spacing = 6 m x 5.5 m
Outer Dimension: L = (5 x 6) + 0.6 = 30.6 m
B = (3 x5.5) + 0.6 = 17.1 m
Area at each Floor = L x B = 30.6 x 17.1 = 523.26 m2
Total floor area = 523.26 x 10 = 5232.6 m2

CALCULATED VALUES-

Table 3.1:Calculated Values for 10 Storey Building

SEISMIC FORCES AND COEFFICIENTS		Zone III	Zone V
Fundamental Time Period (Sec)	T_x	0.5981	
	T_y	0.8065	
Design Horizontal Seismic Coefficient	A_{hx}	0.0364	0.0819
	A_{hy}	0.027	0.0607
Design Horizontal Base Shear(kN)	$\tilde{V}_{bx}$	452.235	1020.61
	$\tilde{V}_{by}$	335.449	756.423
Dynamic Analysis Base Shear (kN)	V_{bx}(SPECX)	1252.64	556.73
	V_{bx}(SPECY)	1233.06	548.03

RESPONSE SPECTRUM SCALE FACTOR -
10 storey Zone III: $\tilde{V}bx < Vbx$ = Modification of scale factor is not required
10 storey Zone V: $\tilde{V}bx < Vbx$ = Modification of scale factor is not required

2. FOR 12 STOREY BUILDING

COVERED FLOOR AREA CALCULATION C/C
Grid Spacing = 6 m x 5.5 m
Outer Dimension: L = (5 x 6) + 0.6 = 30.6 m B = (3 x5.5) + 0.6 = 17.1 m
Area at each Floor = L x B = 30.6 x 17.1 = 523.26 m2
Total floor area = 523.26 x 12 = 6279.12 m2

CALCULATED VALUES-

Table 3. 2: Calculated Values for 12 Storey Building

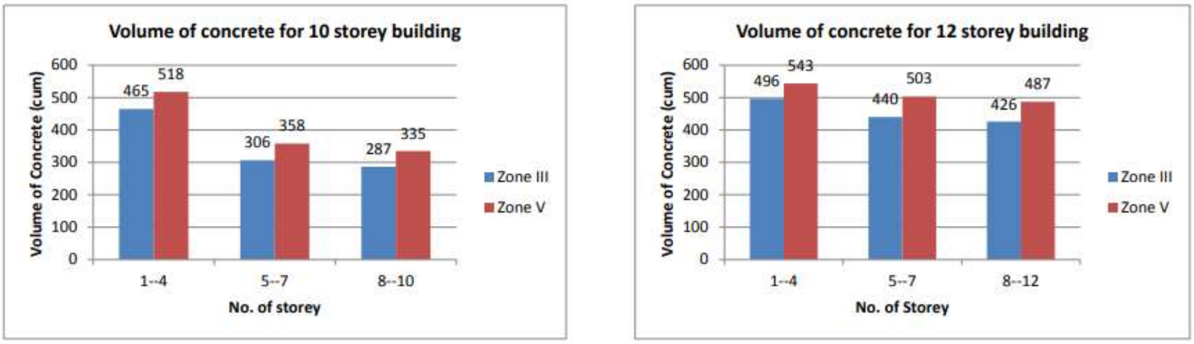
SEISMIC FORCES AND COEFFICIENTS		Zone III	Zone V
Fundamental Time Period (Sec)	T_x	0.7164	
	T_y	0.9660	
Design Horizontal Seismic Coefficient	A_{hx}	0.0304	0.0683
	A_{hy}	0.0225	0.0507
Design Horizontal Base Shear(kN)	$\tilde{V}_{bx}$	416.699	1040.699
	$\tilde{V}_{by}$	341.72	772.352
Dynamic Analysis Base Shear (kN)	V_{bx} (SPECX)	717.03	1613.31
	V_{bx} (SPECY)	700.22	1575.50

RESPONSE SPECTRUM SCALE FACTOR -
12 storey Zone III: $\tilde{V}bx < Vbx$ = Modification of scale factor is not required
12 storey Zone V: $\tilde{V}bx < Vbx$ = Modification of scale factor is not required

IV. RESLUTS

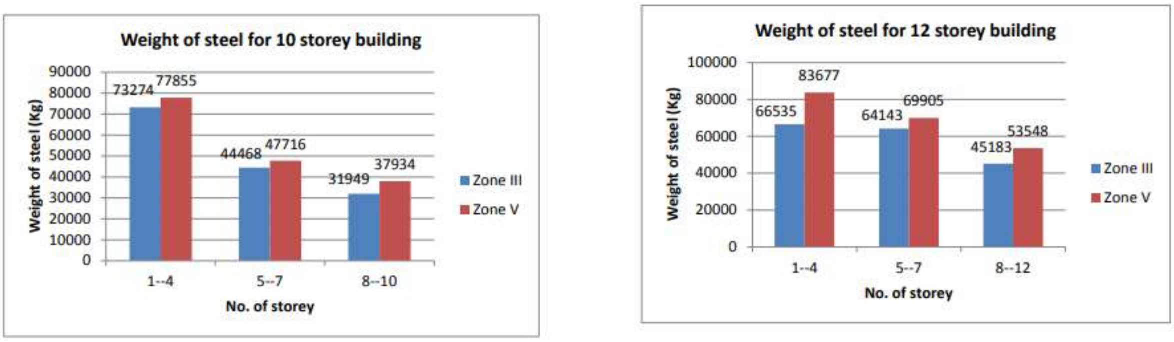
4.1 QUANTITY MODELLING

4.1.1 CONCRETE QUANTITY



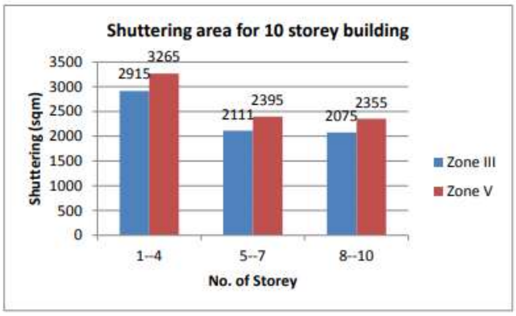
(Fig.4.1 :Volume of Concrete for 10 Storey Building, Volume of Concrete for 12 Storey Building)

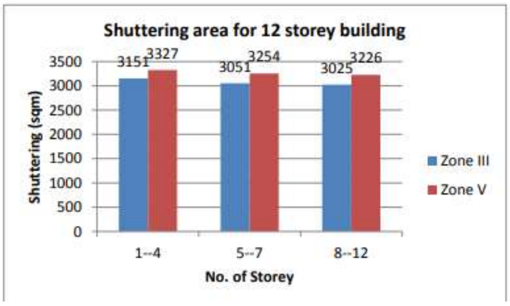
4.1.2 QUANTITY OF STEEL



(Fig.4.2 : Weight of Steel for 10 Storey Building, Weight of Steel for 12Storey Building)

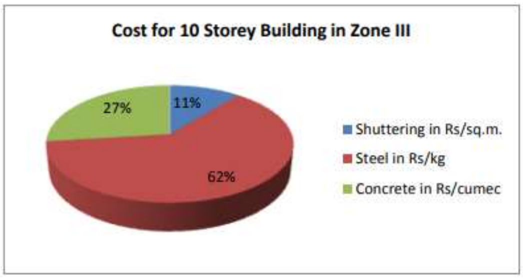
4.1.3 SHUTTERING QUANTITY

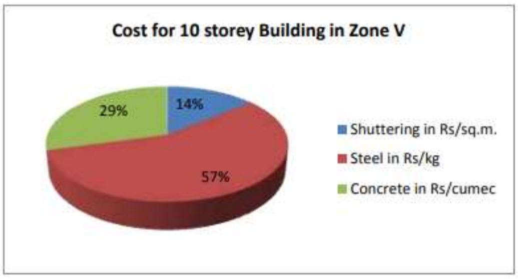




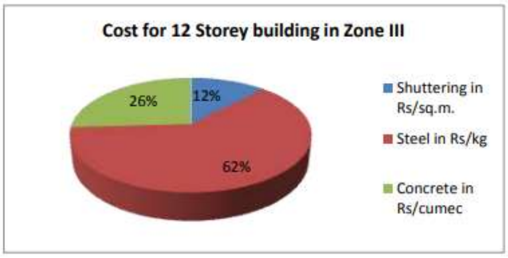
(Fig.4.3 : Shuttering area for 10 storey building, : Shuttering area for 12 storey building)

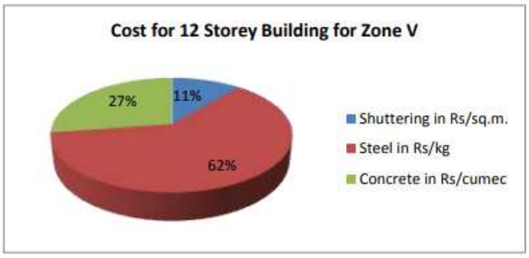
4.2 COST MODELLING





(Fig.4.4 : Cost division for 10 storey building in zone III, Cost division for 10 storey building in zone V)





(Fig.4.5 : : Cost division for 12 storey building in zone III, : Cost division for 12 storey building in zone)

CONCLUSION

For 10 storey building-

a. The quantity of concrete requirement increases by 14.35% per square meter for building in zone V as compared to building in zone III.

b. The quantity of steel requirement increases by 5.55% per square meter for building in zone V as compared to building in zone III.

c. The quantity of shuttering requirement increases by 13.14% per square meter for building in zone V as compared to building in zone III.

d. The overall cost of concrete and steel increases by 30.33% and 9.71% for building in zone V as compared to building in zone III.

e. The overall cost of building increases by 20.6% for building in zone V as compared to building in zone III.

For 12 storey building -

a. The quantity of concrete requirement increases by 11% per square meter for building in zone V as compared to building in zone III.

b. The quantity of steel requirement increases by 28.88% per square meter for building in zone V as compared to building in zone III.

c. The quantity of shuttering requirement increases by 13.12% per square meter for building in zone V as compared to building in zone III.

d. The overall cost of concrete and steel increases by 29.48% and 17.95% for building in zone V as compared to building in zone III.

e. The overall cost of building increases by 18.6% for building in zone V as compared to building in zone III.

FUTURE SCOPE

i. The work can be extended in making the result further accurate by following proper detailing method.
ii. Continuing the work for zone II and zone IV as well as non-seismic zone we can be the accurate cost premium.
iii. The work can be extended for the higher storeyes and low rise building too.
iv. The work can be further extended for residential as well as industrial building.
v. The work can be extended with variation of construction material from light weight concrete to Steel-Concrete composite construction.

ACKNOWLEDGMENTS

The authors are grateful to the G H RAISONI INSTITUTE OF ENGINEERING AND TECHNOLOGY, NAGPUR, MAHARASHTRA, INDIA, for providing guidances and resources to carry out this work.

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