OPTIMIZATION OF STRUCTURAL MEMBERS IN RCC STRUCTURE USING E-TABS

A Dissertation Report

Submitted in the Partial fulfilment of the

Requirement for Award of the Degree

of

MASTER OF TECHNOLOGY

In

STRUCTURAL ENGINEERING

By

Bidhan Sharma
(11302807)

Under the guidance of

Mrs. Geeta Mehta
(Assistant Professor)

School of Civil Engineering
Lovely Professional University
Phagwara,Punjab (India)–144411

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Department of Civil Engineering
Lovely Professional University
Phagwara – 144411, Punjab (India)

CERTIFICATE

*This is to certify that the Dissertation-ll Report entitled "***OPTIMIZATION OF STRUCTURAL MEMBERS IN RCC STRUCTURE USING E-TABS***", submitted by* ***Mr. Bidhan Sharma bearing Reg. no.: 11302807****in partial fulfillment of the requirements for the award of* ***Master of Technology in Civil Engineering*** *with specialization in "***Structural Engineering***" during session 2014-2015 in Lovely Professional University, Punjab is an authentic work carried out by him under my supervision and guidance.*

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other university/institute for the award of any Degree or Diploma.

Head of Department
Mandeep Kaur
School of Civil Engineering
Lovely Professional University

Dissertation Guide
Geeta Mehta
Assistant Professor
Lovely Professional University

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, G+13 and G+15 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

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LOVELY PROFESSIONAL UNIVERSITY
Phagwara – 144411, Punjab (India)

Department of Civil Engineering

DECLARATION STATEMENT

I, ***Bidhan Sharma*** *bearing reg. no.* ***11302807****, a student of* ***Master of Technology*** *in* ***Civil Engineering*** *with specialization in "***Structural Engineering***" at Lovely Professional University, Phagwara, Punjab, hereby declare that the work presented in this Dissertation-ll entitled "***OPTIMIZATION OF STRUCTURAL MEMBERS IN RCC STRUCTURE USING E-TABS***" is the outcome of my own bonafide work and is correct to the best of my knowledge and this work has been undertaken taking care of Engineering Ethics. It contains no material previously published or written by another person nor material which has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.*

Bidhan Sharma (11302807)
School of Civil Engineering
Lovely Professional University

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ABBREVIATIONS

Notation	Abbreviation
ACI	American Concrete Institute
ASCE	American Society of Civil Engineering
ATC	Applied Technology Council
BIS	Bureau of Indian Standards
BMC	Batch Mix Concrete
BSSC	Building Seismic Safety Council
DSR	Delhi Schedule of Rates
FEM	Finite Element Method
FEMA	Federal Emergency Management Agency
IDA	incremental dynamic analyses
IS	Indian Standard
LLRS	lateral load resisting system
NEHRP	National Earthquake Hazard Reduction Program
PAR	Plinth Area Rates
RCC	Reinforced Cement Concrete
RMC	Ready Mix Concrete
STAAD	Structural Analysis and Design

NOMENCLATURE

Sl. No.	Nomenclature	Notation
1	Design horizontal seismic coefficient	A_h
2	Dead Load	DL
3	Earthquake load	EQ
4	Live load	LL
5	Fundamental Natural Time Period	$T_{x,y}$
6	Design base shear	$\tilde{V}_b$
7	Dynamic base shear	V_b
8	Seismic Weight	W
9	Wind Load	WL

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CHAPTER 1
INTRODUCTION

1.1 GENERAL

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.

Based on the output obtained from the detailed analysis, the quantity modelling is done using Microsoft Excel. Further cost models for each building is prepared as per the cost given by Delhi Schedule Rate (DSR) 2013.

1.2 NEED OF STUDY

The comparative study on cost factor for reinforced concrete low to medium-rise building is required due to the following reasons:

i. For efficient use of resources that are majorly used in construction of building.
ii. For achieving the accuracy in calculating the quantity and cost of all the structural components.

iii. It is expected to be very helpful for the Designer, Architect, Engineers, Contractors and Investors in the every stages of a construction project.
iv. Proper analysis and design will led to safer and economic buildings which can be constructed with optimal and rational utilization of resources.
v. It is necessary in achieving the efficiency in the selection of the structural system of a particular building
vi. Bridging the gap and reducing the confusion between the Designers and the Architectures office and the site of construction.

1.3 OBJECTIVE

The objectives of this study are:

i. To analyze and design the RCC multi-storey building in zones III and V by detailed method using the ETABS software.
ii. To know the effect of earthquake zones on the cost of construction of medium rise buildings (10-16 storey).
iii. To present an approach for an optimized quantity and cost modeling of superstructure systems of medium rise buildings.
iv. The quantity modeling & cost modeling data can directly be used on field in preconstruction stage for the quantities & cost estimation of steel, concrete, shuttering for different zones. The quantity modeling & cost modeling data can directly be used on field in preconstruction stage for the quantities & cost estimation of steel, concrete, shuttering for different zones.

1.4 SCOPE

The scopes of this study are:

i. The approach for design & detailing of structural systems according to the seismic codes.
ii. Design process for structural systems and a software analysis of multistoried building for different stories and for different seismic zone.
iii. To deal with the calculation for quantities of concrete and steel incorporating the different combination of loadings.
iv. For different loading cases and seismic conditions quantity of concrete, quantity of steel and the cost will be worked out.

CHAPTER 2
LITERATURE REVIEW

2.1 GENERAL

Before proceeding to any study or research, intensive literature study is vital to get accustomed to the current state of understanding, ongoing researches on the field and the challenges to be addressed.

The literature study is divided into two categories viz. previous research works, conference papers and published works, and relevant Indian and International codes and standards.

2.2 PREVIOUS RESEARCH WORKS AND CONFERENCE PAPERS

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 concrete-steel 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.

Mahbuba Begum, et.al. (2013) the author has conducted a cost analysis in the concrete-steel 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.

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.

The author highlighted the points such as ease of construction using composite materials. The time saving factors, faster construction rate, less manpower involved, lighter dead load hence smaller foundation, and all of these lead to saving of time and economy was discussed in the paper. The author concludes with the advantages of composite structure over RCC. The paper also showed that the deflection and storey drift is almost double in composite structure as that of RCC, but the value is still within the permissible limit of the code.

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.

Thiruvengadam.V. et.al. (2010) this work presents the cost prediction of building foundations designed for seismic resistance in low, moderate and high seismic zones of Indian subcontinent. Medium rise reinforced concrete buildings are considered with structural system consisting of moment resisting frames with column grids of 7.5m X 7.5m and floor system with solid slabs supported on main grid and secondary beams. The study has brought the requirements of structural quantities and foundation costs per unit built-up area of the buildings and also brings out the cost premium for providing seismic resistance. This work also highlights the achievable economy in foundation costs through appropriate selection of foundation system with proper evaluation of allowable bearing pressure of soils through adequate geotechnical investigations of the building sites

Thiruvengadam.V. et.al. (2004) this paper deals with structural cost modeling of seismically designed and detailed reinforced concrete framed structures for medium rise buildings in various seismic zones of Indian subcontinent. The model provides the total and component wise quantities of structural concrete, steel reinforcement and shuttering material per unit area of floors. The structural system cost and the cost premium for seismic safety are presented. The study is broadly validated from the historic data of seismically designed and constructed buildings. The results of the study would be useful for design professionals and quantity surveyors.

2.3 INDIAN AND INTERNATIONAL CODES AND STANDARDS

Delhi Schedule of Rates (DSR-2013), Central public works department, 2013

Delhi Schedule of Rates, being published by C.P.W.D. from time to time, is a very comprehensive document and useful in execution of works. Apart from C.P.W.D., this Schedule of Rates is used as a guide by a number of departments, public sector undertakings, private sector builders and architects etc.

Plinth Area Rates (PAR-2013), Central public works department, 2013

Plinth area rates is a very useful document for preparation of preliminary estimates of all Government residential buildings and non-residential buildings e.g. offices, colleges, hospitals, schools, hostels, etc. which is in extensive use by all Central Government Departments, Public Sector undertakings, private sector builders and engineers. The rates adopted in the PAR are based on detailed analysis of actual cost of construction of buildings of various types in different parts of the country and provide a realistic basis for assessment of approximate cost of new proposed buildings.

IS 1893 (2002): Criteria for Earthquake Resistant Design of Structures (fifth revision)

This standard (part1) deals with assessment of seismic loads on various structures and earthquake resistant design of buildings. Its basic provisions are applicable to buildings, elevated structures, industrial and stack like structures, bridges, concrete, masonry and earth dams, embankments and retaining walls and other structures. Temporary elements such as scaffolding, temporary excavations need not be designed for earthquake forces. This standard does not deal with the construction features relating to earthquake resistant design in buildings and other structures.

ATC 40: Seismic evaluation and retrofit of concrete buildings Volume-I, Applied Technology Council, California seismic safety commission, 1996

This document contains the main body of the evaluation and retrofit methodology, presented in13 chapters, with a glossary and a list of references. It contains all the parts of the document required for application and use of the methodology for evaluation and retrofit of a building. The first seven chapters address the more general and conceptual aspects of the methodology, which will be of interest to the broader range of the expected audience of building owners and agency representatives, architects, and building officials, as well as structural engineers and analysts. The next five chapters, 8 through 12, address the more technical and analytical aspects of the methodology, expected to be of primary interest only to the structural engineer/analyst members of the audience. The last chapter, 13, provides summary concluding remarks which are of interest to the broader audience. The title page of each chapter contains an audience spectrum bar to assist the reader in assessing the appropriate level of interest.

IS 13920 (1993): Ductile Detail of RCC Structure Subjected to Forces – Guidelines

This standard covers the requirements for designing and detailing of monolithic reinforced concrete buildings so as to give them adequate toughness and ductility to resist severe earthquake shocks without collapse. Provisions of this code shall be adopted in all reinforced concrete structures which are located in seismic zone III, IV or V. The provisions for reinforced concrete construction given herein apply specifically to monolithic reinforced concrete construction. Precast and/or pre-stressed concrete members may be used only if they can provide the same level of ductility as that of a monolithic reinforced concrete construction during or after an earthquake.

IS 4326 (1993): Earthquake Resistant Design & Construction of Buildings-Code of Practice

This standard deals with the selection of materials, special features of design and construction for earthquake resistant buildings including masonry construction using rectangular masonry units, timber construction and buildings with prefabricated flooring/roofing elements. Guidelines for earthquake resistant buildings constructed using masonry of low strength and earthen buildings are covered in separate Indian Standards.

CHAPTER 3

STRUCTURAL SYSTEMS, QUANTITY AND COST MODELLING

3.1 GENERAL

This chapter deals with the background study of the theory related with the research work. The theory of the structural system has been covered but the most importantly the moment resisting frame that has been used in the work has explained in detail. The later part of the chapter deals with the study of quantity and cost modelling, its various aspects along with concept of cost premium.

3.2 STRUCTURAL SYSTEM

The structural system of a high-rise building is designed to cope with the vertical gravity loads and lateral loads caused by wind or seismic activity. The structural system consists only of the members designed to carry the loads, all other members are referred to as non-structural.

Using an appropriate structural system is critical to good seismic performance of buildings. While moment-frame is the most commonly used lateral load resisting structural system, other structural systems also are commonly used (Fig. 3.1) like structural walls, frame-wall system, and braced-frame system.

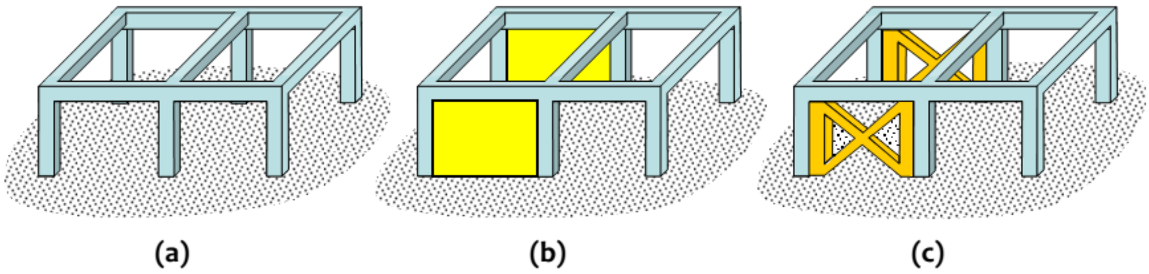


Figure 3. 1: Common Structural Systems Employed in Buildings: (a) Moment frames, (b) Moment frames with structural walls, and (c) Braced moment frames

Sometimes, even more redundant structural systems are necessary, e.g., Tube, Tube-in-Tube and Bundled Tube systems are required in many buildings to improve their earthquake behaviour. These structural systems are used depending on the size, loading, and other design requirements of the building. One structural system commonly used poses special challenges in ensuring good seismic performance of buildings; this is the Flat slab-column system. The system makes the building flexible in the lateral direction and hence the building deforms significantly even under small levels of shaking. Further, it has relatively low lateral strength, and therefore ductility demand during strong earthquake shaking tends to be large; many times, such levels of ductility cannot be incorporated in buildings with flat slab-column system. This structural system should not be used without introducing in the building stiff and strong lateral force resisting elements, like structural walls and braces.

3.2.1 TYPES OF STRUCTURAL SYSTEMS

The structural systems can be super-structural systems or sub-structural systems. They are classified as below.

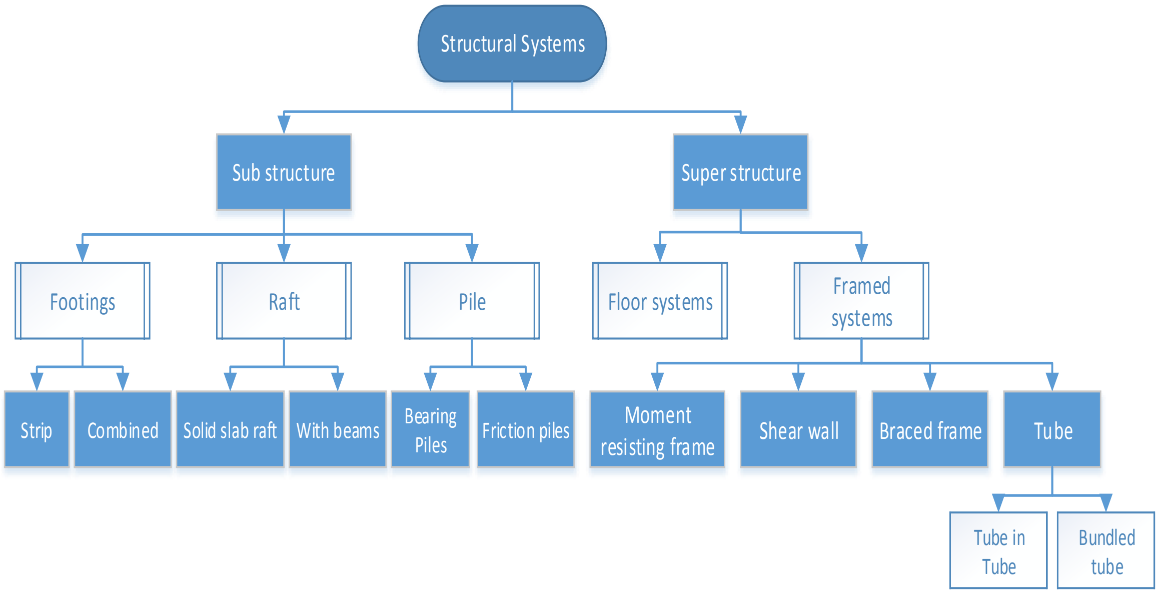


Figure 3. 2: Structural Systems in Sub-Structure and Superstructure

3.2.2 SUPER STRUCTURE SYSTEMS

A classification for the super structural system of a high-rise was introduced in 1969 by Fazlur Khan and was extended to incorporate interior and exterior structures. The primary lateral load-resisting system defines if a structural system is an interior or exterior one. The following super structure systems are possible:

a. Moment resisting frame systems
b. Shear wall systems
c. Braced frame systems

d. Tube systems

e. Flat Slab Building

The primary consideration in the choice of structural system in tall buildings is to provide resistance to lateral loading due to earthquake and wind, which are dynamic in nature.

The choice of the structural system depends on form and functional requirement of the building and should satisfy safety and serviceability. However, with the predominant increase in height, structural requirement becomes the primary design criteria.

3.2.3 MOMENT RESISTING FRAME SYSTEMS

Moment frames consist of a grid of vertical (i.e., columns) and horizontal (i.e., beams) members In this system, the lateral load resistance is provided by the interaction of girders and the columns as shown schematically in Figure 3.3. The resulting "frame" consisting of the beams and columns is designed to keep from changing into a parallelogram by making the connections rigid. Structural toughness, which is the ability to repeatedly sustain reversible stresses in the inelastic range without significant degradation, is essential for a moment-resistant frame designed to resist seismic forces.

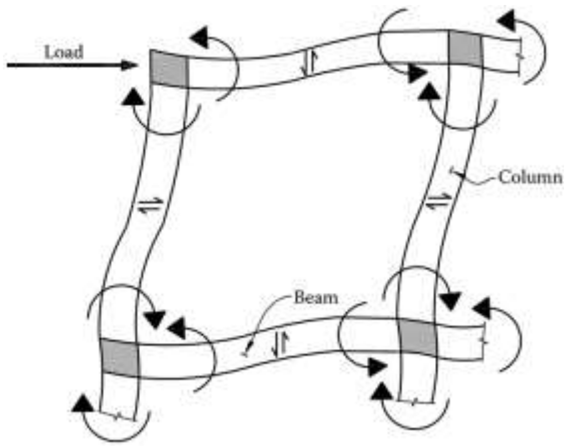


Figure 3. 3: Moment-Resisting Frame

The lateral resistance is provided by keeping the frame from changing into a parallelogram. The interconnection of columns and beams is rigid.

They resist lateral loads through axial forces, bending moment and shear force generated in both beams and columns (Fig. 3.4). Beam and column sections should be designed as under-reinforced sections, and thereby, can be expected to undergo ductile behaviour;

brittle shear failure must be prevented through capacity design procedures. While deciding the structural configuration of the building, predominant flexural behaviour in beams and columns should be facilitated. This can be achieved by using relatively long frame members; short beams and columns attract large forces and are susceptible to fail in a brittle manner.

Figure 3. 4: Behaviour of Moment Frames

The above figure shows the Bending moment, shear force and axial force diagrams in the benchmark building having moment frames.

High tensions can be very detrimental, since severe cracking can result in catastrophic failures when the loading is reversed and the member is also required to resist bending. For this reason, the ACI 318-05/08 requires that the flexural strengths of columns be at least 20% more than the sum of the corresponding strength of the connecting beams at any story. This is to assure that when inelastic action occurs, it will form plastic hinges in the beams, not the columns. Moment-resistant frames can be used in combination with concrete shear walls to provide dual system.

3.3 QUANTITY AND COST MODELLING

Construction cost is an important element that should be monitored at different phases of the building construction process. Construction cost is a factual process designed to give a reliable estimation or prediction of its financial cost. The purpose of construction cost estimation is to provide information for construction decisions including areas in the procurement and pricing of construction, establishing contractual amount of payment, and controlling actual quantities.

Costs are used in construction field from the very conceptual planning stages, through design and construction and during the operation (useful life) of the facility. During the preliminary planning stages of the project, the degree of accuracy of costing is usually limited. The estimates made at this stage are usually conceptual in nature and are based on past trends and the historical knowledge of similar projects. A cost model thus helps to establish this historical background.

The cost of structural system for multistoried buildings falls in the range of 40-50% of the building cost. The cost estimation approach, called cost modeling, has two major objectives; reasonable prediction of the cost at the early stages of the project planning and design and to serve as a tool for the economical evaluation of design alternatives. Being the major cost center, cost modeling of the structural system is of considerable interest to all concerned with the cost management. Cost modeling is also essential for value management exercises.

Cost estimation models are mathematical algorithms or parametric equations used to estimate the costs of a product or project. The results of the models are typically necessary to obtain approval to proceed, and are factored into business plans, budgets, and other financial planning and tracking mechanisms.

3.3.1 QUANTITY MODEL

The quantities of structural concrete, reinforcement steel and shuttering material for slabs, beams and supporting columns for a particular floor area are expressed as equivalent volume of concrete, weight of steel reinforcement and equivalent shuttering area per square meter of the floor area respectively for individual components as well as their combined value. This is called quantity model.

Quantity models are also an insight into the efficient and economic structural design of the building.

3.3.2 COST MODEL

Costs are used in construction field from the very conceptual planning stages, through design and construction and during the operation (useful life) of the facility. During the preliminary planning stages of the project, the degree of accuracy of costing is usually limited. The estimates made at this stage are usually conceptual in nature and are based on past trends and the historical knowledge of similar projects. A cost model thus helps to establish this historical background.

The representation of the quantity model in terms of cost is called the cost model.

Figure 3. 5: Cycle of Project

Cost models are a tool used by the owner, the architect, engineer, contractor, operating personnel, bankers and consumers to arrive at a common language- to assess value. The cost model is the tool used to organize and distribute estimated costs into functional areas that can be easily defined and quantified. Categorizing cost into identifiable functional areas will aid the value engineering effort and start search for high cost areas will aid the value engineering effort and start search for high cost areas. With this concept, a one page visual analysis of the cost for a total system is possible.

There is the mounting awareness of the significance of modeling effective information systems as an important area of building research worthy of commanding funding support. For this reason number of attempts has been made to improve data co-ordination between the users of data in building process.

Rising prices, restriction on the use of capital and interest rates had led increasingly to the need of reliable and useful cost data in the management of design and construction process as well as maintenance. In the construction industry, effective cost information service is vital to ensure that the resources are used to the best advantage. It was for this reason that banks of cost data were established in various countries.

With the known quantities of the structural materials as above and their prevailing unit rates of construction, the structural cost per square meter of the individual floors as well as the average structural cost per square meter of the entire building is arrived.

The above cost model is worked out for buildings with varying number of stroeys in different seismic zones of the country and the effect of height and seismicity of the zone on the cost of the structural system are evaluated to understand the cost implications for designing the buildings to resist seismic forces.

3.4 PROVISIONS FROM DELHI SCHEDULED RATE

3.4.1 DSR 2013 STEEL REINFORCEMENT

The following are the clauses used for the computation of cost of steel reinforcement per kilogram as per Delhi Schedule Rate.

Table 3. 1: DSR- 2013 Provisions for Steel Reinforcement

CLAUSES	CLAUSE STATEMENT	UNIT	RATE (INR)
5.22A	Steel reinforcement for R.C.C. work including straightening, cutting, bending, placing in position and binding all complete above plinth level.		
5.22A.6	Thermo-Mechanically Treated bars	Kg	66.50

3.4.2 DSR- 2013: CONCRETE

The following are the clauses used for the computation of cost of concrete per cumec meter as per Delhi Schedule Rate.

Table 3. 2: DSR- 2013 Provisions for Concrete

CLAUSES	CLAUSE STATEMENT	UNIT	RATE (INR)
5.33	Providing and laying in position machine batched and machine mixed design mix M-25 grade cement concrete for reinforced cement concrete work, using cement content as per approved design mix, including pumping of concrete to site of laying but excluding the cost of centering, shuttering, finishing and reinforcement, including admixtures in recommended proportions as per IS: 9103 to accelerate, retard setting of concrete, improve workability without impairing strength and durability as per direction of Engineer-in-charge. (Note :- Cement content considered in this item is @ 330 kg/cum. Excess/less cement used as per design mix is payable/recoverable separately)		
5.33.2	All works above plinth level up to floor V level	cum	6,353.00
5.34	Extra for providing richer mixes at all floor levels. Note: Excess/less cement over the specified cement		

	content used is payable /recoverable separately.		
5.34.1	Providing M-30 grade concrete instead of M-25 grade BMC/ RMC. (Note:- Cement content considered in M-30 is @ 340 kg/cum)	cum	64.15
5.34.2	Providing M-35 grade concrete instead of M-25 grade BMC/RMC. (Note : Cement content considered in M-35 is @ 350 kg/cum)	cum	128.35
	FOR M25		
	Providing and laying in position machine batched and machine mixed design mix M-25 grade cement concrete for reinforced cement concrete work, using cement content as per approved design mix, including pumping of concrete to site of laying but excluding the cost of centering, shuttering, finishing and reinforcement, including admixtures in recommended proportions as per IS: 9103 to accelerate, retard setting of concrete, improve workability without impairing strength and durability as per direction of Engineer-in-charge.	cum	6,353.00
	FOR M30		
	Providing and laying in position machine batched and machine mixed design mix M-30 grade cement concrete for reinforced cement concrete work, using cement content as per approved design mix, including pumping of concrete to site of laying but excluding the cost of centering, shuttering, finishing and reinforcement, including admixtures in recommended proportions as per IS: 9103 to accelerate, retard setting of concrete, improve workability without impairing strength and durability as per direction of Engineer-in-charge.	cum	6,417.15
	FOR M35		
	Providing and laying in position machine batched and machine mixed design mix M-35 grade cement concrete for reinforced cement concrete work, using cement content as per approved design mix, including pumping of concrete to site of laying but excluding the cost of centering, shuttering, finishing and reinforcement, including admixtures in recommended proportions as per IS: 9103 to accelerate, retard setting of concrete, improve workability without impairing strength and durability as per direction of Engineer-in-charge.	cum	6,805.42

3.4.3 DSR 2013 FORMWORK

The following are the clauses used for the computation of cost of formwork per square meter as per Delhi Schedule Rate.

Table 3. 3: DSR- 2013 Provisions for Formwork

CLAUSES	**CLAUSE STATEMENT**	**UNIT**	**RATE (INR)**
5.9	Centering and shuttering including strutting, propping etc. and removal of form for :		
5.9.1	Foundations, footings, bases of columns, etc. for mass concrete	sq.m.	186.40
5.9.5	Lintels, beams, plinth beams, girders and cantilevers	sq.m.	309.80
5.9.6	Columns, Pillars, Piers, Abutments, Posts and Struts	sq.m.	423.00
5.11	Extra for additional height in centering, shuttering where ever required with adequate bracing, propping etc., including cost of de-shuttering and decentering at all levels, over a height of 3.5 m, for every additional height of 1 metre or part thereof (Plan area to be measured).		
5.11.1	Suspended floors, roofs, landing, beams and balconies (Plan area to be measured)	sq.m.	145.60

Table 3. 4: Table of Combined Rate

ITEMS	RATE (INR)			
	COLUMN	BEAM	SEC. BEAM	SLAB
Shuttering in Rs/sq.m	423.00	309.80	309.80	186.40
Steel in Rs/kg	66.50			
M25 Concrete in Rs/cumec	6353.00			
M30 Concrete in Rs/cumec	6417.15			
M35 Concrete in Rs/cumec	6805.42			

3.5 COST PREMIUM IN BUILDING

In any construction project, cost and time are the major governing factors. Most of the times, cost is easier to control and monitor which is largely dependent on the design phase. Hence in the design it is of great importance to understand the factors contributing to the cost and the impact these factors have in the cost.

Though the present work deals only with the quantity modeling and cost modelling, we work here keeping in view the future scope of the work. Once the quantity and cost modelling is done we proceed for the cost premium.

3.5.1 CONCEPT OF COST PREMIUM

Cost premium for building design is the additional cost required for seismic design, and detailing of a building over non-seismic design of the same building, or the seismic zone with minimum zone factor.

For getting the cost premium for seismic design, cost per square meter for each item is calculated for both seismic and non-seismic case. In structural design, apart from the seismic zone, the structural system and design adopted also contribute to the cost premium.

Hence quantity models and cost models are prerequisites for getting the cost premium.

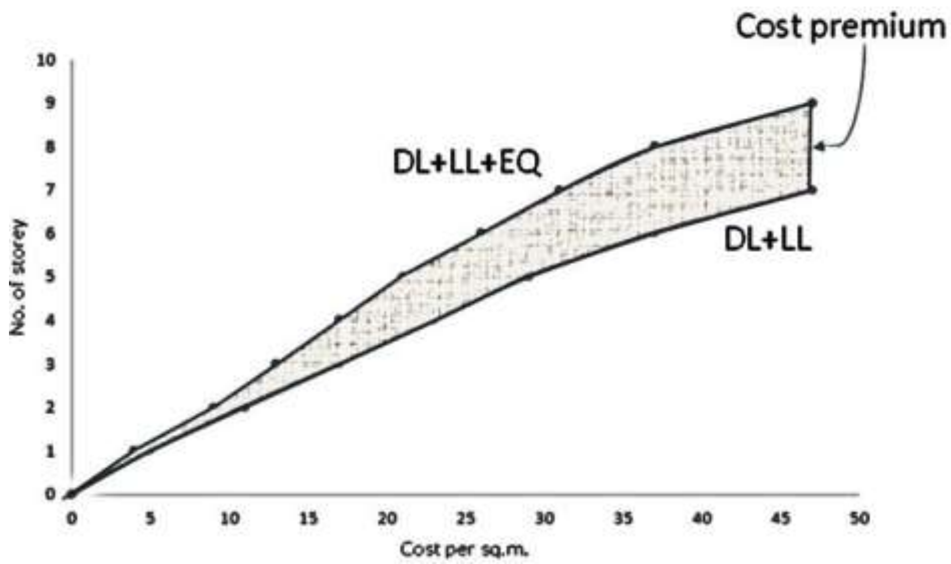


Figure 3. 6: Plot of Cost Premium

CHAPTER 4

BUILDING DETAIL, LOADS AND LOAD COMBINATIONS

4.1 GENERAL

The building considered is a super structure of 6 x 5.5 m grid with 10, 12, 14, 16 storey under the seismic zones Zone III and Zone V.

The building in the study is considered as office type occupancy with Beam and slab type framed structure, without shear walls. The building have uniform grid but member dimensions are changing accordingly with the number of stories. Secondary beams are also being provided at the longer span of the grid. Dimensions of the secondary beams are kept same for the whole building.

The structural model for every building with different seismic zone is prepared and structural analysis and design is done in ETABS software. The load combination for different type of forces is induced in the structure. The member sizes and details are found and fixed by repetitive analyzing and design the structure. Applying the required codes and standards and after checking the feasibility we come to the final member sizes for the superstructure of each building. Hence the one fixed is the most optimized sections

Base Shear according to the seismic weight of the building for every zone is computed for the super structure and compared with respect to each zone to check the increase in base shear accordingly.

4.2 DESCRIPTION OF BUILDING

Grid Size: 6 X 5.5 m

Floor Height:

- 4.0 m in base storey
- 3.6 m for rest of the storey

Structural System: Beams, Colum, Slab and Secondary beams.

No. Of Storey: 10, 12, 14, and 16

Seismic Zones: Zone III and Zone V

4.3 NON-STRUCTURAL WALLS (Infill Walls)

The outer covering of the building is a curtain wall, which are non-structural member. Curtain wall being a non-structural member it is made of lightweight materials, whose function is only to resist air and water infiltration, sway induced by wind and seismic forces acting on the building, and carry its own dead load weight forces. The wall transfers horizontal wind loads that are incident upon it to the main building structure through connections at floors or columns of the building. Glass can be used as the curtain wall, with a great advantage that natural light can penetrate deeper within the building.

4.3.1 BRICK WALL

A brick is a block of ceramic material used in masonry construction, usually laid using various kinds of mortar. It has been regarded as one of the longest lasting and strongest building materials used throughout history. Brickwork is masonry produced by a bricklayer, using bricks and mortar to build up brick structures such as walls. Brickwork is also used to finish corners, door, and window openings, etc. in buildings made of other materials. Where the bricks are to remain fully visible, as opposed to being covered up by plaster or stucco, this is known as face-work or facing brickwork.

Brick sizes are, in general, coordinated so that two rows of bricks laid alongside, with a mortar joint between them, are the same width as the length of a single brick laid across the two rows.

That allows headers, bricks laid at 90 degrees to the direction of the wall, to be built in and tie together two or more layers, of brick. The thickness of a brick wall is measured by the length of a brick, so a wall one brick thick contains two layers of brick, a wall one and a half bricks thick contains three layers, etc.

4.4 LOADING CALCULATION

- Thickness of the outer peripheral brick walls is considered to be 230 mm.
- Thickness of the inner partition brick walls is considered to be 115 mm.
- Cement plaster at both the surfaces is considered 15 mm thick.
- Density of brick work is taken 15.70-18.85 kN/ m^3
  - Average value 17.275 = 17.3 kN/m^3
- Density of cement plaster is taken 20.4 kN/m^3.

Table 4. 1: Loads to be Considered

Load Type		Load
Distributed loads or area loads	Light weight partition	$1kN/m^2$
	Live Load on floor	$4kN/m^2$
	Live Load on terrace	$1.5\ kN/m^2$
Line loads or frame loads	Parapet [Parapet height of 0.9m]	5 kN/m
	Full brick wall	14 kN/m
	Half brick wall	8 kN/m

4.5 LOAD COMBINATIONS USED

As per IS 1893(Part 1): 2002, for Limit State Design we have,

i 1.5* (DL + LL)
ii 1.2* (DL + LL ± EL)
iii 1.5* (DL ± EL)
iv 0.9* DL ± 1.5* EL
v 1.5* (DL ± WL)
vi 1.2* (DL + LL ± WL)

From the above 6 combinations, we derive the following load combinations

4.5.1 FOR SUPERSTRUCTURE DESIGN

i DL + LL
ii 1.5* (DL + LL)
iii 1.5* (DL + WLX)
iv 1.5* (DL - WLX)
v 1.5* (DL + WLY)
vi 1.5* (DL - WLY)
vii 1.2* (DL +LL + WLX)
viii 1.2* (DL +LL - WLX)
ix 1.2* (DL +LL+ WLY)
x 1.2* (DL +LL - WLY)
xi 1.5* (DL + EQX)
xii 1.5* (DL - EQX)
xiii 1.5* (DL + EQY)
xiv 1.5* (DL - EQY)
xv 1.2* (DL +LL + EQX)
xvi 1.2* (DL +LL - EQX)
xvii 1.2* (DL +LL+ EQY)
xviii 1.2* (DL +LL - EQY)

xix 0.9* DL + 1.5* EQX
xx 0.9* DL - 1.5* EQX
xxi 0.9* DL + 1.5* EQY
xxii 0.9* DL - 1.5* EQY

4.5.1 RESPONSE SPECTRUM ANALYSIS

i 1.5 DL + 1.5 SPECX
ii 1.5 DL + 1.5 SPECY
iii 0.9 DL + 1.5 SPECX
iv 0.9 DL + 1.5 SPECY
v 1.2 DL +0.6 LL+ 1.2 SPECX
vi 1.2 DL +0.6 LL+ 1.2 SPECY

CHAPTER 5
ANALYSIS, DESIGN AND MODELLING CONSIDERATION

5.1 GENERAL

The design considerations and modelling of any structural system requires in depth understanding and knowledge as it has to adhere to the real structure. One should have an adequate exposure to various Indian Standard Codes, National Building Codes and Special Publications of Bureau of Indian Standards (BIS), along with some international codes as well. The knowledge filed becomes vital during reinforcement detailing.

5.2 MODELLING CONSIDERATION

5.2.1 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.

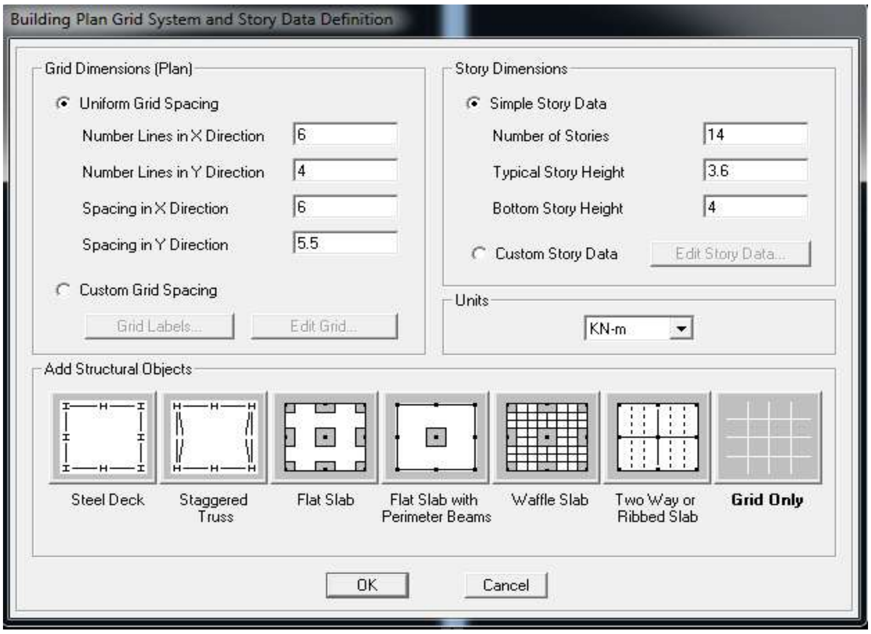


Figure 5. 1: Defining Grid Spacing and Storey Height

5.2.2 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.

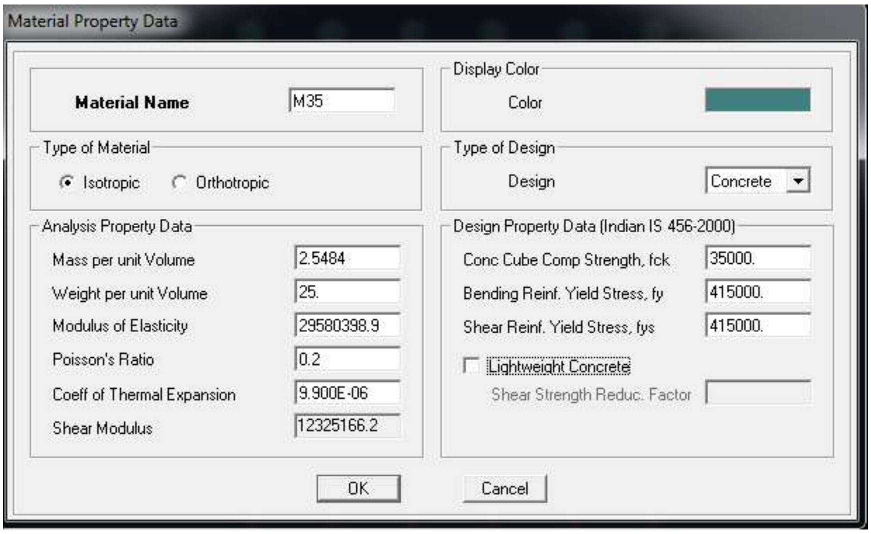


Figure 5. 2: Defining Material Properties

5.2.3 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.

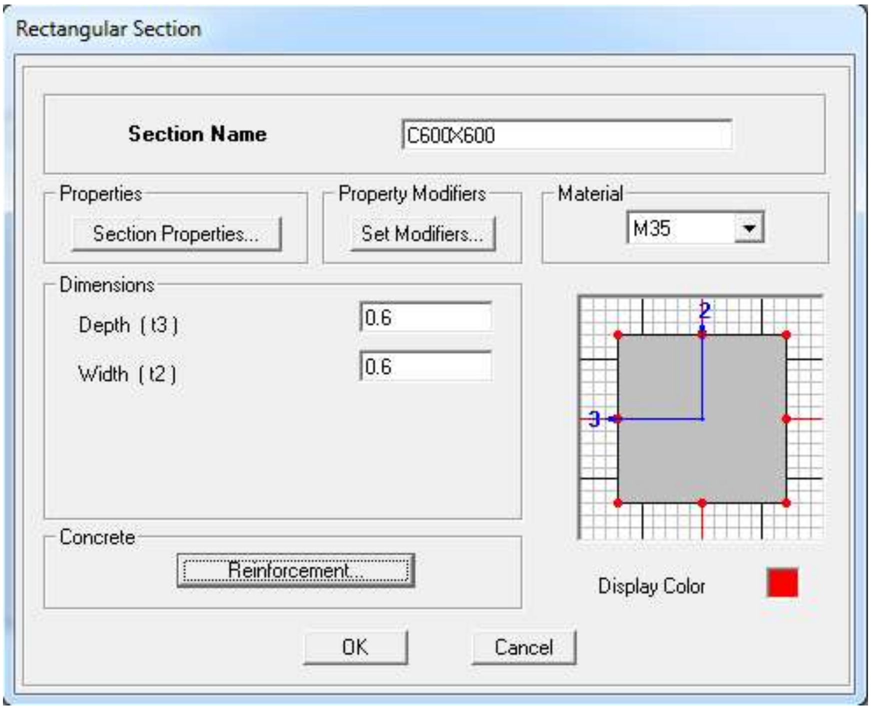


Figure 5. 3: Defining Frame Sections

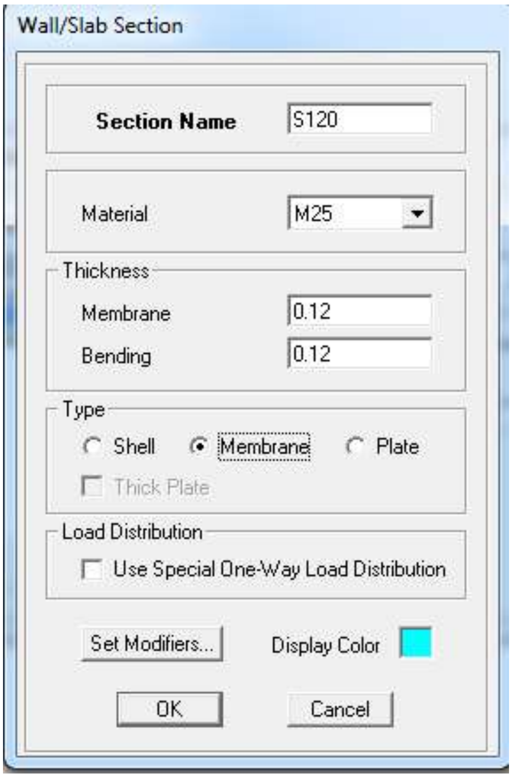


Figure 5. 4: Defining Slab

5.2.4 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.

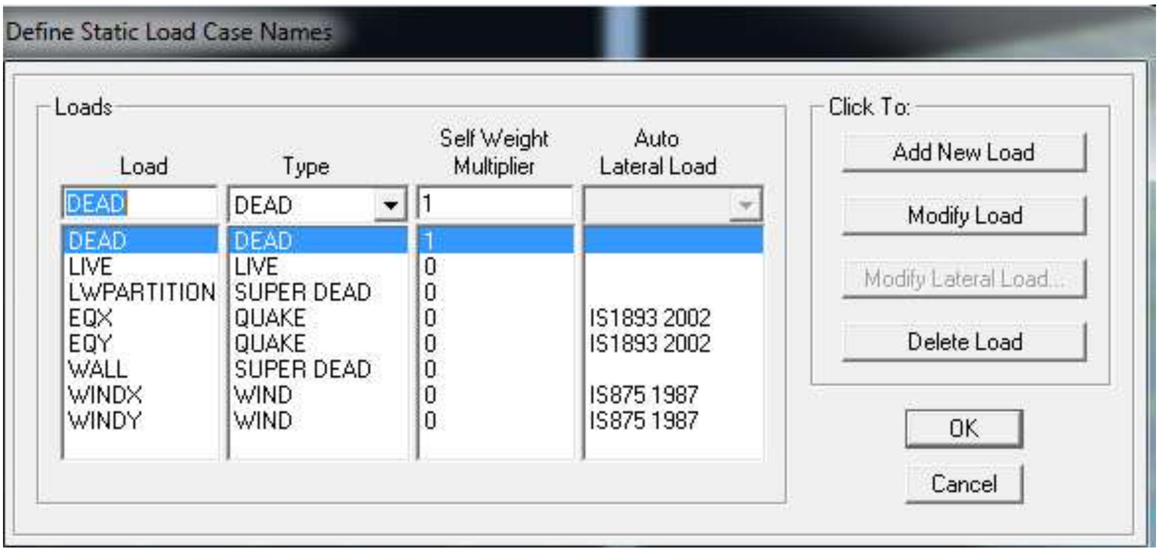


Figure 5. 5: Defining Static Load Cases

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.

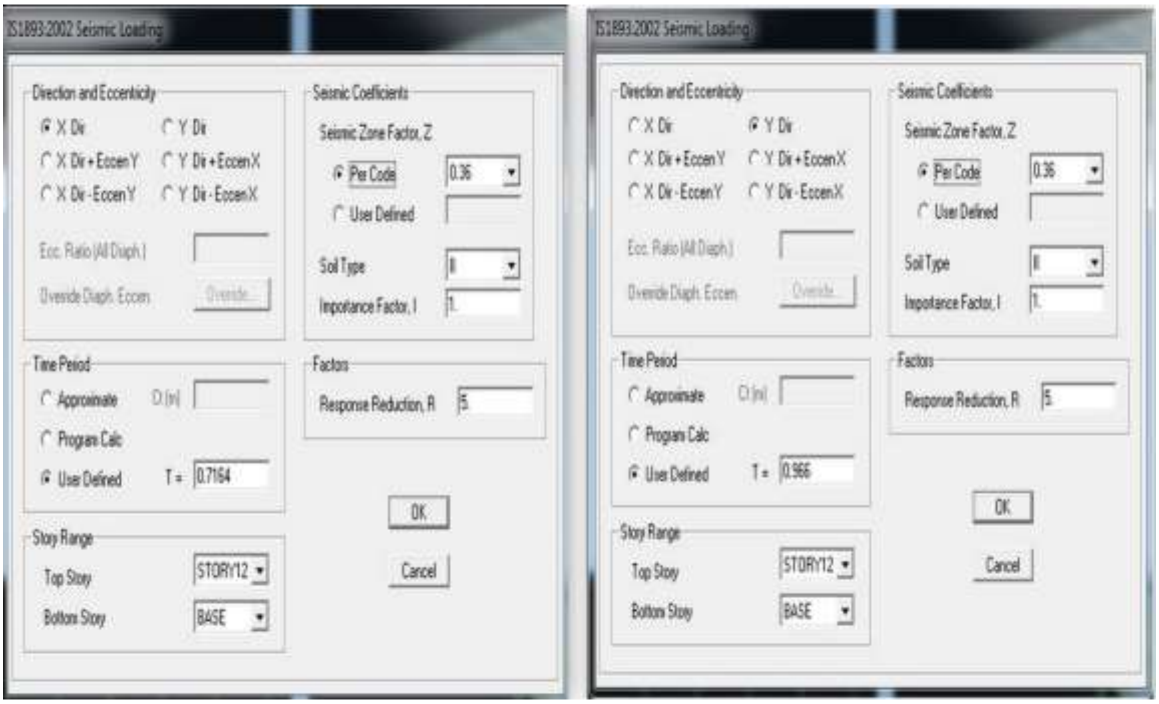


Figure 5. 6: Defining Earthquake loads

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.

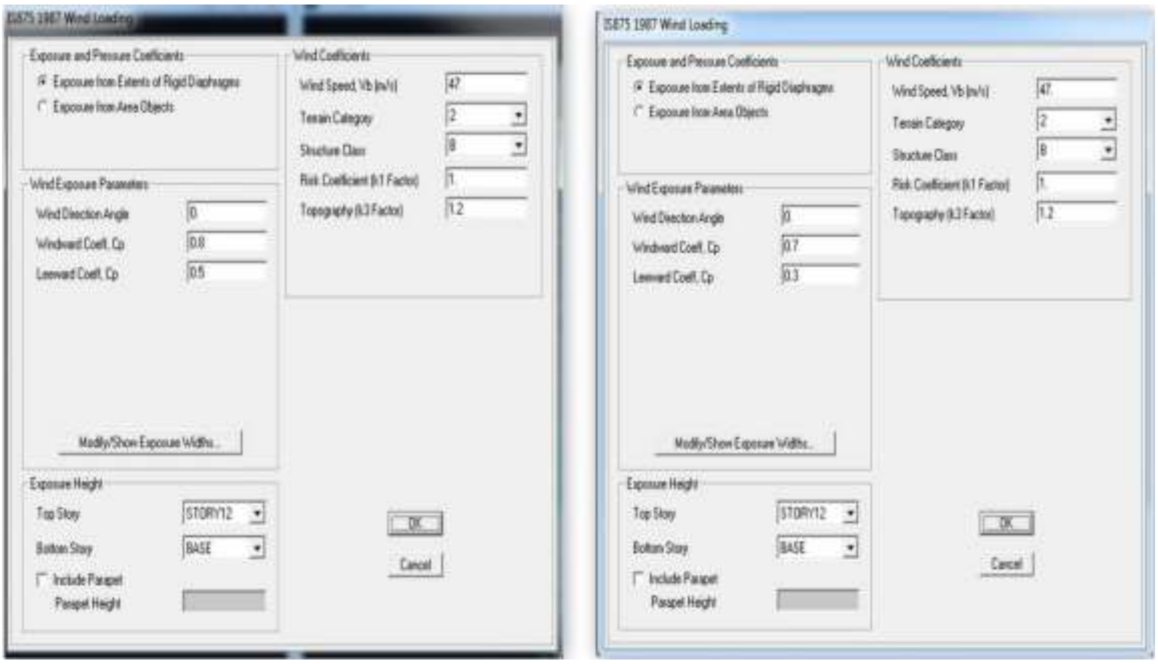


Figure 5. 7: Defining Wind loads

5.2.5 MASS SOURCE DEFINITION

Masses of the structural members are lumped at storey levels. As per IS 1893(Part 1): 2002, Table 8, 50 percentage of live/imposed load is taken into consideration for seismic weight calculation.

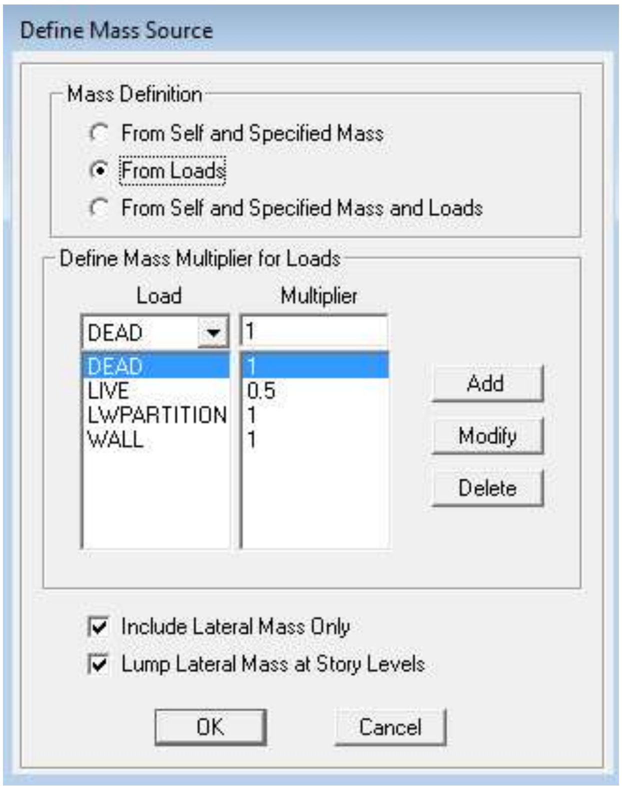


Figure 5. 8: Mass Source Definition

5.2.6 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.

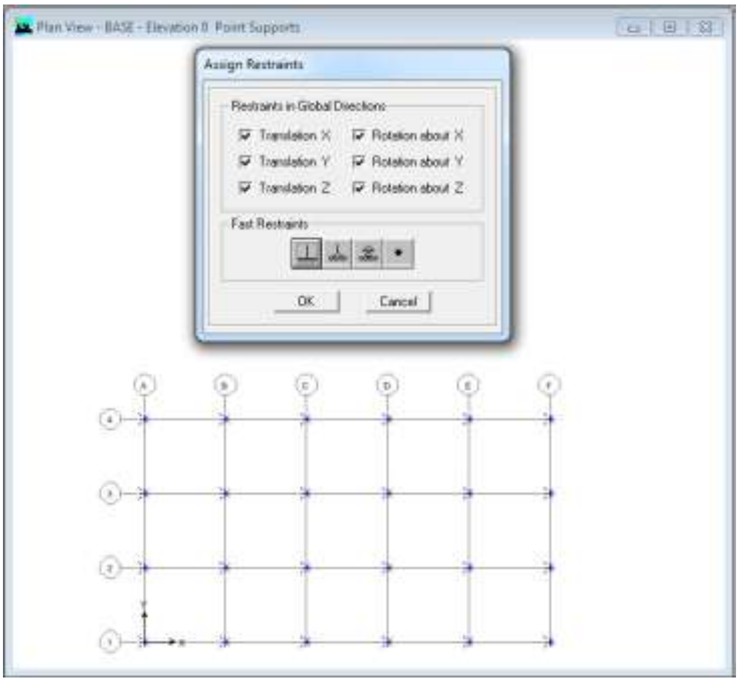


Figure 5. 9: Restrained Support Condition

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.

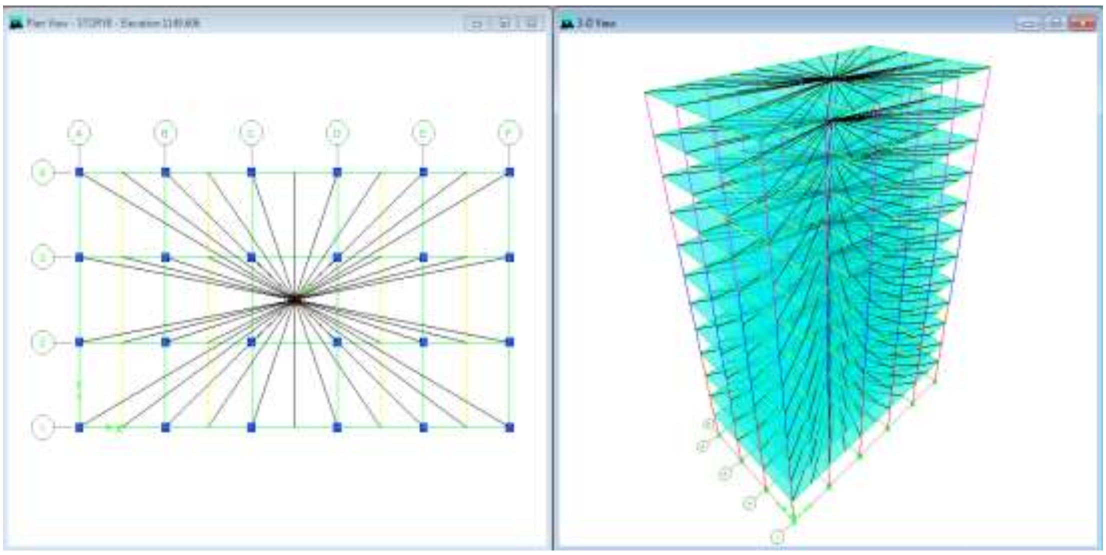


Figure 5. 10: Defining Rigid Diaphragm

5.3 ANALYSIS PARAMETERS

5.3.1 WIND LOAD

Wind load is computed as per IS 875 (Part 3):1987, following are the parameters taken into consideration.

- Wind speed, Vb= 47 m/s
- Terrain category= 2
- Structure class= B
- Risk coefficient factor, k_1= 1
- Terrain, height and structure size factor, k_2= 1.2 (Varies with building height)
- Topography factor, k_3= 1

5.3.2 FUNDAMENTAL NATURAL TIME PERIOD

$$\mathbf{T_{x,y}}=\frac{\mathbf{0.09}h}{\sqrt{d}}$$

Where,

d=Base dimension of the building at the plinth level, in m, along the considered direction of the lateral force.

h= height of building

We calculate fundamental natural time period for all buildings, which remains constant irrespective to the seismic zone.

5.3.3 DESIGN HORIZONTAL SEISMIC COEFFICIENT,

$$A_h=\frac{ZISa}{2Rg}$$

S_a/g is to be taken from clause 6.4.5 of IS 875 (Part 3):1987 for various fundamental natural period of building.

Design horizontal seismic coefficient (A_h) varies with seismic zone, hence it is to be computer for each building in each zones.

Seismic weight (W): Seismic weight of each building is to be calculated manually taking into account the dead and live loads acting on the building.

Design Seismic Base Shear: Design Seismic Base Shear is computed for each building in each zone as per clause 7.5.3 of IS 875 (Part 3):1987 which says: $\mathbf{\tilde{V}_b=A_hW}$

5.3.4 CALCULATION OF SCALE FACTOR

As per Clause 7.8.2 of IS 875 (Part 3):1987, scale factor of $\tilde{V}_b / V_b$ is calculated and applied for dynamic analysis. When the base shear V_b from dynamic analysis is less than the base shear $\tilde{V}_b$ manually calculated using a fundamental period T_a (as per Clause.7.6), all the response quantities (member forces,displacements, storey forces, storey shears and basereactions) are multiplied by the scale factor of $\tilde{V}_b / V_b$.

5.3.5 CHECK FOR SCALE FACTOR

In the analysis using ETABS, first we run response spectrum with factor equal to $\frac{g}{2R}$ (=0.981) and we obtain V_b. If $V_b > \tilde{V}_b$ there is no need to apply scale factor so we proceed. Else we use the scale factor value of $\frac{\tilde{V}b}{Vb} * \frac{g}{2R}$.

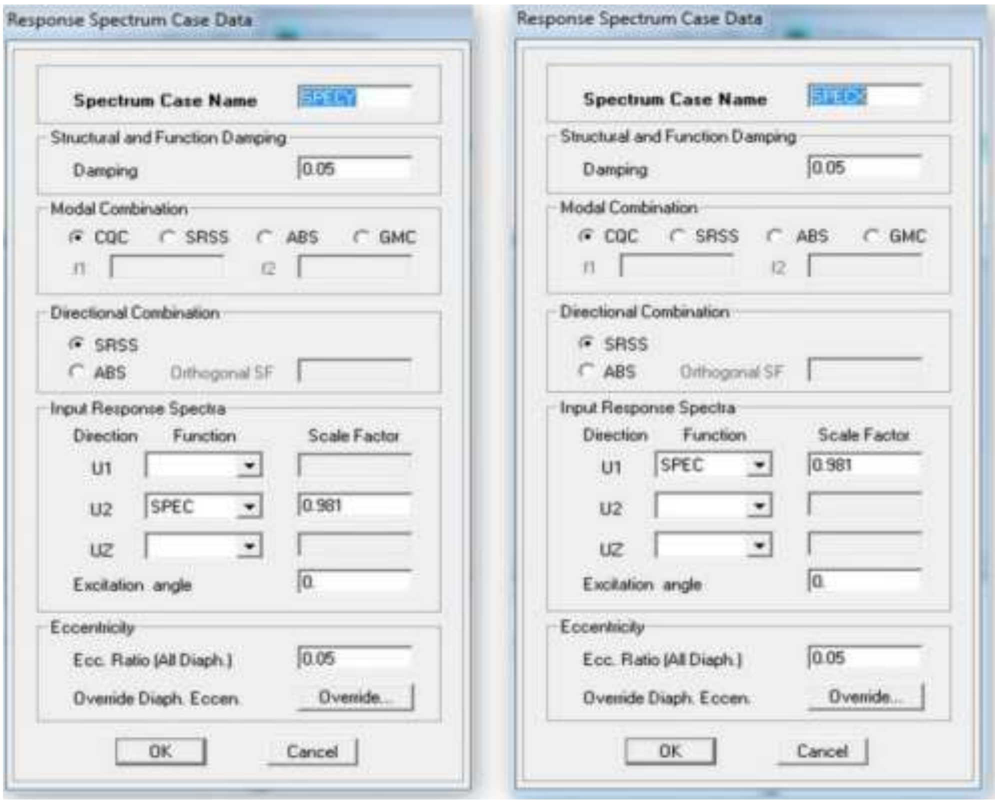


Figure 5. 11: Scale Factor in Response Spectrum

5.4 DESIGN PARAMETERS

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

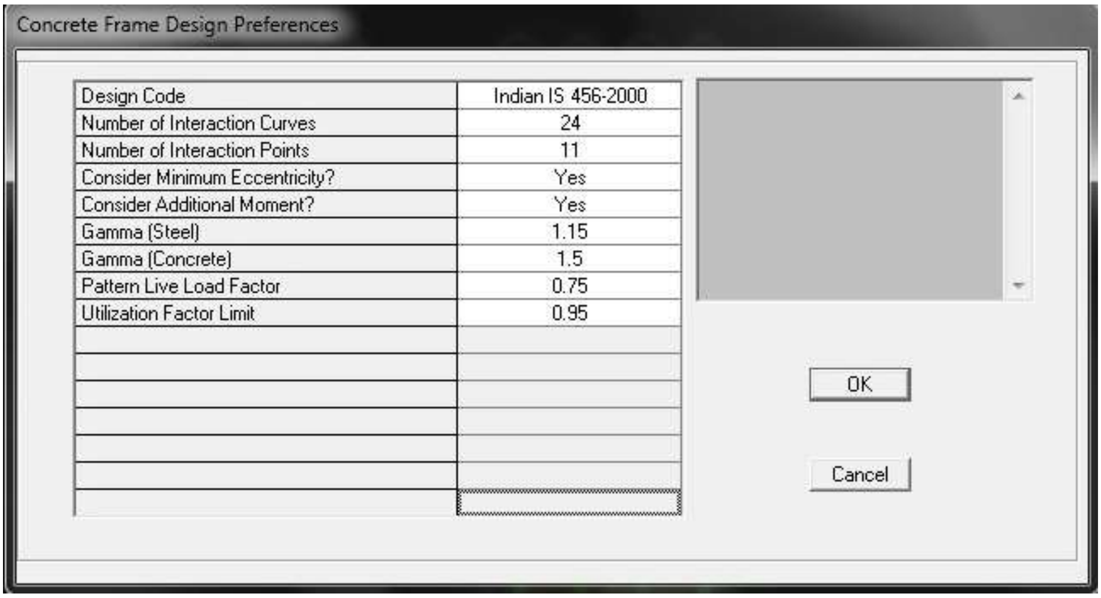


Figure 5. 12: Concrete Frame Design Preferences in ETABS

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.

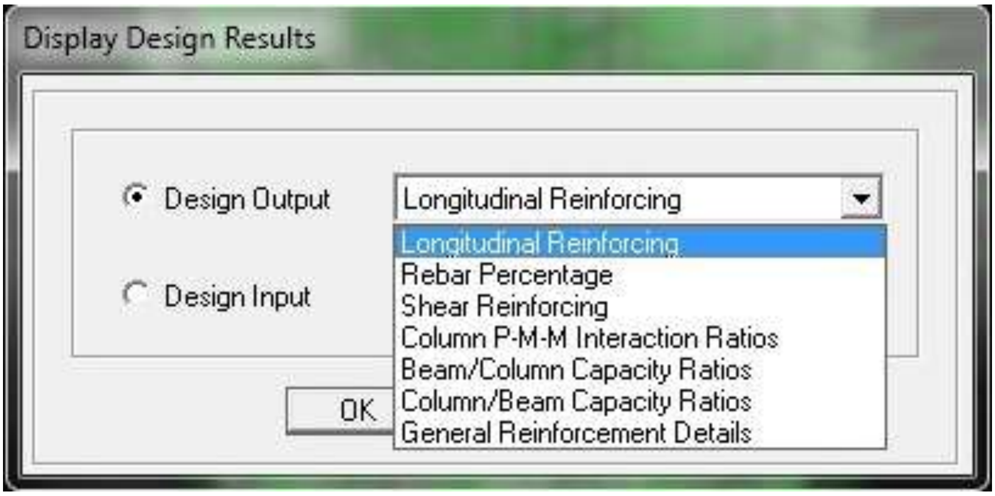


Figure 5. 13: Concrete Frame Design Output Options

CHAPTER 6

CALCULATION OF SEISMIC FORCES AND COEFFICIENTS

6.1 GENERAL

This chapter includes all the calculations involved in the analysis of the building. The chapter involves the calculation of seismic weight, fundamental natural period, design horizontal seismic coefficient and design base shear. For the seismic weight the member sizes used are the optimized member sizes from E-TABS. Fundamental natural period and design horizontal seismic coefficient are computed as per IS 1893 (Part-I) 2002. Seismic weight of building which comes from dead and live loads are lumped at each storey level as per the equivalent static load method. We get the dynamic base shear from the response spectrum analysis in E-TABS and the design base shear is calculated manually. The values of both base shears are compared and we check for scale factor.

6.2 FOR 10 STOREY BUILDING

6.2.1 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 m^2

Total floor area = 523.26 x 10 = 5232.6 m^2

6.2.2 CALCULATED VALUES

Table 6. 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

6.2.3 RESPONSE SPECTRUM SCALE FACTOR

10 storey Zone III:

$\tilde{V}_{bx} < V_{bx}$ = Modification of scale factor is not required

10 storey Zone V:

$\tilde{V}_{bx} < V_{bx}$ = Modification of scale factor is not required

6.3 FOR 12 STOREY BUILDING

6.3.1 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 m^2

Total floor area = 523.26 x 12 = 6279.12 m^2

6.3.2 CALCULATED VALUES

Table 6. 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

6.3.3 RESPONSE SPECTRUM SCALE FACTOR

12 storey Zone III:

$\tilde{V}_{bx} < V_{bx}$ = Modification of scale factor is not required

12 storey Zone V:

$\tilde{V}_{bx} < V_{bx}$ = Modification of scale factor is not required

6.4 FOR 14 STOREY BUILDING

6.4.1 COVERED FLOOR AREA CALCULATION

C/C Grid Spacing = 6 m x 5.5 m

Outer Dimension for Zone V

L = (5 x 6) + 0.65 = 30.65 m B = (3 x5.5) + 0.65 = 17.15 m

Area at each Floor Zone V = L x B = 30.65 x 17.15 = 525.647 m^2

Total floor area for zone V = 525.647 x 14 = 7359.058 m^2

Outer Dimension for Zone III

L = (5 x 6) + 0.6 = 30.6 m B = (3 x5.5) + 0.6 = 17.1 m

Area at each Floor Zone III = L x B = 30.6 x 17.1 = 523.26 m^2

Total floor area for zone III = 523.26 x 14 = 7325.64 m^2

6.4.2 CALCULATED VALUES

Table 6. 3: Calculated Values for 14 Storey Building

SEISMIC FORCES AND COEFFICIENTS		Zone III	Zone V
Fundamental Time Period (Sec)	T_x	0.8347	
	T_y	1.1255	
Design Horizontal Seismic Coefficient	A_{hx}	0.0261	0.0586
	A_{hy}	0.0193	0.0435
Design Horizontal Base Shear(kN)	$\tilde{V}_{bx}$	469.026	1542.679
	$\tilde{V}_{by}$	346.827	783.955
Dynamic Analysis Base Shear (kN)	V_{bx} (SPECX)	731.51	1645.90
	V_{bx} (SPECY)	715.84	1610.63

6.4.3 RESPONSE SPECTRUM SCALE FACTOR

14 storey Zone III:

$\tilde{V}_{bx} < V_{bx}$ = Modification of scale factor is not required

14 storey Zone V:

$\tilde{V}_{bx} < V_{bx}$ = Modification of scale factor is not required

6.5 FOR 16 STOREY BUILDING

6.5.1 COVERED FLOOR AREA CALCULATION

C/C Grid Spacing = 6 m x 5.5 m

Outer Dimension for Zone V

L = (5 x 6) + 0.65 = 30.65 m B = (3 x 5.5) + 0.65 = 17.15 m

Area at each Floor Zone V = L x B = 30.65 x 17.15 = 525.647 m^2

Total floor area for zone V = 525.647 x 14 = 7359.058 m^2

Outer Dimension for Zone III

L = (5 x 6) + 0.6 = 30.6 m B = (3 x 5.5) + 0.6 = 17.1 m

Area at each Floor Zone III = L x B = 30.6 x 17.1 = 523.26 m^2

Total floor area for zone III = 523.26 x 14 = 7325.64 m^2

6.5.2 CALCULATED VALUES

Table 6. 4: Calculated Values for 16 Storey Building

SEISMIC FORCES AND COEFFICIENTS		Zone III	Zone V
Fundamental Time Period (Sec)	T_x	0.9530 Sec	
	T_y	1.2852 Sec	
Design Horizontal Seismic Coefficient	A_{hx}	0.0228	0.0514
	A_{hy}	0.0169	0.0381
Design Horizontal Base Shear(kN)	$\tilde{V}_{bx}$	472.81	1066.86
	$\tilde{V}_{by}$	350.23	790.801
Dynamic Analysis Base Shear (kN)	V_{bx} (SPECX)	820.69	1846.56
	V_{bx} (SPECY)	794.57	1787.78

6.5.3 RESPONSE SPECTRUM SCALE FACTOR

16 storey Zone III:

$\tilde{V}_{bx<}$ V_{bx} = Modification of scale factor is not required

16 storey Zone V:

$\tilde{V}_{bx<}$ V_{bx} = Modification of scale factor is not required

CHAPTER 7

RESULT AND DISCUSSIONS

7.1 GENERAL

This chapter includes the tabulated result of all the work involved in the present work. From the optimized structural component sizes and computed floor area calculation to the quantity and cost modelling, we have here presented all the results in the most felicitous framework. All the result has been crafted using Microsoft Excels hence manual calculation errors are eliminated.

7.2 FLOOR AREA

Though the grid of the plan is same for all the buildings, the floor area varies with the column dimensions at the base storey.

Table 7. 1: Floor Area for Buildings in Zone III

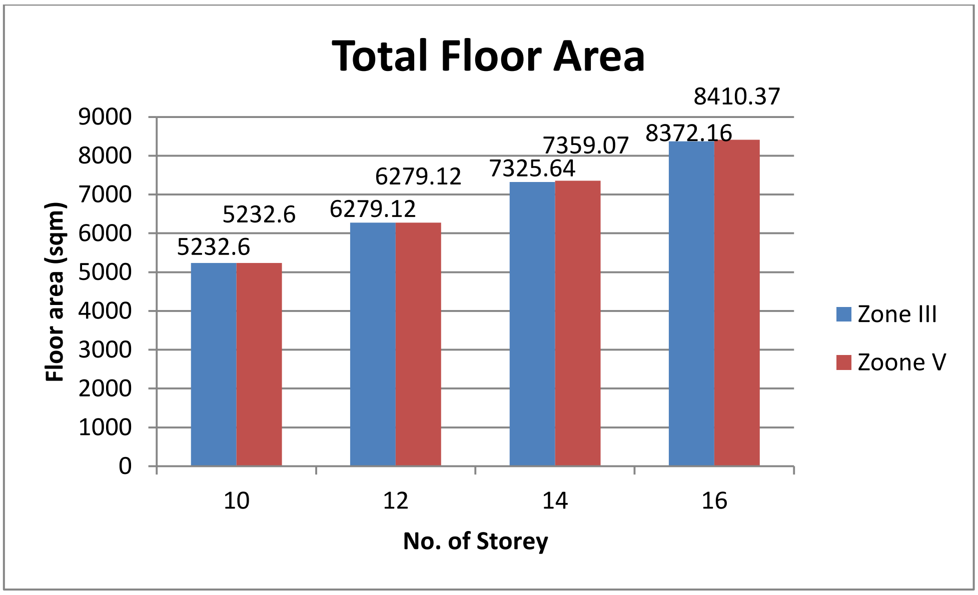
1	**10 Storeyed Building : C/C Grid Spacing = 6 X 5.5 m ; Col Size = 600 X 600 mm**
	Outer Dimension = L = (5 x 6) + 0.6 = 30.6 m ; B = (3 x 5.5) + 0.6 = 17.1 m
	Area at one Floor = L x B = 30.6 x 17.1 = 523.26 Sqm
	Floor Area of Building = 10 x 523.26 = 5232.6 **Sqm**
2	**12 Storeyed Building : C/C Grid Spacing = 6 X 5.5 m ; Col Size = 600 X 600 mm**
	Outer Dimension = L = (5 x 6) + 0.6 = 30.6 m ; B = (3 x 5.5) + 0.6 = 17.1 m
	Area at one Floor = L x B = 30.6 x 17.1 = 523.26 Sqm
	Floor Area of Building = 12 x 523.26 = 6279.12 **Sqm**
3	**14 Storeyed Building : C/C Grid Spacing = 6 X 5.5 m ; Col Size = 600 X 600 mm**
	Outer Dimension = L = (5 x 6) + 0.6 = 30.6 m ; B = (3 x 5.5) + 0.6 = 17.1 m
	Area at one Floor = L x B = 30.6 x 17.1 = 523.26 Sqm
	Floor Area of Building = 14 x 523.26 = 7325.64 **Sqm**
4	**16 Storeyed Building : C/C Grid Spacing = 6 X 5.5 m ; Col Size = 600 X 600 mm**
	Outer Dimension = L = (5 x 6) + 0.6 = 30.6 m ; B = (3 x 5.5) + 0.6 = 17.1 m
	Area at one Floor = L x B = 30.6 x 17.1 = 523.26 Sqm
	Floor Area of Building = 16 x 523.26 = 8372.16 **Sqm**

The result shows no significant difference in total floor are between zone III and zone V. There is absolutely no change in floor area between zone III and zone V for 10 and 12 storey buildings, but there is some change for the same for 14 and 16 storey buildings.

Though at each level the difference is only 2.42 sqm, but multiplying the number of storeys there comes a difference of 33.88 sqm and 38.72 sqm for 14 storey and 16 storey building respectively.

Table 7. 2: Floor Area for Buildings in Zone V

1	**10 Storeyed Building : C/C Grid Spacing = 6 X 5.5 m ; Col Size = 600 X 600 mm**
	Outer Dimension = L = (5 x 6) + 0.6 = 30.6 m ; B = (3 x 5.5) + 0.6 = 17.1 m
	Area at one Floor = L x B = 30.6 x 17.1 = 523.26 Sqm
	Floor Area of Building = 10 x 523.26 = 5232.6 **Sqm**
2	**12 Storeyed Building : C/C Grid Spacing = 6 X 5.5 m ; Col Size = 600 X 600 mm**
	Outer Dimension = L = (5 x 6) + 0.6 = 30.6 m ; B = (3 x 5.5) + 0.6 = 17.1 m
	Area at one Floor = L x B = 30.6 x 17.1 = 523.26 Sqm
	Floor Area of Building = 12 x 523.26 = 6279.12 **Sqm**
3	**14 Storeyed Building : C/C Grid Spacing = 6 X 5.5 m ; Col Size = 650 X 650 mm**
	Outer Dimension = L = (5 x 6) + 0.65 = 30.65 m ; B = (3 x 5.5) + 0.65 = 17.15 m
	Area at one Floor = L x B = 30.65 x 17.15 = 525.648 Sqm
	Floor Area of Building = 14 x 525.648 = 7359.07 **Sqm**
4	**16 Storeyed Building : C/C Grid Spacing = 6 X 5.5 m ; Col Size = 650 X 650 mm**
	Outer Dimension = L = (5 x 6) + 0.65 = 30.65 m ; B = (3 x 5.5) + 0.65 = 17.15 m
	Area at one Floor = L x B = 30.65 x 17.15 = 525.648 Sqm
	Floor Area of Building = 16 x 525.648 = 8410.368 **Sqm**



Graph 7. 1: Comparison Plot for Total Floor Area

7.3 MEMBER SIZES

Optimized member sizes, that has been found after repetitive analysis and design of building in E-TABS has be tabulated below for each zone. The member section chosen are the minimum sections that pass through the deflection and storey drift as per IS 1893 (Part-I) 2002. Materials grade used for structural components at each storey has also been mentioned precisely.

Table 7. 3: Member Sizes and Materials of Buildings in Zone III

MEMBER SIZES FOR ZONE III									CONCRETE MIX		
BUILDING STOREY	BUILDING HEIGHT	EACH FLOOR AREA	TOTAL FLOOR AREA	NO. OF STOREY	COLUMN SIZES	MAIN BEAM SIZES	SECONDARY BEAM SIZES	SLAB THICKNESS	COLUMNS	SLABS, BEAMS & SECONDARY BEAM	STEEL GRADE
		sqm	sqm		mm	mm	mm	mm			
10	36.4 m	523.26	5232.6	upto 4 Storey	600 x 600	600 x 300	300 x 300	120	M25	M25	Fe-415
				from 5 to 7 storey	450 x 450				M30		
				from 8 to 10 storey	350 X 350				M35		
12	43.6 m	523.26	6279.12	upto 4 Storey	600 x 600	600 x 350	400 x 250	120	M25	M25	Fe-415
				from 5 to 8 storey	450 x 450				M30		
				from 9 to 12 storey	400 x 400				M35		
14	50.8 m	523.26	7325.64	upto 5 storey	650 x 650	600 x 350	400 x 250	120	M25	M25	Fe-415
				from 6 to 9 storey	500 x 500				M30		
				from 10 to 14 storey	400 x 400				M35		
16	58 m	523.26	8372.16	upto 5 storey	600 x 600	600 X 400	400 x 250	120	M25	M25	Fe-415
				from 6 to 10 storey	500 x 500				M30		
				from 11 to 16 storey	450 x 450				M35		

Table 7. 4: Member Sizes and Materials of Buildings in Zone V

MEMBER SIZES FOR ZONE V									CONCRETE MIX		
BUILDING STOREY	BUILDING HEIGHT	EACH FLOOR AREA	TOTAL FLOOR AREA	NO. OF STOREY	COLUMN SIZES	MAIN BEAM SIZES	SECONDARY BEAM SIZES	SLAB THICKNESS	COLUMNS	SLABS, BEAMS & SECONDARY BEAM	STEEL GRADE
		sqm	sqm		mm	mm	mm	mm			
10	36.4 m	523.26	5232.6	upto 4 Storey	600 x 600	600 x 300	300 x 300	120	M25	M25	Fe-415
				from 5 to 7 storey	500 x 500				M30		
				from 8 to 10 storey	400 x400				M35		
12	43.6 m	523.26	6279.12	upto 4 Storey	600 x 600	600 x 350	400 x 250	120	M25	M25	Fe-415
				from 5 to 8 storey	500 x 500				M30		
				from 9 to 12 storey	450 x 450				M35		
14	50.8 m	525.648	7359.07	upto 5 storey	650 x 650	600 x 350	400 x 250	120	M25	M25	Fe-415
				from 6 to 9 storey	500 x 500				M30		
				from 10 to 14 storey	450 x 450				M35		
16	58 m	525.648	8410.37	upto 5 storey	650 x 650	600 X 400	400 x 250	120	M25	M25	Fe-415
				from 6 to 10 storey	600 x 600				M30		
				from 11 to 16 storey	500 x 500				M35		

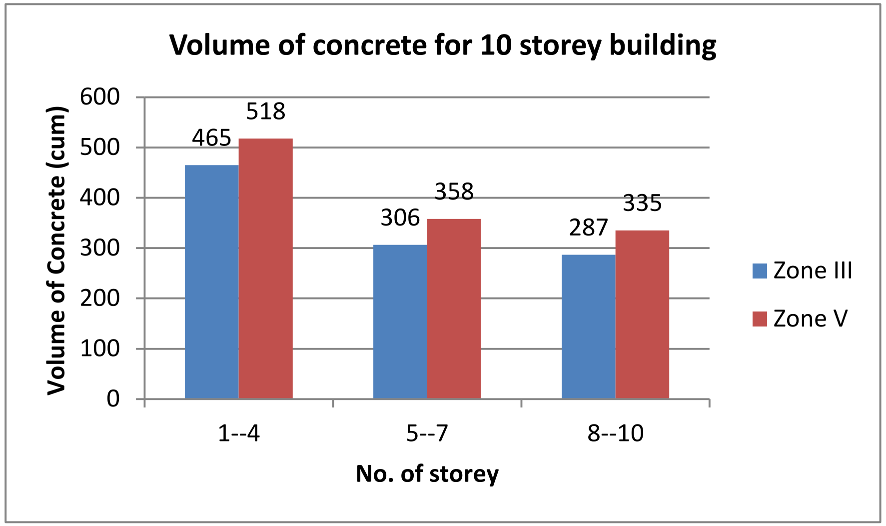
The dimensions of secondary beams and slabs has been kept similar for almost all the buildings as these are designed take the axial loading only (no bending) and loading conditions are same throughout. The sizes of the main beams, shows almost no variations between the zones, except for 10 storey building. We observe an average increment of about 50mm in the dimension of columns when same building is designed for zone III and zone V.

7.4 QUANTITY MODELLING

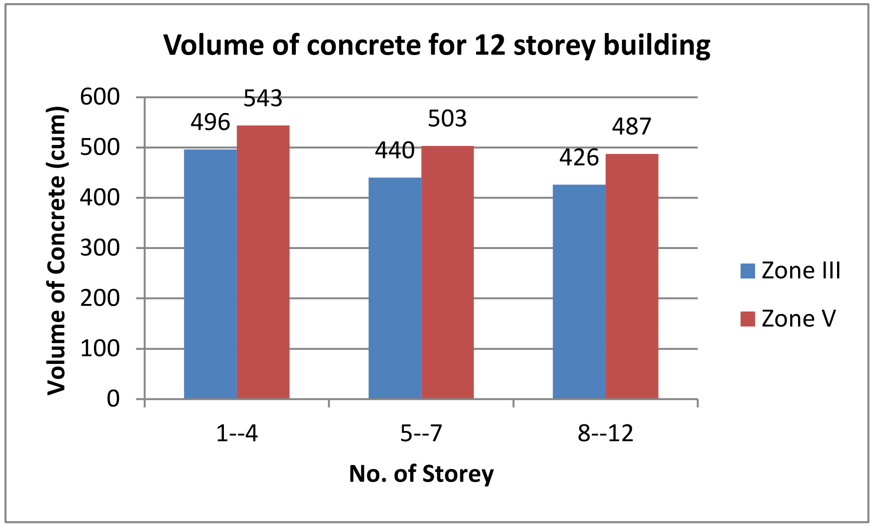
Quantity modelling compromises the quantity of concrete in cumec, steel in Kg and shuttering in square meter. All the detailed calculation and results have been shown below for each parameter as well in the Appendix as mentioned in the following sections.

7.4.1 CONCRETE QUANTITY

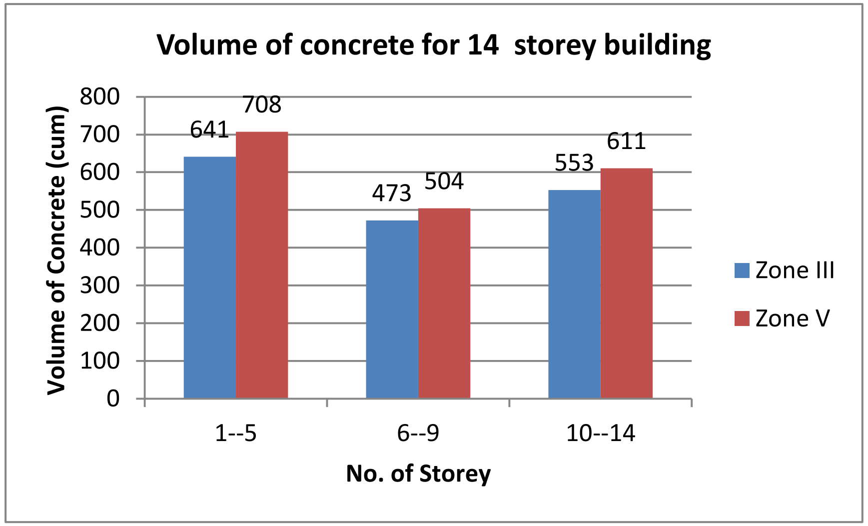
The volume of the concrete for each storey has been calculated along with the grade of concrete used. The following graph 7.2 to graph 7.5 shows the comparison of concrete volume for each coupled storey building zone wise. Graph 7.6 shows the volume of concrete for each building in different zones. Graph 7.7 shows the comparison of concrete volume requirement for each building per square meter of floor area.



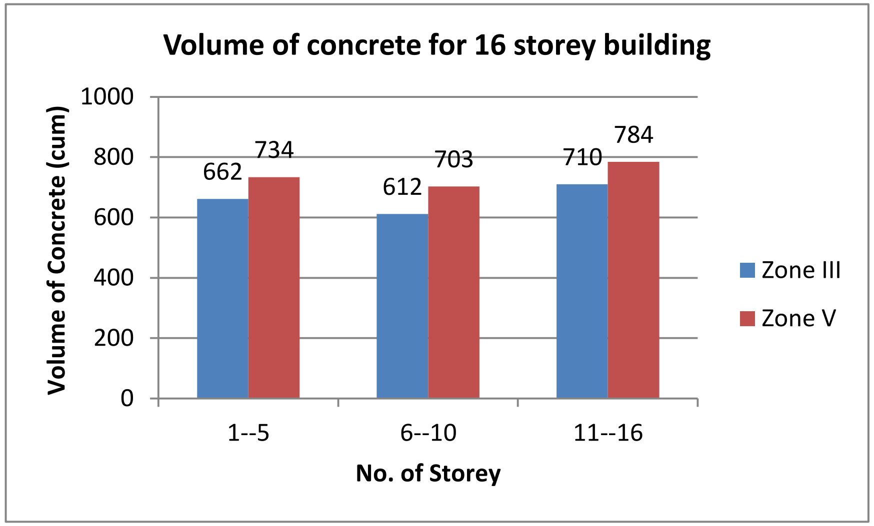
Graph 7. 2: Volume of Concrete for 10 Storey Building



Graph 7. 3: Volume of Concrete for 12 Storey Building

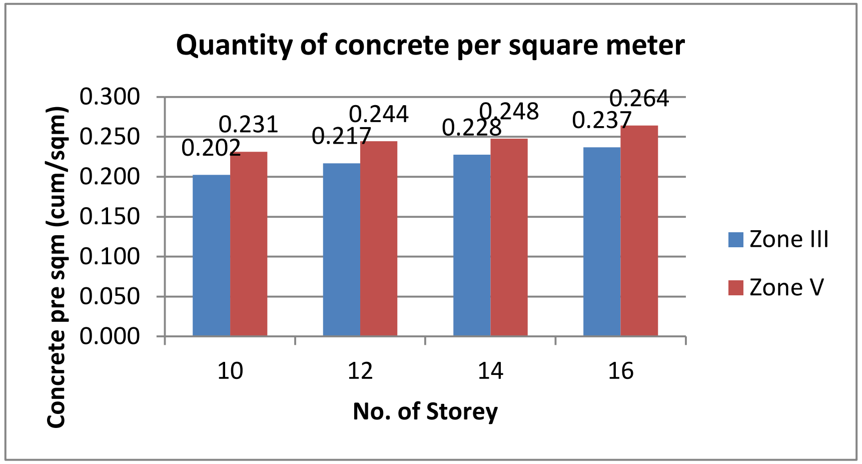


Graph 7.4: Volume of Concrete for 14 Storey Building

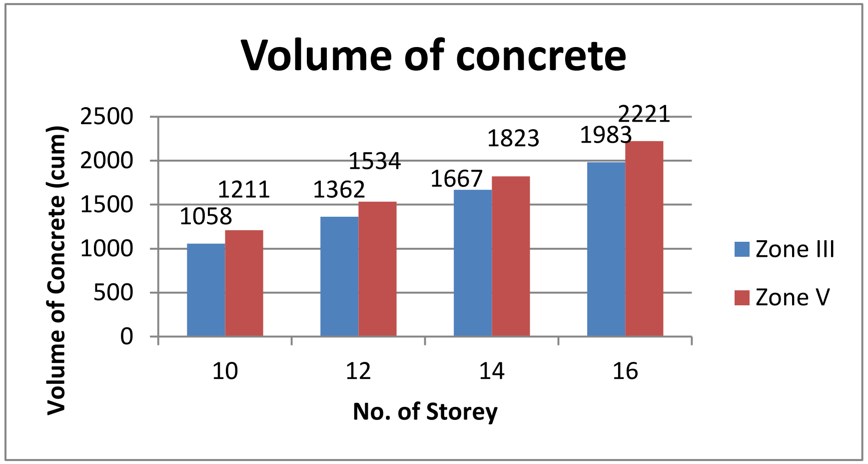


Graph 7. 5: Volume of Concrete for 16 Storey Building

aph



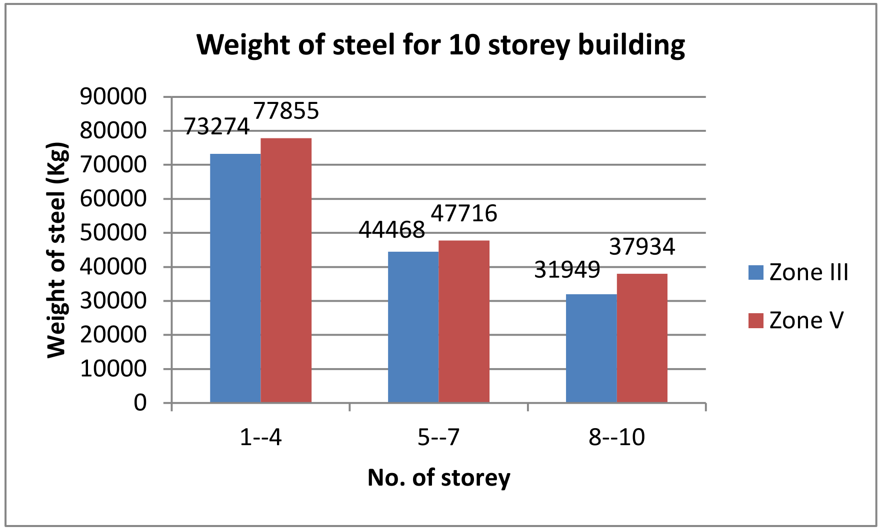
Graph 7. 6: Volume of Concrete



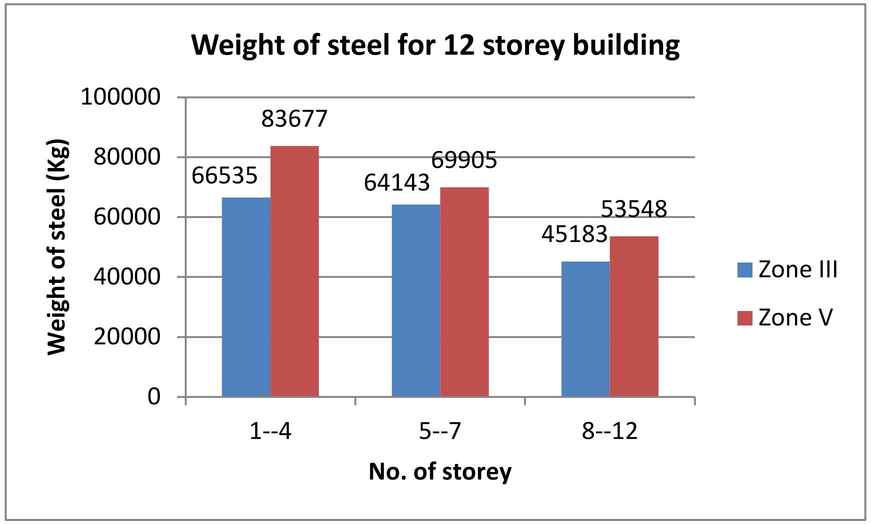
Graph 7. 7: Volume of Concrete per Sqm of Floor Area

7.4.2 QUANTITY OF STEEL

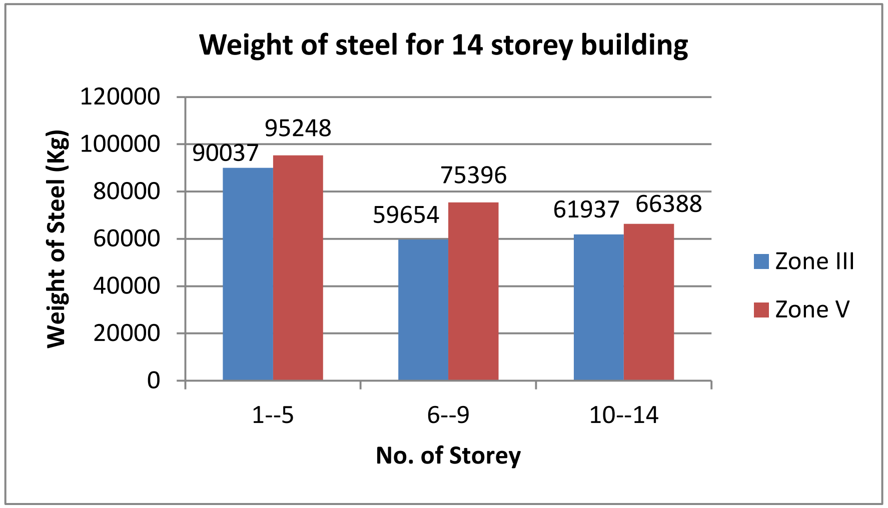
The weight of steel for each storey has been calculated from the design output given by E-TABS. Accurate detailing couldn't be performed due to the lack of field experience, hence a critical rebar and stirrup percentage is considered. The following graph 7.8 to graph 7.11 shows the comparison of weight of steel for each coupled storey building zone wise. Graph 7.12 shows the weight of steel for each building in different zones. Graph 7.13 shows the comparison of concrete volume requirement for each building per square meter of floor area.



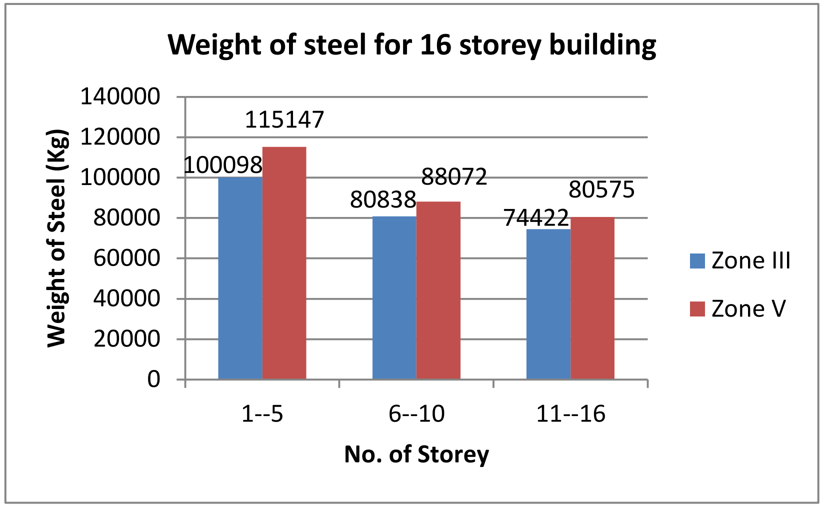
Graph 7. 8: Weight of Steel for 10 Storey Building



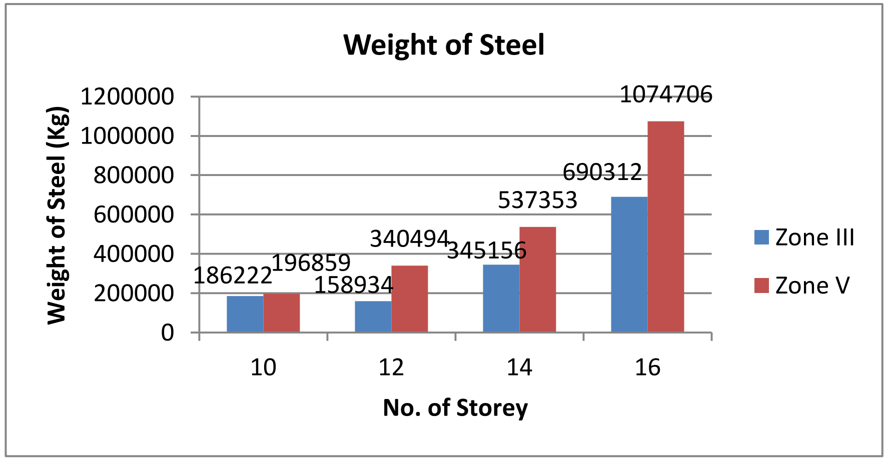
Graph 7. 9: Weight of Steel for 12Storey Building



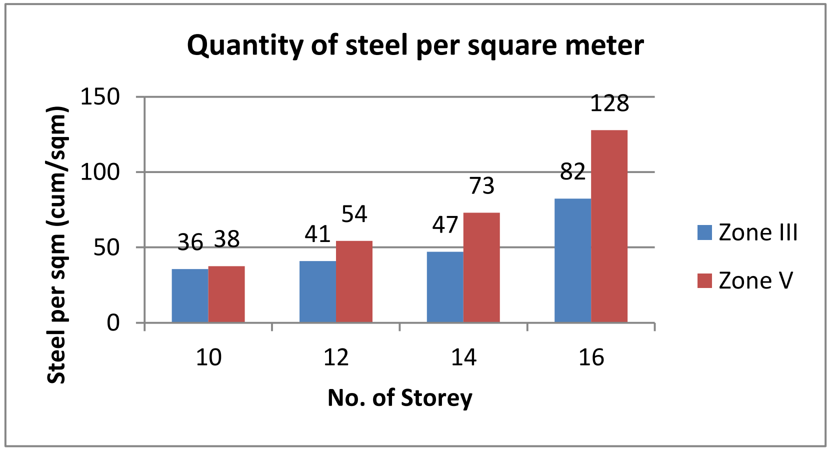
Graph 7.10: Weight of Steel for 14 Storey Building



Graph 7.11: Weight of Steel for 16Storey Building



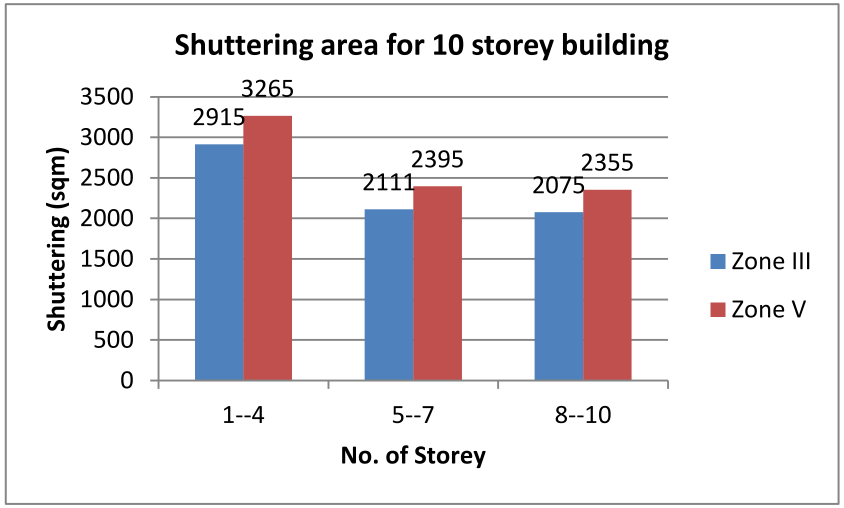
Graph 7.12: Quantity of Steel



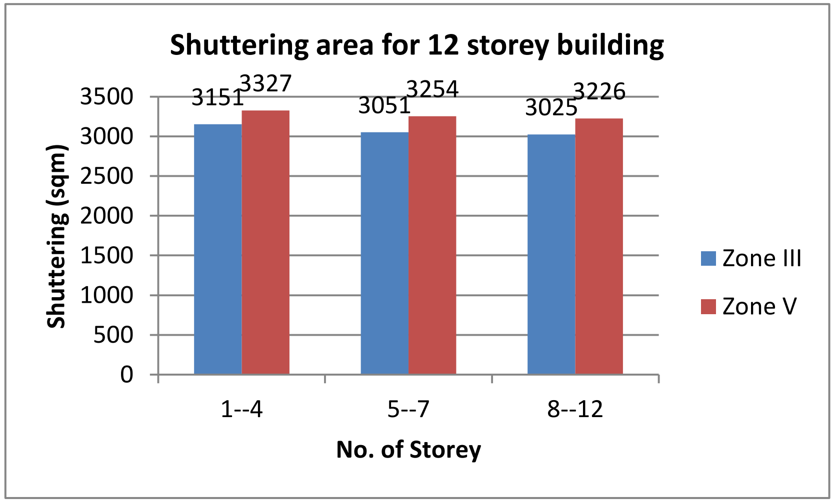
Graph 7.13: Quantity of Steel pre sqm of Floor Area

7.4.3 SHUTTERING QUANTITY

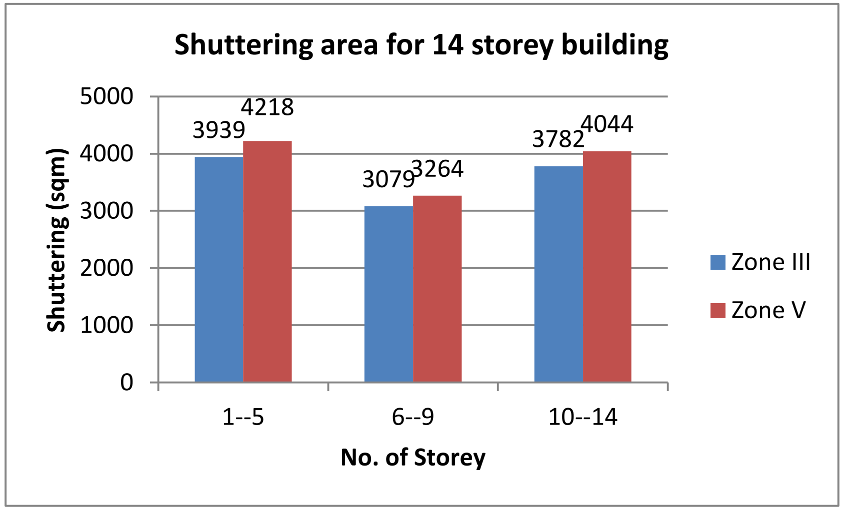
The quantity of shuttering for each storey has been calculated for the entire structural component. The following graph 7.14 to graph 7.17 shows the comparison of concrete volume for each coupled storey building zone wise. Graph 7.18 shows the quantity of shuttering required for each building in different zones. Graph 7.18 shows the comparison of concrete volume requirement for each building per square meter of floor area.



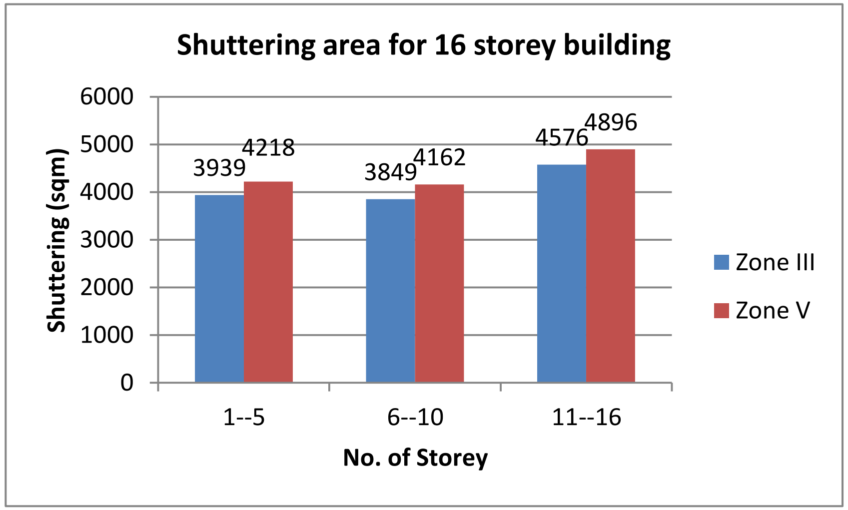
Graph 7.14: Shuttering area for 10 storey building



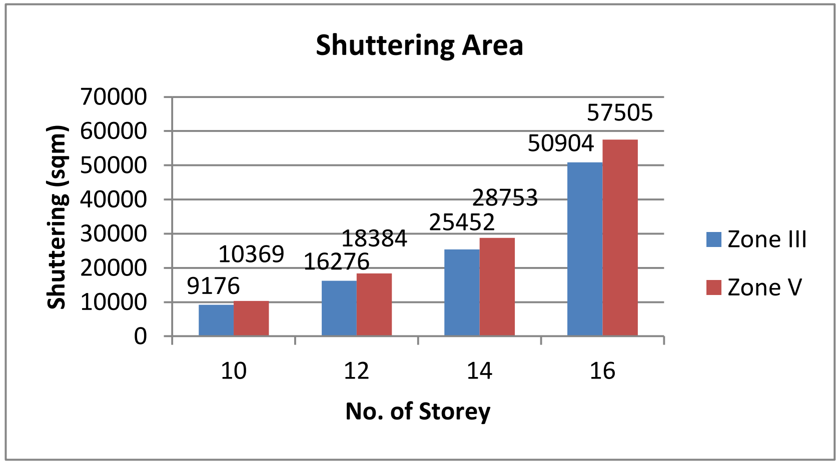
Graph 7.15: Shuttering area for 12 storey building



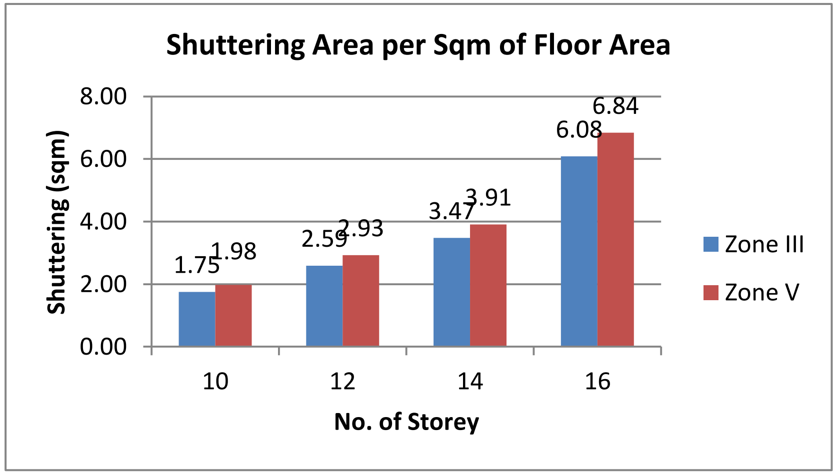
Graph 7.16: Shuttering area for 14 storey building



Graph 7.17: Shuttering area for 16 storey building



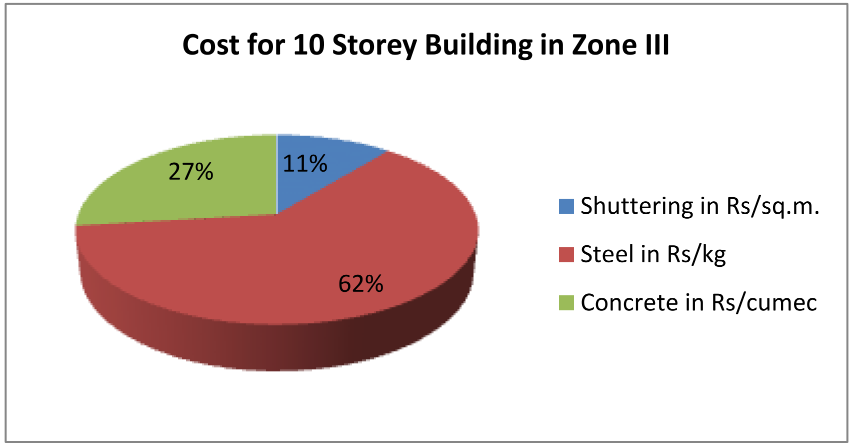
Graph 7.18: Shuttering area



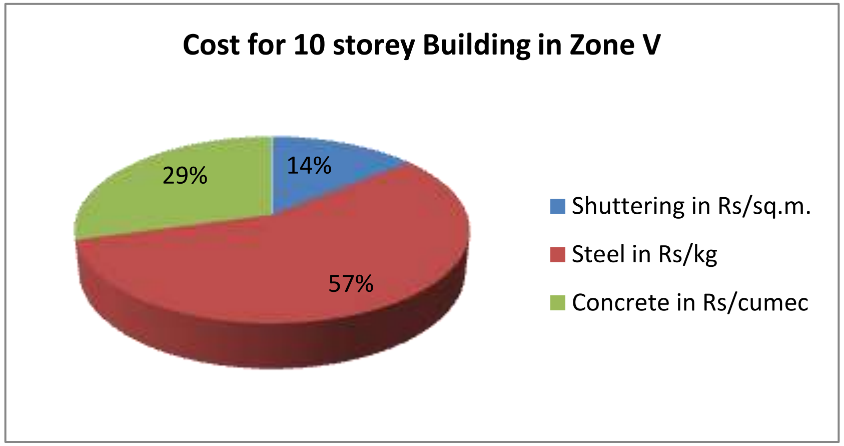
Graph 7.19: Shuttering area per Sqm of Floor Area

7.5 COST MODELLING

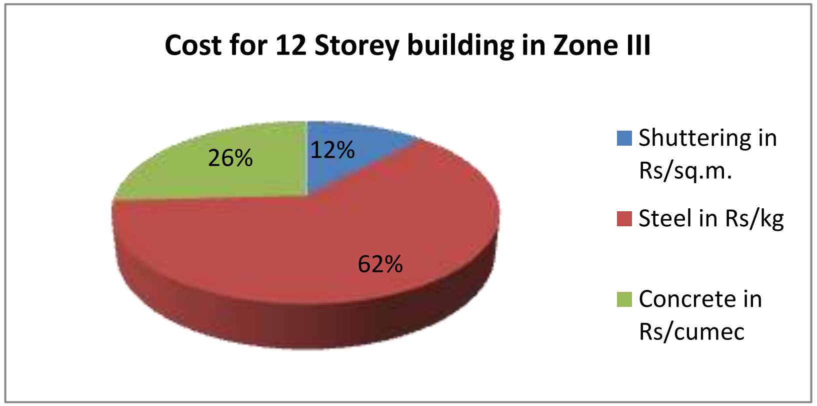
Cost modelling compromises the cost of concrete in Rs/cumec, steel in Rs/ Kg and shuttering in Rs/sqm. The following are the graph 7.20 to graph 7.27 shows the comparison of the percentage of share each component of the structure into consideration.



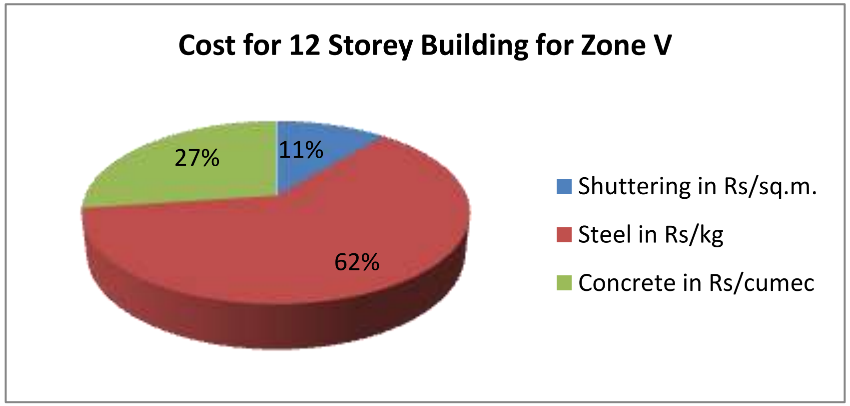
Graph 7.20: Cost division for 10 storey building in zone III



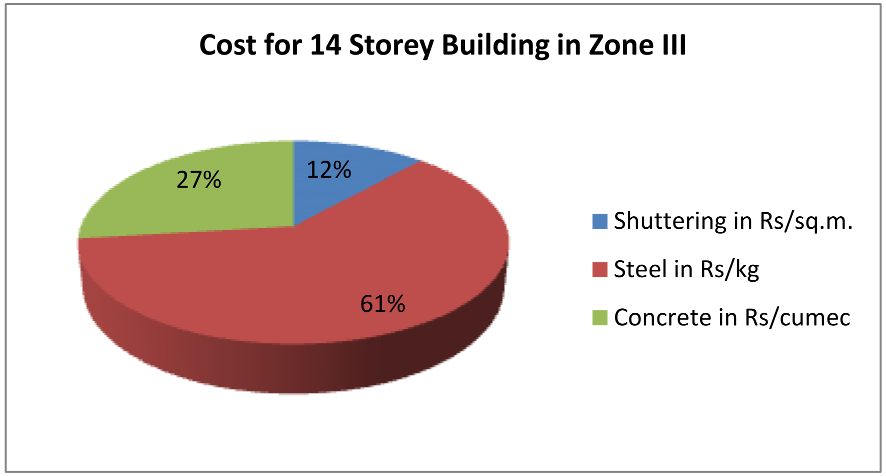
Graph 7.21: Cost division for 10 storey building in zone V



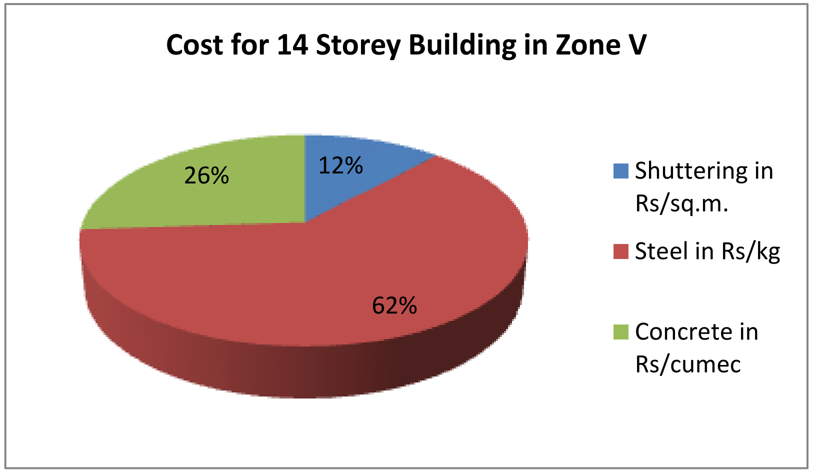
Graph 7.22: Cost division for 12 storey building in zone III



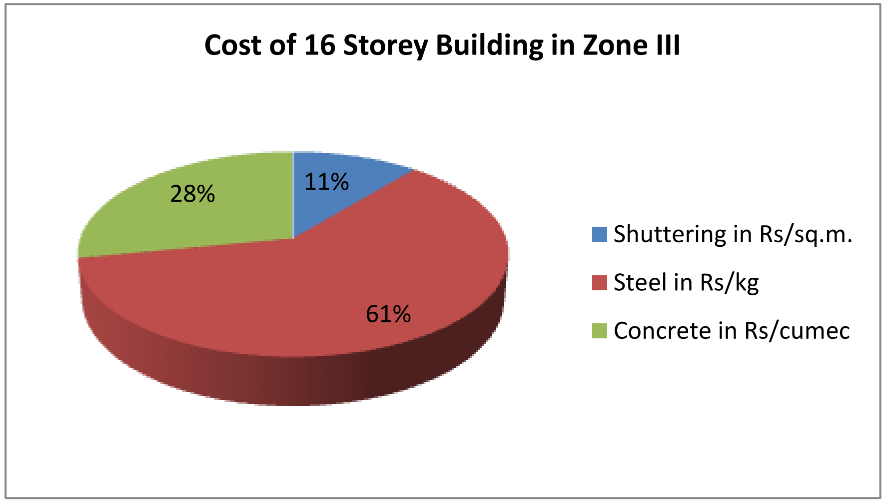
Graph 7.23: Cost division for 12 storey building in zone



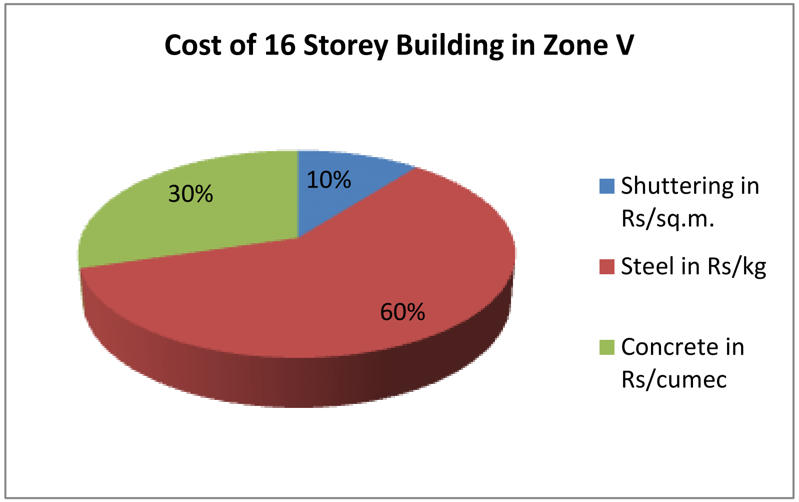
Graph 7.24: Cost division for 14 storey building in zone III



Graph 7.25: Cost division for 14 storey building in zone



Graph 7.26: Cost division for 16 storey building in zone III



Graph 7.27: Cost division for 16 storey building in zone

7.5.1 COST PRE SQUARE FLOOR AREA

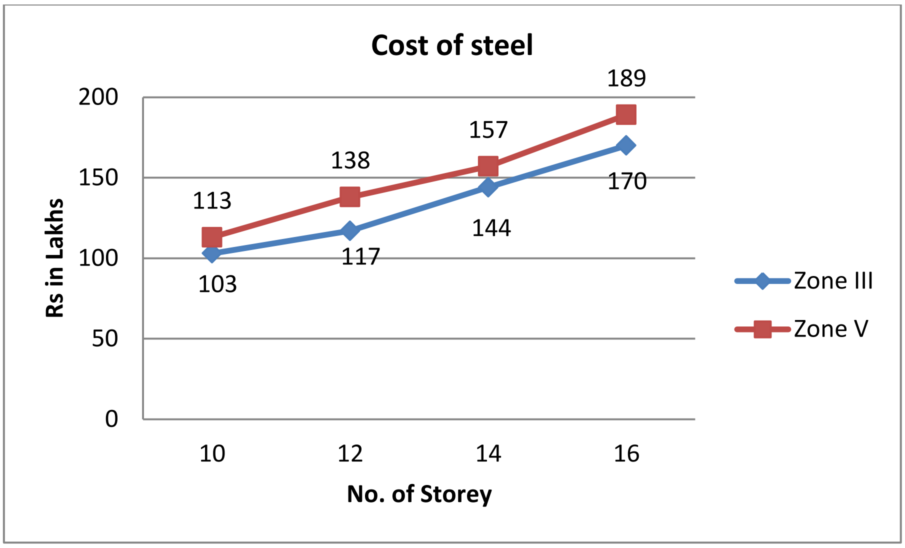
This section includes the cost of each component per square meter of floor area. The values for each building in different zones are shown in tables below.

Table 7.5: Cost of Component per Square Floor Area for Zone III

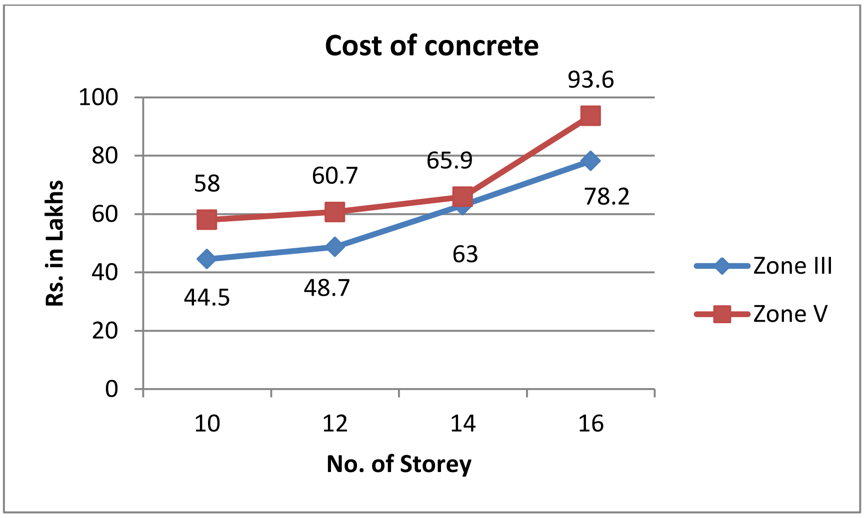
Building Storey	Total Floor Area	Cost of Shuttering	Cost	Cost of Steel	Cost	Cost of Concrete	Cost
	Sqm	Rs	Rs/sq m	Rs	Rs/sq m	Rs	Rs/sq m
10	5233	1802690	345	10259093	1961	4446303	850
12	6279	2275305	362	11694794	1862	4874306	776
14	7326	2742035	374	14359087	1960	6302764	860
16	8372	3050190	364	16981358	2028	7824316	935

Table 7.6: Cost of Component per Square Floor Area for ZoneV

Building Storey	Total Floor Area	Cost of Shuttering	Cost	Cost of Steel	Cost	Cost of Concrete	Cost
	Sqm	Rs	Rs/sq m	Rs	Rs/sq m	Rs	Rs/sq m
10	5233	2812181	537	11264540	2153	5836157	1115
12	6279	2479044	395	13774105	2194	6071571	967
14	7359	2981565	405	15696167	2133	6589129	895
16	8410	3347666	398	18872275	2244	9364289	1113



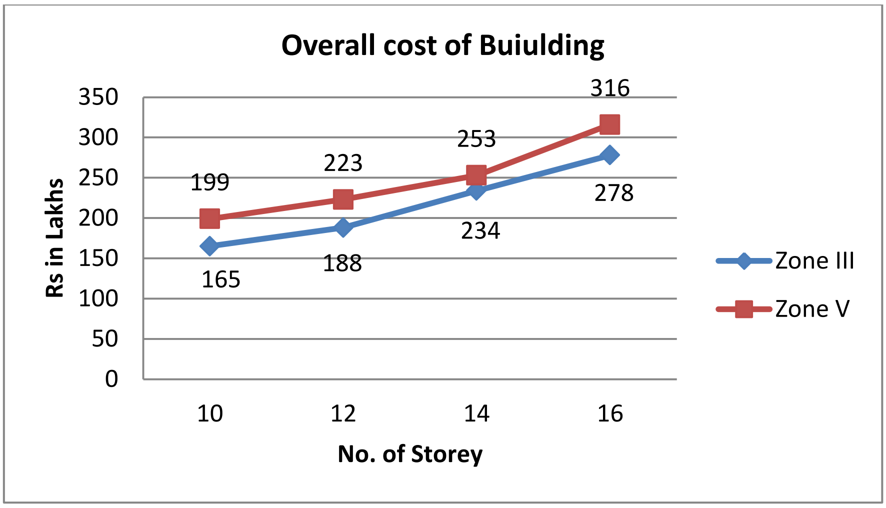
Graph 7.28: Cost of steel



Graph 7.29: Cost of Concrete

Table 7.7: Cost of Building (Cost in Rs)

Building Storey	Zone III	Zone V	Increase in cost
10	16508086.11	19912877.97	3404791.86
12	18844404.8	22324720.43	3480315.63
14	23403886.54	25266860.52	1862973.97
16	27855864.18	31584229.98	3728365.8



Graph 7.30: Overall Cost of Building

CHAPTER 8

CONCLUSION AND FUTURE SCOPE

8.1 CONCLUSION

In this chapter we calculate the cost premium after deriving the quantity and cost model in the previous chapter. Also we sum up the various research results and have a look at them in different perspectives.

From the above work discussed in the previous chapter we arrived to the following conclusion:

i 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.

ii 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.

iii For 14 Storey Building

a. The quantity of concrete requirement increases by 8.77% per square meter for building in zone V as compared to building in zone III.
b. The quantity of steel requirement increases by 55.32% per square meter for building in zone V as compared to building in zone III.
c. The quantity of shuttering requirement increases by 12.97% 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 14.6% and 9.03% for building in zone V as compared to building in zone III.
e. The overall cost of building increases by 8.12% for building in zone V as compared to building in zone III.

iv For 16 Storey building:

a. The quantity of concrete requirement increases by 11.39% per square meter for building in zone V as compared to building in zone III.
b. The quantity of steel requirement increases by 56.09% per square meter for building in zone V as compared to building in zone III.
c. The quantity of shuttering requirement increases by 12.5% 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 19.69% and 11.17% for building in zone V as compared to building in zone III.
e. The overall cost of building increases by 13.67% for building in zone V as compared to building in zone III.

v The average percentage contribution towards overall cost of building by concrete, shuttering and steel are 27.5%, 11.625% and 61.125% respectively.

vi The quantity modelling approach in the present work can provide a better estimation of the cost of a project.

vii These results will be very convenient for the investors to understand the cost involved in various construction stages.

8.2 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.

REFERENCES

1 Shweta A. Wagh and Dr. U. P Waghe " Comparative Study of RCC and Concrete-Steel Composite Structures" *Journal of engineering Research and Application* (IJERA) Volume 4, Issue 4, April 2014, pp. 821-818

2 Mahbuba Begum, Md. Serajus Salekin, N.M. Tauhid Belal Khan and W. Ahmed "Cost Analysis of Concrete-Steel Composite Structures in Bangladesh" *Asian Journal of Civil Engineering* Volume-4 Issue 6, April 2013, pp. 935-944

3 Thiruvengadam, V., et.al "Cost Predection of building Foundations Designed for Seismic Resistance", *14th European Conference on Earthquake Engineering (ECEE),* China, August 3-9, 2010

4 Anish N. Shah and Dr. P.S. Pajgade "Comparison of R.C.C. and composite multistoried buildings" *International Journal of Engineering Research and Applications (IJERA)* Volume 3, Issue 2, April 2013, 534-539

5 Aniket Sijaria, Prof. Anubhav Rai, Prof. Y. K. Bajpai "Cost Comparison between RCC Slab & Steel Composite Slab Structure of G+5 Storied Building" *International Journal of Scientific & Engineering Research* Volume 5, Issue 6, June 2014, pp. 893-896

6 A.M. Mwafy, et.al. "Seismic Assessment and Cost-Effectiveness of High-Rise Buildings with Increasing Concrete Strengths" *15th World Conference on Earthquake Engineering (WCEE)*, Lisboa, 2012

7 Thiruvengadam, V., et.al**.** "Cost modeling of reinforced concrete buildings designed for seismic effects", *13th World Conference on Earthquake Engineering*, Vancouver, B.C., Canada, August 1-6, 2004

8 Thakre Kant Rishi, "Quantity and Cost Analysis of R.C.C Multistoried Buildings in Different Seismic Zones of India", Seminar Report, *Building Engineering & Management, SPA* New Delhi, May 2011

9 Rahul RANA, Limin JIN and Atila ZEKIOGLU, "Pushover analysis of a 19 story concrete shear wall building", *13th World Conference on Earthquake Engineering*, Vancouver, B.C., Canada August 1-6, 2004 Paper No. 133

10 Sengupta Amlan.K, K Gnanasekaran : Seismic Evaluation and Retrofit of Multi-storeyed RC Buildings in India- Research at IIT Madras, Seismic Evaluation and Retrofit of Buildings, November 22-23, 2004

11 Slak T, Kilar V : Simplified Ranking System for Recognition and Evaluation of Earthquake Architecture, *The 14th World Conference on Earthquake Engineering*, October 12-17, 2008

12 Nayak. V. Narayan : Foundation Design Manual, Dhanpat Rai Publications (P) Ltd, 1996

13 Alam N, Alam Shahria M, Tesfamariam S : Building's seismic Vulnerability Assessment Methods : A Comparative Study, January 2012

14 Edward L. Wilson: Three-Dimensional Static and Dynamic Analysis of Structures: A Physical Approach with Emphasis on Earthquake Engineering, Computers and Structures Inc., Berkeley, Califor

BIBLOGRAPHY

1. IS 1893:2002 – Criteria For Earthquake Resistant Design Of Structures (Fifth Revision)
2. IS 4326:1993 – Earthquake Resistant Design &Construction of Buildings – Code of Practice
3. IS 456:2000 – Plain and Reinforced Concrete – Code of Practice (Fourth Revision)
4. IS 13920:1993 – Ductile Detail of RCC Structure Subjected to Forces – Guidelines
5. Delhi Schedule of Rates 2013 – Central public works department, Government of India, New Delhi.
6. Eurocode 8 – Design of structures for earthquake resistance – Part 1: General rules, seismic actions and rules for buildings, 2004.
7. International Building Code, 2003 International code council.
8. ATC 40: Seismic evaluation and retrofit of concrete buildings which is published by the Applied Technology Council under California seismic safety commission
9. FEMA 450: NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures, Part 1 and 2, 2003
10. Gilani Roomi : Earthquake risk reduction in pre & post disaster situation, Seminar Report, Dec 2009, Building Engineering & Management, SPA.

APPENDIX A
WEIGHT OF CONCRETE

APPENDIX A1: Weight of Concrete for 10 Storey Building at Zone V

Storey No.	Beams			Secondary Beams			Columns			Slabs		
	Length	Size	Volume	Length	Size	Volume	Length	Size	Volume	Depth	Area	Volume
	m	sqm	cum	m	sqm	cum	m	sqm	cum	m	sqm	cum
1	219	0.18	39.42	82.5	0.09	7.425	96	0.36	34.56	0.12	514.62	61.7544
2	219	0.18	39.42	82.5	0.09	7.425	86.4	0.36	31.104	0.12	514.62	61.7544
3	219	0.18	39.42	82.5	0.09	7.425	86.4	0.36	31.104	0.12	514.62	61.7544
4	219	0.18	39.42	82.5	0.09	7.425	86.4	0.36	31.104	0.12	514.62	61.7544
5	219	0.18	39.42	82.5	0.09	7.425	86.4	0.25	21.6	0.12	517.26	62.0712
6	219	0.18	39.42	82.5	0.09	7.425	86.4	0.25	21.6	0.12	517.26	62.0712
7	219	0.18	39.42	82.5	0.09	7.425	86.4	0.25	21.6	0.12	517.26	62.0712
8	219	0.18	39.42	82.5	0.09	7.425	86.4	0.16	13.824	0.12	519.42	62.3304
9	219	0.18	39.42	82.5	0.09	7.425	86.4	0.16	13.824	0.12	519.42	62.3304
10	219	0.18	39.42	82.5	0.09	7.425	86.4	0.16	13.824	0.12	519.42	62.3304
Total			**394**			**74.25**			**234.1**			**620.2**

APPENDIX A2: Weight of Concrete for 10 Storey Building at Zone III

Storey No.	Beams			Secondary Beams			Columns			Slabs		
	Length	Size	Volume	Length	Size	Volume	Length	Size	Volume	Depth	Area	Volume
	m	sqm	cum	m	sqm	cum	m	sqm	cum	m	sqm	cum
1	219	0.12	26.28	82.5	0.09	7.425	96	0.36	34.56	0.12	514.62	61.7544
2	219	0.12	26.28	82.5	0.09	7.425	86.4	0.36	31.104	0.12	514.62	61.7544
3	219	0.12	26.28	82.5	0.09	7.425	86.4	0.36	31.104	0.12	514.62	61.7544
4	219	0.12	26.28	82.5	0.09	7.425	86.4	0.36	31.104	0.12	514.62	61.7544
5	219	0.12	26.28	82.5	0.09	7.425	86.4	0.2025	17.496	0.12	517.26	62.0712
6	219	0.12	26.28	82.5	0.09	7.425	86.4	0.2025	17.496	0.12	517.26	62.0712
7	219	0.12	26.28	82.5	0.09	7.425	86.4	0.2025	17.496	0.12	517.26	62.0712
8	219	0.12	26.28	82.5	0.09	7.425	86.4	0.1225	10.584	0.12	519.42	62.3304
9	219	0.12	26.28	82.5	0.09	7.425	86.4	0.1225	10.584	0.12	519.42	62.3304
10	219	0.12	26.28	82.5	0.09	7.425	86.4	0.1225	10.584	0.12	519.42	62.3304
Total			**262.8**			**74.25**			**212.112**			**620.2**

APPENDIX A3: Weight of Concrete for 12 Storey Building at Zone V

Storey No.	Beams			Secondary Beams			Columns			Slabs		
	Length	Size	Volume	Length	Size	Volume	Length	Size	Volume	Depth	Area	Volume
	m	sqm	cum	m	sqm	cum	m	sqm	cum	m	sqm	cum
1	219	0.21	45.99	82.5	0.1	8.25	96	0.36	34.56	0.12	514.62	61.7544
2	219	0.21	45.99	82.5	0.1	8.25	86.4	0.36	31.104	0.12	514.62	61.7544
3	219	0.21	45.99	82.5	0.1	8.25	86.4	0.36	31.104	0.12	514.62	61.7544
4	219	0.21	45.99	82.5	0.1	8.25	86.4	0.36	31.104	0.12	514.62	61.7544
5	219	0.21	45.99	82.5	0.1	8.25	86.4	0.25	21.6	0.12	517.26	62.0712
6	219	0.21	45.99	82.5	0.1	8.25	86.4	0.25	21.6	0.12	517.26	62.0712
7	219	0.21	45.99	82.5	0.1	8.25	86.4	0.25	21.6	0.12	517.26	62.0712
8	219	0.21	45.99	82.5	0.1	8.25	86.4	0.25	21.6	0.12	517.26	62.0712
9	219	0.21	45.99	82.5	0.1	8.25	86.4	0.2025	17.496	0.12	518.4	62.208
10	219	0.21	45.99	82.5	0.1	8.25	86.4	0.2025	17.496	0.12	518.4	62.208
11	219	0.21	45.99	82.5	0.1	8.25	86.4	0.2025	17.496	0.12	518.4	62.208
12	219	0.21	45.99	82.5	0.1	8.25	86.4	0.2025	17.496	0.12	518.4	62.208
Total			**551.9**			**99**			**284.3**			**744.1**

APPENDIX A4: Weight of Concrete for 12 Storey Building at Zone III

Storey No.	Beams			Secondary Beams			Columns			Slabs		
	Length	Size	Volume	Length	Size	Volume	Length	Size	Volume	Depth	Area	Volume
	m	sqm	cum	m	sqm	cum	m	sqm	cum	m	sqm	cum
1	219	0.15	32.85	82.5	0.1	8.25	96	0.36	34.56	0.12	514.62	61.7544
2	219	0.15	32.85	82.5	0.1	8.25	86.4	0.36	31.104	0.12	514.62	61.7544
3	219	0.15	32.85	82.5	0.1	8.25	86.4	0.36	31.104	0.12	514.62	61.7544
4	219	0.15	32.85	82.5	0.1	8.25	86.4	0.36	31.104	0.12	514.62	61.7544
5	219	0.15	32.85	82.5	0.1	8.25	86.4	0.2025	17.496	0.12	517.26	62.0712
6	219	0.15	32.85	82.5	0.1	8.25	86.4	0.2025	17.496	0.12	517.26	62.0712
7	219	0.15	32.85	82.5	0.1	8.25	86.4	0.2025	17.496	0.12	517.26	62.0712
8	219	0.15	32.85	82.5	0.1	8.25	86.4	0.2025	17.496	0.12	517.26	62.0712
9	219	0.15	32.85	82.5	0.1	8.25	86.4	0.16	13.824	0.12	518.4	62.208
10	219	0.15	32.85	82.5	0.1	8.25	86.4	0.16	13.824	0.12	518.4	62.208
11	219	0.15	32.85	82.5	0.1	8.25	86.4	0.16	13.824	0.12	518.4	62.208
12	219	0.15	32.85	82.5	0.1	8.25	86.4	0.16	13.824	0.12	518.4	62.208
Total			**394.2**			**99**			**253.152**			**744.1344**

APPENDIX A5: Weight of Concrete for 14 Storey Building at Zone V

Storey No.	Beams			Secondary Beams			Columns			Slabs		
	Length	Size	Volume	Length	Size	Volume	Length	Size	Volume	Depth	Area	Volume
	m	sqm	cum	m	sqm	cum	m	sqm	cum	m	sqm	cum
1	219	0.2275	49.8225	82.5	0.1	8.25	96	0.4225	40.56	0.12	513.12	61.5744
2	219	0.2275	49.8225	82.5	0.1	8.25	86.4	0.4225	36.504	0.12	513.12	61.5744
3	219	0.2275	49.8225	82.5	0.1	8.25	86.4	0.4225	36.504	0.12	513.12	61.5744
4	219	0.2275	49.8225	82.5	0.1	8.25	86.4	0.4225	36.504	0.12	513.12	61.5744
5	219	0.2275	49.8225	82.5	0.1	8.25	86.4	0.4225	36.504	0.12	513.12	61.5744
6	219	0.2275	49.8225	82.5	0.1	8.25	86.4	0.25	21.6	0.12	517.26	62.0712
7	219	0.2275	49.8225	82.5	0.1	8.25	86.4	0.25	21.6	0.12	517.26	62.0712
8	219	0.2275	49.8225	82.5	0.1	8.25	86.4	0.25	21.6	0.12	517.26	62.0712
9	219	0.2275	49.8225	82.5	0.1	8.25	86.4	0.25	21.6	0.12	517.26	62.0712
10	219	0.2275	49.8225	82.5	0.1	8.25	86.4	0.2025	17.496	0.12	518.4	62.208
11	219	0.2275	49.8225	82.5	0.1	8.25	86.4	0.2025	17.496	0.12	518.4	62.208
12	219	0.2275	49.8225	82.5	0.1	8.25	86.4	0.2025	17.496	0.12	518.4	62.208
13	219	0.2275	49.8225	82.5	0.1	8.25	86.4	0.2025	17.496	0.12	518.4	62.208
14	219	0.2275	49.8225	82.5	0.1	8.25	86.4	0.2025	17.496	0.12	518.4	62.208
Total			**697.5**			**115.5**			**360.5**			**867.2**

APPENDIX A6: Weight of Concrete for 14 Storey Building at Zone III

Storey No.	Beams			Secondary Beams			Columns			Slabs		
	Length	Size	Volume	Length	Size	Volume	Length	Size	Volume	Depth	Area	Volume
	m	sqm	cum	m	sqm	cum	m	sqm	cum	m	sqm	cum
1	219	0.175	38.325	82.5	0.1	8.25	96	0.36	34.56	0.12	513.12	61.5744
2	219	0.175	38.325	82.5	0.1	8.25	86.4	0.36	31.104	0.12	513.12	61.5744
3	219	0.175	38.325	82.5	0.1	8.25	86.4	0.36	31.104	0.12	513.12	61.5744
4	219	0.175	38.325	82.5	0.1	8.25	86.4	0.36	31.104	0.12	513.12	61.5744
5	219	0.175	38.325	82.5	0.1	8.25	86.4	0.36	31.104	0.12	513.12	61.5744
6	219	0.175	38.325	82.5	0.1	8.25	86.4	0.25	21.6	0.12	517.26	62.0712
7	219	0.175	38.325	82.5	0.1	8.25	86.4	0.25	21.6	0.12	517.26	62.0712
8	219	0.175	38.325	82.5	0.1	8.25	86.4	0.25	21.6	0.12	517.26	62.0712
9	219	0.175	38.325	82.5	0.1	8.25	86.4	0.25	21.6	0.12	517.26	62.0712
10	219	0.175	38.325	82.5	0.1	8.25	86.4	0.16	13.824	0.12	518.4	62.208
11	219	0.175	38.325	82.5	0.1	8.25	86.4	0.16	13.824	0.12	518.4	62.208
12	219	0.175	38.325	82.5	0.1	8.25	86.4	0.16	13.824	0.12	518.4	62.208
13	219	0.175	38.325	82.5	0.1	8.25	86.4	0.16	13.824	0.12	518.4	62.208
14	219	0.175	38.325	82.5	0.1	8.25	86.4	0.16	13.824	0.12	518.4	62.208
Total			**536.6**			**115.5**			**314.5**			**867.2**

APPENDIX A7: Weight of Concrete for 16 Storey Building at Zone V

Storey No.	Beams			Secondary Beams			Columns			Slabs		
	Length	Size	Volume	Length	Size	Volume	Length	Size	Volume	Depth	Area	Volume
	m	sqm	cum	m	sqm	cum	m	sqm	cum	m	sqm	cum
1	219	0.24	52.56	82.5	0.1	8.25	96	0.4225	40.56	0.12	513.12	61.5744
2	219	0.24	52.56	82.5	0.1	8.25	86.4	0.4225	36.504	0.12	513.12	61.5744
3	219	0.24	52.56	82.5	0.1	8.25	86.4	0.4225	36.504	0.12	513.12	61.5744
4	219	0.24	52.56	82.5	0.1	8.25	86.4	0.4225	36.504	0.12	513.12	61.5744
5	219	0.24	52.56	82.5	0.1	8.25	86.4	0.4225	36.504	0.12	513.12	61.5744
6	219	0.24	52.56	82.5	0.1	8.25	86.4	0.36	31.104	0.12	514.62	61.7544
7	219	0.24	52.56	82.5	0.1	8.25	86.4	0.36	31.104	0.12	514.62	61.7544
8	219	0.24	52.56	82.5	0.1	8.25	86.4	0.36	31.104	0.12	514.62	61.7544
9	219	0.24	52.56	82.5	0.1	8.25	86.4	0.36	31.104	0.12	514.62	61.7544
10	219	0.24	52.56	82.5	0.1	8.25	86.4	0.36	31.104	0.12	514.62	61.7544
11	219	0.24	52.56	82.5	0.1	8.25	86.4	0.25	21.6	0.12	517.26	62.0712
12	219	0.24	52.56	82.5	0.1	8.25	86.4	0.25	21.6	0.12	517.26	62.0712
13	219	0.24	52.56	82.5	0.1	8.25	86.4	0.25	21.6	0.12	517.26	62.0712
14	219	0.24	52.56	82.5	0.1	8.25	86.4	0.25	21.6	0.12	517.26	62.0712
15	219	0.24	52.56	82.5	0.1	8.25	86.4	0.25	21.6	0.12	517.26	62.0712
16	219	0.24	52.56	82.5	0.1	8.25	86.4	0.25	21.6	0.12	517.26	62.0712
Total			**841**			**132**			**471.7**			**989.1**

APPENDIX A8: Weight of Concrete for 16 Storey Building at Zone III

Storey No.	BEAMS			Secondary Beams			columns			Slabs		
	Length	Size	Volume	Length	Size	Volume	Length	Size	Volume	Depth	Area	Volume
	m	sqm	cum	m	sqm	cum	m	sqm	cum	m	sqm	cum
1	219	0.2	43.8	82.5	0.1	8.25	96	0.36	34.56	0.12	513.12	61.5744
2	219	0.2	43.8	82.5	0.1	8.25	86.4	0.36	31.104	0.12	513.12	61.5744
3	219	0.2	43.8	82.5	0.1	8.25	86.4	0.36	31.104	0.12	513.12	61.5744
4	219	0.2	43.8	82.5	0.1	8.25	86.4	0.36	31.104	0.12	513.12	61.5744
5	219	0.2	43.8	82.5	0.1	8.25	86.4	0.36	31.104	0.12	513.12	61.5744
6	219	0.2	43.8	82.5	0.1	8.25	86.4	0.25	21.6	0.12	514.62	61.7544
7	219	0.2	43.8	82.5	0.1	8.25	86.4	0.25	21.6	0.12	514.62	61.7544
8	219	0.2	43.8	82.5	0.1	8.25	86.4	0.25	21.6	0.12	514.62	61.7544
9	219	0.2	43.8	82.5	0.1	8.25	86.4	0.25	21.6	0.12	514.62	61.7544
10	219	0.2	43.8	82.5	0.1	8.25	86.4	0.25	21.6	0.12	514.62	61.7544
11	219	0.2	43.8	82.5	0.1	8.25	86.4	0.2025	17.496	0.12	517.26	62.0712
12	219	0.2	43.8	82.5	0.1	8.25	86.4	0.2025	17.496	0.12	517.26	62.0712
13	219	0.2	43.8	82.5	0.1	8.25	86.4	0.2025	17.496	0.12	517.26	62.0712
14	219	0.2	43.8	82.5	0.1	8.25	86.4	0.2025	17.496	0.12	517.26	62.0712
15	219	0.2	43.8	82.5	0.1	8.25	86.4	0.2025	17.496	0.12	517.26	62.0712
16	219	0.2	43.8	82.5	0.1	8.25	86.4	0.2025	17.496	0.12	517.26	62.0712
Total			**700.8**			**132**			**372**			**989.1**

APPENDIX B
WEIGHT OF INFILL WALL

APPENDIX B1: Weight of Infill Walls for 10 Storey Building at Zone III And Zone V

Storey No.	Exterior Walls				Interior walls			
	Length	Depth	Height	Volume	Length	Depth	Height	Volume
	m	m	m	cum	m	m	m	cum
1	93	0.23	3	64.17	126	0.115	3	43.47
2	93	0.23	3	64.17	126	0.115	3	43.47
3	93	0.23	3	64.17	126	0.115	3	43.47
4	93	0.23	3	64.17	126	0.115	3	43.47
5	93	0.23	3	64.17	126	0.115	3	43.47
6	93	0.23	3	64.17	126	0.115	3	43.47
7	93	0.23	3	64.17	126	0.115	3	43.47
8	93	0.23	3	64.17	126	0.115	3	43.47
9	93	0.23	3	64.17	126	0.115	3	43.47
10	93	0.23	0.9	19.251				
Total				**596.8**				**391.2**

APPENDIX B2: Weight of Infill Walls for 12 Storey Building at Zone III And Zone V

Storey No.	Exterior Walls				Interior walls			
	Length	Depth	Height	Volume	Length	Depth	Height	Volume
	m	m	m	cum	m	m	m	cum
1	93	0.23	3	64.17	126	0.115	3	43.47
2	93	0.23	3	64.17	126	0.115	3	43.47
3	93	0.23	3	64.17	126	0.115	3	43.47
4	93	0.23	3	64.17	126	0.115	3	43.47
5	93	0.23	3	64.17	126	0.115	3	43.47
6	93	0.23	3	64.17	126	0.115	3	43.47
7	93	0.23	3	64.17	126	0.115	3	43.47
8	93	0.23	3	64.17	126	0.115	3	43.47
9	93	0.23	3	64.17	126	0.115	3	43.47
10	93	0.23	3	64.17	126	0.115	3	43.47
11	93	0.23	3	64.17	126	0.115	3	43.47
12	93	0.23	0.9	19.251				

Total				725.1				478.2

APPENDIX B3: Weight of Infill Walls for 14 Storey Building at Zone III And Zone V

	Exterior Walls				Interior walls			
Storey No.	Length	Depth	Height	Volume	Length	Depth	Height	Volume
	m	m	m	cum	m	m	m	cum
1	93	0.23	3	64.17	126	0.115	3	43.47
2	93	0.23	3	64.17	126	0.115	3	43.47
3	93	0.23	3	64.17	126	0.115	3	43.47
4	93	0.23	3	64.17	126	0.115	3	43.47
5	93	0.23	3	64.17	126	0.115	3	43.47
6	93	0.23	3	64.17	126	0.115	3	43.47
7	93	0.23	3	64.17	126	0.115	3	43.47
8	93	0.23	3	64.17	126	0.115	3	43.47
9	93	0.23	3	64.17	126	0.115	3	43.47
10	93	0.23	3	64.17	126	0.115	3	43.47
11	93	0.23	3	64.17	126	0.115	3	43.47
12	93	0.23	3	64.17	126	0.115	3	43.47
13	93	0.23	3	64.17	126	0.115	3	43.47
14	93	0.23	0.9	19.251				
Total				**853.5**				**565.1**

APPENDIX B4: Weight of Infill Walls for 16 Storey Building at Zone III And Zone V

Storey No.	Exterior Walls				Interior walls			
	Length	Depth	Height	Volume	Length	Depth	Height	Volume
	m	m	m	cum	m	m	m	cum
1	93	0.23	3	64.17	126	0.115	3	43.47
2	93	0.23	3	64.17	126	0.115	3	43.47
3	93	0.23	3	64.17	126	0.115	3	43.47
4	93	0.23	3	64.17	126	0.115	3	43.47
5	93	0.23	3	64.17	126	0.115	3	43.47
6	93	0.23	3	64.17	126	0.115	3	43.47
7	93	0.23	3	64.17	126	0.115	3	43.47
8	93	0.23	3	64.17	126	0.115	3	43.47
9	93	0.23	3	64.17	126	0.115	3	43.47
10	93	0.23	3	64.17	126	0.115	3	43.47
11	93	0.23	3	64.17	126	0.115	3	43.47
12	93	0.23	3	64.17	126	0.115	3	43.47
13	93	0.23	3	64.17	126	0.115	3	43.47
14	93	0.23	3	64.17	126	0.115	3	43.47
15	93	0.23	3	64.17	126	0.115	3	43.47

16	93	0.23	0.9	19.251				
Total				**981.8**				**652.1**

APPENDIX C
CONCRETE AND SHUTTERING QUANTITIES

APPENDIX C1: Concrete and Shuttering Quantities for 10 Storey Building at Zone V

10 STOREY ZONE V CONCRETE AND SHUTTERING QUANTITIES			No. of Member each floor	No of floors	Total no. of member	Breadth (b)	Depth (D)	L/H	Plan Area Calculation	Volume of Concrete	Volume of Concrete per member	Concrete/sqm	Grade of Concrete Mix	Shuttering	Shuttering/sqm
						M	M	M	Sqm	Cum	Cum			Sqm	
			GROSS FLOOR AREA (each floor)						523.260						
First Storey to Fourth Storey	VERTICAL MEMBERS	COLUMN	24	4	96	0.6	0.6	3.7	34.56	127.872	1.332	0.061	M35	255.744	0.122
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	4	16	0.3	0.6	30	144	86.400	5.4	0.041	M25	604.8	0.289
		TRANSVERSE BEAM	6	4	24	0.3	0.6	16.5	118.8	71.280	2.97	0.034	M25	498.96	0.238
		SECONDARY BEAM	5	4	20	0.3	0.3	15.3	91.800	27.540	1.377	0.013	M25	201.960	0.096
	TOTAL	Total Plan Area of column, beam & secondary beam							389.160						
		GROSS FLOOR AREA	1	4		17.1		30.6	2093.040						
		NET SLAB AREA					0.12		1703.880	204.466	51.116	0.098	M25	1703.880	0.814
		TOTAL								517.6	62.195	0.247		3265.3	1.560
			GROSS FLOOR AREA (each floor)						523.260						
Fifth Storey to Seventh Storey	VERTICAL MEMBERS	COLUMN	24	3	72	0.5	0.5	3.6	18	64.8	0.9	0.041	M30	129.6	0.083
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	3	12	0.3	0.6	30	108	64.800	5.4	0.041	M25	453.6	0.289
		TRANSVERSE BEAM	6	3	18	0.3	0.6	16.5	89.1	53.460	2.97	0.034	M25	374.22	0.238
		SECONDARY BEAM	5	3	15	0.3	0.3	15.3	68.850	20.655	1.377	0.013	M25	151.470	0.096
	TOTAL	Total Plan Area of column, beam & secondary beam							283.950						
		GROSS FLOOR AREA	1	3		17.1		30.6	1569.780						
		NET SLAB AREA					0.12		1285.830	154.300	51.433	0.098	M25	1285.830	0.819
		TOTAL								358.0	62.080	0.228		2394.7	1.526
			GROSS FLOOR AREA (each floor)						523.260						
Eighth Storey to Tenth Storey	VERTICAL MEMBERS	COLUMN	24	3	72	0.4	0.4	3.6	11.52	41.472	0.576	0.026	M25	82.944	0.053
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	3	12	0.3	0.6	30	108	64.800	5.4	0.041	M25	453.6	0.289
		TRANSVERSE BEAM	6	3	18	0.3	0.6	16.5	89.1	53.460	2.97	0.034	M25	374.22	0.238
		SECONDARY BEAM	5	3	15	0.3	0.3	15.3	68.850	20.655	1.377	0.013	M25	151.470	0.096
	TOTAL	Total Plan Area of column, beam & secondary beam							277.470						
		GROSS FLOOR AREA	1	3		17.1		30.6	1569.780						
		NET SLAB AREA					0.12		1292.310	155.077	51.692	0.099	M25	1292.310	0.823
		TOTAL								335.5	62.015	0.214		2354.5	1.500

APPENDIX C2: Concrete and Shuttering Quantities for 10 Storey Building at Zone III

10 STOREY ZONE III CONCRETE AND SHUTTERING QUANTITIES			No. of Member each floor	No of floors	Total no. of member	Breadth (b)	Depth (D)	L/H	Plan Area Calculation	Volume of Concrete	Volume of Concrete per member	Concrete/sqm	Grade of Concrete Mix	Shuttering	Shuttering/sqm
						M	M	M	Sqm	Cum	Cum			Sqm	
			GROSS FLOOR AREA (each floor)						523.260						
First Storey to Fourth Storey	VERTICAL MEMBERS	COLUMN	24	4	96	0.6	0.6	3.7	34.56	127.872	1.332	0.061	M35	255.744	0.122
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	4	16	0.3	0.4	30	144	57.600	3.6	0.028	M25	412.8	0.197
		TRANSVERSE BEAM	6	4	24	0.3	0.4	16.5	118.8	47.520	1.98	0.023	M25	340.56	0.163
		SECONDARY BEAM	5	4	20	0.3	0.3	15.3	91.800	27.540	1.377	0.013	M25	201.960	0.096
	TOTAL	Total Plan Area of column, beam & secondary beam							389.160						
		GROSS FLOOR AREA	1	4		17.1		30.6	2093.040						
		NET SLAB AREA					0.12		1703.880	204.466	51.116	0.098	M25	1703.880	0.814
		TOTAL								465.0	59.405	0.222		2914.9	1.393
			GROSS FLOOR AREA (each floor)						523.260						
Fifth Storey to Seventh Storey	VERTICAL MEMBERS	COLUMN	24	3	72	0.45	0.45	3.6	14.58	52.488	0.729	0.033	M30	104.976	0.067
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	3	12	0.3	0.4	30	108	43.200	3.6	0.028	M25	309.6	0.197
		TRANSVERSE BEAM	6	3	18	0.3	0.4	16.5	89.1	35.640	1.98	0.023	M25	255.42	0.163
		SECONDARY BEAM	5	3	15	0.3	0.3	15.3	68.850	20.655	1.377	0.013	M25	151.470	0.096
	TOTAL	Total Plan Area of column, beam & secondary beam							280.530						
		GROSS FLOOR AREA	1	3		17.1		30.6	1569.780						
		NET SLAB AREA					0.12		1289.250	154.710	51.570	0.099	M25	1289.250	0.821
		TOTAL								306.7	59.256	0.195		2110.7	1.345
			GROSS FLOOR AREA (each floor)						523.260						
Eighth Storey to Tenth Storey	VERTICAL MEMBERS	COLUMN	24	3	72	0.35	0.35	3.6	8.82	31.752	0.441	0.020	M25	63.504	0.040
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	3	12	0.3	0.4	30	108	43.200	3.6	0.028	M25	309.6	0.197
		TRANSVERSE BEAM	6	3	18	0.3	0.4	16.5	89.1	35.640	1.98	0.023	M25	255.42	0.163
		SECONDARY BEAM	5	3	15	0.3	0.3	15.3	68.850	20.655	1.377	0.013	M25	151.470	0.096
	TOTAL	Total Plan Area of column, beam & secondary beam							274.770						
		GROSS FLOOR AREA	1	3		17.1		30.6	1569.780						
		NET SLAB AREA					0.12		1295.010	155.401	51.800	0.099	M25	1295.010	0.825
		TOTAL								286.6	59.198	0.183		2075.0	1.322

APPENDIX C3: Concrete and Shuttering Quantities for 12 Storey Building at Zone V

12 STOREY ZONE V CONCRETE AND SHUTTERING QUANTITIES			No. of Member each floor	No of floors	Total no. of member	Breadth (b)	Depth (D)	L/H	Plan Area Calculation	Volume of Concrete	Volume of Concrete per member	Concrete/sqm	Grade of Concrete Mix	Shuttering	Shuttering/sqm
						M	M	M	Sqm	Cum	Cum			Sqm	
			GROSS FLOOR AREA (each floor)						523.260						
First Storey to Fourth Storey	VERTICAL MEMBERS	COLUMN	24	4	96	0.6	0.6	3.7	34.56	127.872	1.332	0.061	M35	255.744	0.122
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	4	16	0.35	0.6	30	168	100.800	6.3	0.048	M25	628.8	0.300
		TRANSVERSE BEAM	6	4	24	0.35	0.6	16.5	138.6	83.160	3.465	0.040	M25	518.76	0.248
		SECONDARY BEAM	5	4	20	0.25	0.4	15.3	76.500	30.600	1.53	0.015	M25	247.860	0.118
	TOTAL	Total Plan Area of column, beam & secondary beam							417.660						
		GROSS FLOOR AREA	1	4		17.1		30.6	2093.040						
		NET SLAB AREA					0.12		1675.380	201.046	50.261	0.096	M25	1675.380	0.800
		TOTAL								543.5	62.888	0.260		3326.5	1.589
			GROSS FLOOR AREA (each floor)						523.260						
Fifth Storey to Eight Storey	VERTICAL MEMBERS	COLUMN	24	4	96	0.5	0.5	3.6	24	86.4	0.9	0.041	M35	172.8	0.083
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	4	16	0.35	0.6	30	168	100.800	6.3	0.048	M25	628.8	0.300
		TRANSVERSE BEAM	6	4	24	0.35	0.6	16.5	138.6	83.160	3.465	0.040	M25	518.76	0.248
		SECONDARY BEAM	5	4	20	0.25	0.4	15.3	76.500	30.600	1.53	0.015	M25	247.860	0.118
	TOTAL	Total Plan Area of column, beam & secondary beam							407.100						
		GROSS FLOOR AREA	1	4		17.1		30.6	2093.040						
		NET SLAB AREA					0.12		1685.940	202.313	50.578	0.097	M25	1685.940	0.805
		TOTAL								503.3	62.773	0.240		3254.2	1.555
			GROSS FLOOR AREA (each floor)						523.260						
Ninth Storey to Twelvth Storey	VERTICAL MEMBERS	COLUMN	24	4	96	0.45	0.45	3.6	19.44	69.984	0.729	0.033	M35	139.968	0.067
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	4	16	0.35	0.6	30	168	100.800	6.3	0.048	M25	628.8	0.300
		TRANSVERSE BEAM	6	4	24	0.35	0.6	16.5	138.6	83.160	3.465	0.040	M25	518.76	0.248
		SECONDARY BEAM	5	4	20	0.25	0.4	15.3	76.500	30.600	1.53	0.015	M25	247.860	0.118
	TOTAL	Total Plan Area of column, beam & secondary beam							402.540						
		GROSS FLOOR AREA	1	4		17.1		30.6	2093.040						
		NET SLAB AREA					0.12		1690.500	202.860	50.715	0.097	M25	1690.500	0.808
		TOTAL								487.4	62.739	0.233		3225.9	1.541

APPENDIX C4: Concrete and Shuttering Quantities for 12 Storey Building at Zone III

12 STOREY ZONE III CONCRETE AND SHUTTERING QUANTITIES			No. of Member each floor	No of floors	Total no. of member	Breadth (b)	Depth (D)	L/H	Plan Area Calculation	Volume of Concrete	Volume of Concrete per member	Concrete/sqm	Grade of Concrete Mix	Shuttering	Shuttering/sqm
						M	M	M	Sqm	Cum	Cum			Sqm	
			GROSS FLOOR AREA (each floor)						523.260						
First Storey to Fourth Storey	VERTICAL MEMBERS	COLUMN	24	4	96	0.6	0.6	3.7	34.56	127.872	1.332	0.061	M35	255.744	0.122
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	4	16	0.3	0.5	30	144	72.000	4.5	0.034	M25	508.8	0.243
		TRANSVERSE BEAM	6	4	24	0.3	0.5	16.5	118.8	59.400	2.475	0.028	M25	419.76	0.201
		SECONDARY BEAM	5	4	20	0.25	0.4	15.3	76.500	30.600	1.53	0.015	M25	247.860	0.118
	TOTAL	Total Plan Area of column, beam & secondary beam							373.860						
		GROSS FLOOR AREA	1	4		17.1		30.6	2093.040						
		NET SLAB AREA					0.12		1719.180	206.302	51.575	0.099	M25	1719.180	0.821
		TOTAL								496.2	61.412	0.237		3151.3	1.506
			GROSS FLOOR AREA (each floor)						523.260						
Fifth Storey to Eight Storey	VERTICAL MEMBERS	COLUMN	24	4	96	0.45	0.45	3.6	19.44	69.984	0.729	0.033	M35	139.968	0.067
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	4	16	0.3	0.5	30	144	72.000	4.5	0.034	M25	508.8	0.243
		TRANSVERSE BEAM	6	4	24	0.3	0.5	16.5	118.8	59.400	2.475	0.028	M25	419.76	0.201
		SECONDARY BEAM	5	4	20	0.25	0.4	15.3	76.500	30.600	1.53	0.015	M25	247.860	0.118
	TOTAL	Total Plan Area of column, beam & secondary beam							358.740						
		GROSS FLOOR AREA	1	4		17.1		30.6	2093.040						
		NET SLAB AREA					0.12		1734.300	208.116	52.029	0.099	M25	1734.300	0.829
		TOTAL								440.1	61.263	0.210		3050.7	1.458
			GROSS FLOOR AREA (each floor)						523.260						
Ninth Storey to Twelvth Storey	VERTICAL MEMBERS	COLUMN	24	4	96	0.4	0.4	3.6	15.36	55.296	0.576	0.026	M35	110.592	0.053
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	4	16	0.3	0.5	30	144	72.000	4.5	0.034	M25	508.8	0.243
		TRANSVERSE BEAM	6	4	24	0.3	0.5	16.5	118.8	59.400	2.475	0.028	M25	419.76	0.201
		SECONDARY BEAM	5	4	20	0.25	0.4	15.3	76.500	30.600	1.53	0.015	M25	247.860	0.118
	TOTAL	Total Plan Area of column, beam & secondary beam							354.660						
		GROSS FLOOR AREA	1	4		17.1		30.6	2093.040						
		NET SLAB AREA					0.12		1738.380	208.606	52.151	0.100	M25	1738.380	0.831
		TOTAL								425.9	61.232	0.203		3025.4	1.445

APPENDIX C5: Concrete and Shuttering Quantities for 14 Storey Building at Zone V

14 STOREY ZONE V CONCRETE AND SHUTTERING QUANTITIES			No. of Member each floor	No of floors	Total no. of member	Breadth (b)	Depth (D)	L/H	Plan Area Calculation	Volume of Concrete	Volume of Concrete per member	Concrete/sqm	Grade of Concrete Mix	Shuttering	Shuttering/sqm
						M	M	M	Sqm	Cum	Cum			Sqm	
			GROSS FLOOR AREA (each floor)						525.648						
First Storey to Fifth Storey	VERTICAL MEMBERS	COLUMN	24	5	120	0.65	0.65	3.7	50.7	187.59	1.56325	0.071	M35	375.18	0.143
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	5	20	0.35	0.6	30	210	126.000	6.3	0.048	M25	786	0.299
		TRANSVERSE BEAM	6	5	30	0.35	0.6	16.5	173.25	103.950	3.465	0.040	M25	648.45	0.247
		SECONDARY BEAM	5	5	25	0.25	0.4	15.3	95.625	38.250	1.53	0.015	M25	309.825	0.118
	TOTAL	Total Plan Area of column, beam & secondary beam							529.575						
		GROSS FLOOR AREA	1	5		17.15		30.65	2628.238						
		NET SLAB AREA					0.12		2098.663	251.840	50.368	0.096	M25	2098.663	0.799
		TOTAL								707.6	63.226	0.269		4218.1	1.605
			GROSS FLOOR AREA (each floor)						525.648						
Sixth Storey to Ninth Storey	VERTICAL MEMBERS	COLUMN	24	4	96	0.5	0.5	3.6	24	86.4	0.9	0.041	M35	172.8	0.082
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	4	16	0.35	0.6	30	168	100.800	6.3	0.048	M25	628.8	0.299
		TRANSVERSE BEAM	6	4	24	0.35	0.6	16.5	138.6	83.160	3.465	0.040	M25	518.76	0.247
		SECONDARY BEAM	5	4	20	0.25	0.4	15.3	76.500	30.600	1.53	0.015	M25	247.860	0.118
	TOTAL	Total Plan Area of column, beam & secondary beam							407.100						
		GROSS FLOOR AREA	1	4		17.15		30.65	2102.590						
		NET SLAB AREA					0.12		1695.490	203.459	50.865	0.097	M25	1695.490	0.806
		TOTAL								504.4	63.060	0.240		3263.7	1.552
			GROSS FLOOR AREA (each floor)						525.648						
Tenth Storey to Fourteenth Storey	VERTICAL MEMBERS	COLUMN	24	5	120	0.45	0.45	3.6	24.3	87.48	0.729	0.033	M35	174.96	0.067
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	5	20	0.35	0.6	30	210	126.000	6.3	0.048	M25	786	0.299
		TRANSVERSE BEAM	6	5	30	0.35	0.6	16.5	173.25	103.950	3.465	0.040	M25	648.45	0.247
		SECONDARY BEAM	5	5	25	0.25	0.4	15.3	95.625	38.250	1.53	0.015	M25	309.825	0.118
	TOTAL	Total Plan Area of column, beam & secondary beam							503.175						
		GROSS FLOOR AREA	1	5		17.15		30.65	2628.238						
		NET SLAB AREA					0.12		2125.063	255.008	51.002	0.097	M25	2125.063	0.809
		TOTAL								610.7	63.026	0.232		4044.3	1.539

APPENDIX C6: Concrete and Shuttering Quantities for 14 Storey Building at Zone III

14 STOREY ZONE III CONCRETE AND SHUTTERING QUANTITIES			No. of Member each floor	No of floors	Total no. of member	Breadth (b)	Depth (D)	L/H	Plan Area Calculation	Volume of Concrete	Volume of Concrete per member	Concrete/sqm	Grade of Concrete Mix	Shuttering	Shuttering/sqm
						M	M	M	Sqm	Cum	Cum			Sqm	
			GROSS FLOOR AREA (each floor)						523.260						
First Storey to Fifth Storey	VERTICAL MEMBERS	COLUMN	24	5	120	0.6	0.6	3.7	43.2	159.84	1.332	0.061	M35	319.68	0.122
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	5	20	0.35	0.5	30	210	105.000	5.25	0.040	M25	666	0.255
		TRANSVERSE BEAM	6	5	30	0.35	0.5	16.5	173.25	86.625	2.8875	0.033	M25	549.45	0.210
		SECONDARY BEAM	5	5	25	0.25	0.4	15.3	95.625	38.250	1.53	0.015	M25	309.825	0.118
	TOTAL	Total Plan Area of column, beam & secondary beam							522.075						
		GROSS FLOOR AREA	1	5		17.1		30.6	2616.300						
		NET SLAB AREA					0.12		2094.225	251.307	50.261	0.096	M25	2094.225	0.800
		TOTAL								641.0	61.261	0.245		3939.2	1.506
			GROSS FLOOR AREA (each floor)						523.260						
Sixth Storey to Ninth Storey	VERTICAL MEMBERS	COLUMN	24	4	96	0.5	0.5	3.6	24	86.4	0.9	0.041	M35	172.8	0.083
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	4	16	0.35	0.5	30	168	84.000	5.25	0.040	M25	532.8	0.255
		TRANSVERSE BEAM	6	4	24	0.35	0.5	16.5	138.6	69.300	2.8875	0.033	M25	439.56	0.210
		SECONDARY BEAM	5	4	20	0.25	0.4	15.3	76.500	30.600	1.53	0.015	M25	247.860	0.118
	TOTAL	Total Plan Area of column, beam & secondary beam							407.100						
		GROSS FLOOR AREA	1	4		17.1		30.6	2093.040						
		NET SLAB AREA					0.12		1685.940	202.313	50.578	0.097	M25	1685.940	0.805
		TOTAL								472.6	61.146	0.226		3079.0	1.471
			GROSS FLOOR AREA (each floor)						523.260						
Tenth Storey to Fourteenth Storey	VERTICAL MEMBERS	COLUMN	24	5	120	0.4	0.4	3.6	19.2	69.12	0.576	0.026	M35	138.24	0.053
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	5	20	0.35	0.5	30	210	105.000	5.25	0.040	M25	666	0.255
		TRANSVERSE BEAM	6	5	30	0.35	0.5	16.5	173.25	86.625	2.8875	0.033	M25	549.45	0.210
		SECONDARY BEAM	5	5	25	0.25	0.4	15.3	95.625	38.250	1.53	0.015	M25	309.825	0.118
	TOTAL	Total Plan Area of column, beam & secondary beam							498.075						
		GROSS FLOOR AREA	1	5		17.1		30.6	2616.300						
		NET SLAB AREA					0.12		2118.225	254.187	50.837	0.097	M25	2118.225	0.810
		TOTAL								553.2	61.081	0.211		3781.7	1.445

APPENDIX C7: Concrete and Shuttering Quantities for 16 Storey Building at Zone V

16 STOREY ZONE V CONCRETE AND SHUTTERING QUANTITIES			No. of Member each floor	No of floors	Total no. of member	Breadth (b)	Depth (D)	L/H	Plan Area Calculation	Volume of Concrete	Volume of Concrete per member	Concrete/sqm	Grade of Concrete Mix	Shuttering	Shuttering/sqm
						M	M	M	Sqm	Cum	Cum			Sqm	
			GROSS FLOOR AREA (each floor)						525.648						
First Storey to Fifth Storey	VERTICAL MEMBERS	COLUMN	24	5	120	0.65	0.65	3.7	50.7	187.59	1.56325	0.071	M35	375.18	0.143
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	5	20	0.4	0.6	30	240	144.000	7.2	0.055	M25	816	0.310
		TRANSVERSE BEAM	6	5	30	0.4	0.6	16.5	198	118.800	3.96	0.045	M25	673.2	0.256
		SECONDARY BEAM	5	5	25	0.25	0.4	15.3	95.625	38.250	1.53	0.015	M25	309.825	0.118
	TOTAL	Total Plan Area of column, beam & secondary beam							584.325						
		GROSS FLOOR AREA	1	5		17.15		30.65	2628.238						
		NET SLAB AREA					0.12		2043.913	245.270	49.054	0.093	M25	2043.913	0.778
		TOTAL								733.9	63.307	0.279		4218.1	1.605
			GROSS FLOOR AREA (each floor)						525.648						
Sixth Storey to tenth Storey	VERTICAL MEMBERS	COLUMN	24	5	120	0.6	0.6	3.6	43.2	155.52	1.296	0.059	M35	311.04	0.118
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	5	20	0.4	0.6	30	240	144.000	7.2	0.055	M25	816	0.310
		TRANSVERSE BEAM	6	5	30	0.4	0.6	16.5	198	118.800	3.96	0.045	M25	673.2	0.256
		SECONDARY BEAM	5	5	25	0.25	0.4	15.3	95.625	38.250	1.53	0.015	M25	309.825	0.118
	TOTAL	Total Plan Area of column, beam & secondary beam							576.825						
		GROSS FLOOR AREA	1	5		17.15		30.65	2628.238						
		NET SLAB AREA					0.12		2051.413	246.170	49.234	0.094	M25	2051.413	0.781
		TOTAL								702.7	63.220	0.267		4161.5	1.583
			GROSS FLOOR AREA (each floor)						525.648						
Eleventh Storey to Sixteenth Storey	VERTICAL MEMBERS	COLUMN	24	6	144	0.5	0.5	3.6	36	129.6	0.9	0.041	M35	259.2	0.082
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	6	24	0.4	0.6	30	288	172.800	7.2	0.055	M25	979.2	0.310
		TRANSVERSE BEAM	6	6	36	0.4	0.6	16.5	237.6	142.560	3.96	0.045	M25	807.84	0.256
		SECONDARY BEAM	5	6	30	0.25	0.4	15.3	114.750	45.900	1.53	0.015	M25	371.790	0.118
	TOTAL	Total Plan Area of column, beam & secondary beam							676.350						
		GROSS FLOOR AREA	1	6		17.15		30.65	3153.885						
		NET SLAB AREA					0.12		2477.535	297.304	49.551	0.094	M25	2477.535	0.786
		TOTAL								788.2	63.141	0.250		4895.6	1.552

APPENDIX C8: Concrete and Shuttering Quantities for 16 Storey Building at Zone III

16 STOREY ZONE III CONCRETE AND SHUTTERING QUANTITIES			No. of Member each floor	No of floors	Total no. of member	Breadth (b)	Depth (D)	L/H	Plan Area Calculation	Volume of Concrete	Volume of Concrete per member	Concrete/sqm	Grade of Concrete Mix	Shuttering	Shuttering/sqm
						M	M	M	Sqm	Cum	Cum			Sqm	
			GROSS FLOOR AREA (each floor)						523.260						
First Storey to Fifth Storey	VERTICAL MEMBERS	COLUMN	24	5	120	0.6	0.6	3.7	43.2	159.84	1.332	0.061	M35	319.68	0.122
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	5	20	0.4	0.5	30	240	120.000	6	0.046	M25	696	0.266
		TRANSVERSE BEAM	6	5	30	0.4	0.5	16.5	198	99.000	3.3	0.038	M25	574.2	0.219
		SECONDARY BEAM	5	5	25	0.25	0.4	15.3	95.625	38.250	1.53	0.015	M25	309.825	0.118
	TOTAL	Total Plan Area of column, beam & secondary beam							576.825						
		GROSS FLOOR AREA	1	5		17.1		30.6	2616.300						
		NET SLAB AREA					0.12		2039.475	244.737	48.947	0.094	M25	2039.475	0.780
		TOTAL								661.8	61.109	0.253		3939.2	1.506
			GROSS FLOOR AREA (each floor)						523.260						
Sixth Storey to Tenth Storey	VERTICAL MEMBERS	COLUMN	24	5	120	0.5	0.5	3.6	30	108	0.9	0.041	M35	216	0.083
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	5	20	0.4	0.5	30	240	120.000	6	0.046	M25	696	0.266
		TRANSVERSE BEAM	6	5	30	0.4	0.5	16.5	198	99.000	3.3	0.038	M25	574.2	0.219
		SECONDARY BEAM	5	5	25	0.25	0.4	15.3	95.625	38.250	1.53	0.015	M25	309.825	0.118
	TOTAL	Total Plan Area of column, beam & secondary beam							563.625						
		GROSS FLOOR AREA	1	5		17.1		30.6	2616.300						
		NET SLAB AREA					0.12		2052.675	246.321	49.264	0.094	M25	2052.675	0.785
		TOTAL								611.6	60.994	0.234		3848.7	1.471
			GROSS FLOOR AREA (each floor)						523.260						
Eleventh Storey to Sixteenth Storey	VERTICAL MEMBERS	COLUMN	24	6	144	0.45	0.45	3.6	29.16	104.976	0.729	0.033	M35	209.952	0.067
	HORIZONTAL MEMBER	LONGITUDNAL BEAM	4	6	24	0.4	0.5	30	288	144.000	6	0.046	M25	835.2	0.266
		TRANSVERSE BEAM	6	6	36	0.4	0.5	16.5	237.6	118.800	3.3	0.038	M25	689.04	0.219
		SECONDARY BEAM	5	6	30	0.25	0.4	15.3	114.750	45.900	1.53	0.015	M25	371.790	0.118
	TOTAL	Total Plan Area of column, beam & secondary beam							669.510						
		GROSS FLOOR AREA	1	6		17.1		30.6	3139.560						
		NET SLAB AREA					0.12		2470.050	296.406	49.401	0.094	M25	2470.050	0.787
		TOTAL								710.1	60.960	0.226		4576.0	1.458