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A Study on Structural Optimization of Multistoried RCC Buildings

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***Abstract*—** In view of the vast growth in RCC construction, a research based on optimization of multistoried RCC buildings was carried out since so many years. Many projects come across financial constraints during their development stages. This project is emphasizing on the further development of optimization integrated with different techniques to judge the cost effectiveness of RCC structure. The present study focuses on analysis of (G+10) RCC space frame structure using various optimization methodologies. The analysis of space frame was done by Seismic Coefficient Method and Response Spectrum Method using ETABS Software. The project aims at finding a concrete solution on optimization techniques for economic analysis and design of RCC space frame with dual systems. (Moment resisting frames with shear walls or bracings.) In this project optimization was carried out on whole building frame not on an individual element. The fundamental optimization criterion chosen is the area of reinforcement per square feet. Analysis and design results are presented in the form of required area of reinforcement per square feet in (mm^2) in optimization techniques for overall structure. The result shows that, after application of different optimization methodologies, a significant saving in cost of material and there by the cost of construction can be done.

***Index Terms*— Special Moment Resisting Frame (SMRF), Diaphragm action, Fundamental time period, Base shear, Reinforcement, Masonry infill, Prismatic and Non-prismatic beam.**

I. INTRODUCTION

India is a developing country, huge construction projects are yet to come as undeveloped cities are needed to develop since so many years. In current century, many construction projects all over the world are going through financial crises because of high financial budgets. Time delay takes place which in turn affects the growth of the construction of huge projects. In order to avoid time delay and thereby the growth, economic construction methodology should be adopted. To economize the structure structural optimization techniques should be used. For large projects it is necessary to go for structural optimization because it directly affects cost of construction. Many Metropolitan cities are facing vast growth of infrastructure whether it may be in terms of horizontal development or vertical development. Metropolitan cities like Delhi and Mumbai have high population and in forth coming years land availability problems will increase tremendously which will in turn affect the overall growth of the city, so most of the builders in construction industries prefers vertical development of structures. As we increases number of stories or height of structure, huge lateral forces come into picture which will tend to increase the construction cost of the project in terms of consumption of steel, concrete and such other materials. Hence usually optimization techniques are adopted to economize the structure.

New and different approaches to design have become possible through the increased speed of computers and software tools of optimization theory. The optimization exercise commences right from the architectural concept stage. Suggested grid dimensions by architecture usually do not result into most economical structural member sizes and reinforcement consumption. In general optimization includes discretization of a whole structure into a series of sub frames with slab, beams, columns and footings. The main parameters involved in the investigation of this project are fundamental time period, base shear, and area of reinforcement and volume of concrete per square feet in (mm^2). These parameters are indirectly indicates the cost effectiveness of the individual technique and there by the structure.

II. PARAMETRIC INVESTIGATION

A structure is analyzed and designed using two methods Seismic Coefficient Method and Response Spectrum Method for seismic zone III with various ways of optimization. In general analysis and design results are presented in the form of required area of reinforcement per square feet in (mm^2) for optimization techniques for overall structure. After extensive analysis and design of structure, area of reinforcement per square feet is taken as a predominant parameter in order to identify the cost effectiveness and optimistic characteristics of structure and its behavior.

III. Objectives of Structural Optimization

3. To find out the most economical way of optimization.
4. To treat most economical way of optimization as a design tool for the practicing engineers in order to complete the project in stipulated time and less financial budget.

IV. PROBLEM FORMULATION

For huge multistoried projects quantity of steel and concrete is quite high. In this project different techniques are used so as to optimize the overall design cost of project. Table 3.1 represents methodologies of optimization used in project.

A multistoried RCC (G+10) moment resisting space frame is analyzed using software ETABS. The dimension of building is length 18m and width is 18m. This building is assumed to be located in zone III.

A building plan is selected by considering a grid of beams and columns. Beam grid includes main beam and secondary beams. The plan of the building is as shown in Figure 3.1.

V. INVESTIGATION METHODOLOGY

Investigation consists of analyzing (G+10) RCC space frame with various optimization methodologies. The optimization exercise began right from architectural concept stage as the previous grid dimensions not resulted into most economical structural member sizes and reinforcement consumption. The structural optimization includes variation of combinations of concrete grade, percentages of reinforcement, member sizes and thicknesses and composite materials. For example, when a model with second optimization technique was to be exercised, the previous ETABS model itself was edited as many times as the further combinations planned. Each time a variable parameter was changed, the ETABS model was run to compare the performance and the quantities with the other models i. e. analyzing 61 different buildings (Obviously with same architectural geometry) to decide the best combination of material properties, member sizes and reinforcement content to arrive at the most appropriate structural combination. The study identified the best system of optimization technique which results into a least cost for a particular structure.

VI. DESIGN PARAMETERS

7. Structural Steel - TOR Steel
8. Concrete - M-20, M-25, M-30
9. Seismic Zone - III
10. Importance Factor - 1.5
11. Response Reduction Factor - 5
12. Foundation - Hard Soil

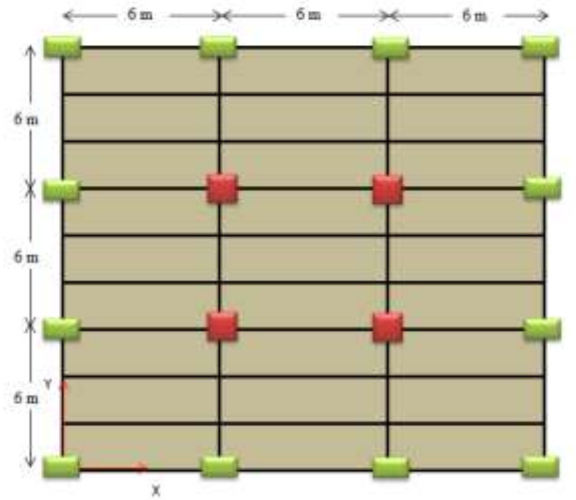


Figure 3.1: Plan of Building

TABLE 3.1 – Optimization Methodology

Sr. No.	Model	Description
1	Model I	Slab supported on secondary beam with varying spacing and direction.
2	Model II	Grade variation of materials for structural elements.
3	Model III	Optimization using types of RCC Flanged beams and variation in slab thickness.
4	Model IV	Optimization using dead load reduction.
5	Model V	Optimization using Diaphragm action.
6	Model VI	Size variation in columns and beams, floor wise column size reduction, column orientation.
7	Model VII	Placement of reinforcement along major and minor axis of column
8	Model VIII	Optimization using bare frame and infill frame.
9	Model IX	Optimization using Prismatic or Non Prismatic section of beam
10	Model X	Comparison of OMRF and SMRF for zone II
11	Model XI	Optimization using Shear wall and bracings.
12	Model XII	Optimization with different types of foundation

VII. RESULTS

Analysis and Design results are presented in the form of fundamental time period, base shear, area of reinforcement and volume of concrete required per square feet respectively for each model with different optimization techniques. After extensive analysis and design of structure to overcome the economic constraints between existing structure and analyzed structure, area of reinforcement and volume of concrete per square feet is taken as a predominant parameter in order to identify the cost effectiveness.

12.1 Model I) - Slab Supported On Secondary Beam with Varying Spacing and Direction

6.1.1 Optimization Using Slab Supported On Secondary Beam with Varying Spacing

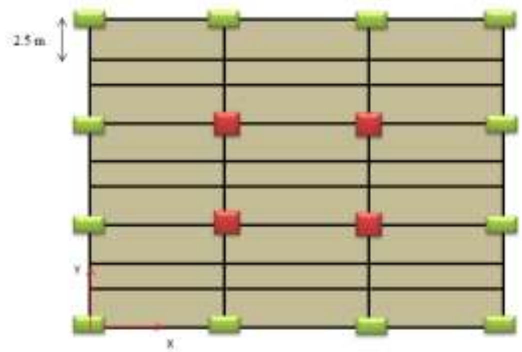


Figure 6.1: Models I - Slab with Main and Secondary Beam at Spacing 2.5 m

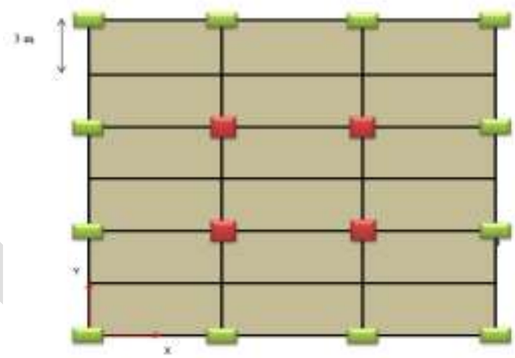


Figure 6.2: Models I - Slab with Main and Secondary Beam at Spacing 3m

Variation of Total Area of Reinforcement and Concrete according to different spacing of Secondary Beams by seismic coefficient method and response spectrum method is given in Table 6.1.1 and 6.1.2.

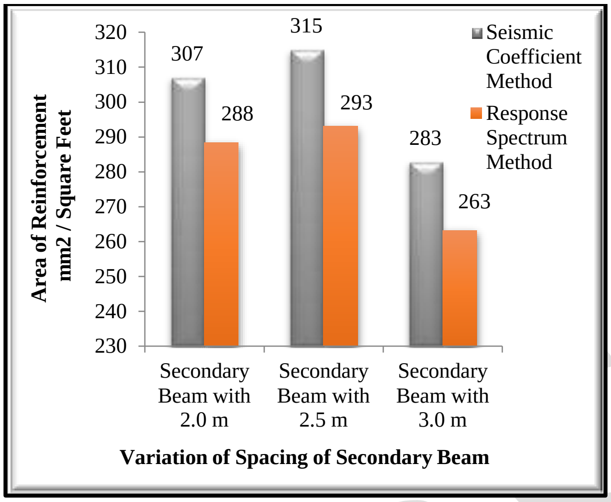
Table 6.1.1 -Values of Reinforcement and Concrete for Different Spacing of Secondary Beam by using Seismic Coefficient Method

Sr. No.	Slab with Secondary Beam With Varying Spacing	Seismic Coefficient Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	Model I A- Secondary beam at	307.2419	0.03
2	Model I B- Secondary beam at	315.2560	0.03
3	**Model I C- Secondary beam at**	**283.0518**	**0.027**

Table 6.1.2 -Values of Reinforcement and Concrete for Different Spacing of Secondary Beam by using Response Spectrum Method

Sr. No.	Slab with Secondary Beam With Varying Spacing	Response Spectrum Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	Model I A- Secondary beam at	288.3348	0.03
2	Model I B- Secondary beam at	293.1088	0.03
3	**Model I C- Secondary beam at**	**263.1375**	**0.027**

Variation of Total Area of Reinforcement according to different spacing of Secondary Beams by seismic coefficient method and response spectrum method is given in Graph 6.1.1.



Graph 6.1.1 Total Area of Reinforcement for Variation of Spacing of Secondary Beams

6.1.2 Optimization Using Slab Supported On Secondary Beam with Varying Directions

Variation of Total Area of Reinforcement and Concrete according to different model trials on directions of Secondary Beams by Seismic Coefficient Method and Response Spectrum Method is given in Table 6.1.3 and 6.1.4.

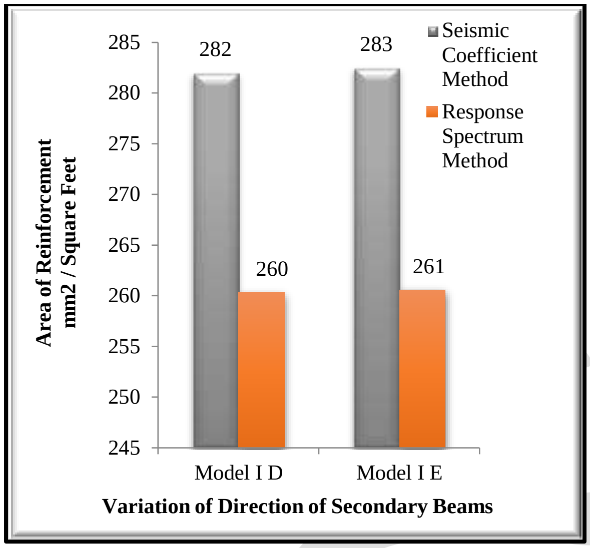
Variation of Total Area of Reinforcement according to different model trials on directions of Secondary Beams by seismic coefficient method and response spectrum method is given in Graph 6.1.2.

Table 6.1.3 - Values of Reinforcement and Concrete for secondary beams in different direction by using Seismic Coefficient Method

Sr. No.	Slab with Secondary Beam with Varying Direction	Seismic Coefficient Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	**Model I D**	**282.0206**	**0.027**
2	Model I E	282.5282	0.027

Table 6.1.4 - Values of Reinforcement and Concrete for secondary beams in different direction by using Response Spectrum Method

Sr. No.	Slab with Secondary Beam with Varying Direction	Response Spectrum Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	**Model I D**	**260.3515**	**0.027**
2	Model I E	260.5631	0.027



Graph 6.1.2: Total Area of Reinforcement for Variation of Direction of Secondary Beams

6.2 Model II - Optimization Using Grade Variation for Structural Elements

Variation of Total Area of Reinforcement and Concrete according to grade variation of materials is given in Table 6.2.1 and 6.2.2.

6.3 Model III - Optimization Using Types of RCC Flanged Beams and Variation in Slab Thickness

6.3.1 Optimization using Comparison of Flanged (T-Beam) and Rectangular Beam

Variation of Total Area of Reinforcement and Concrete according to different Types of Beams by Seismic Coefficient Method and Response Spectrum Method is given in Table 6.3.1 and 6.3.2.

Table 6.2.1 - **Values of Reinforcement and Concrete according to Variation in Grade of Concrete and Grade of Steel for Slab, Beam and Column by using Seismic Coefficient Method**

Sr. No.	Varying Grade of Concrete and Grade of Steel for Slab, Beam and Column	Seismic Coefficient Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	M20,Fe 415	282.0206	0.027
2	M20,Fe500	240.0274	0.027
3	M20,Fe550	221.3533	0.027
4	M25,Fe415	273.1808	0.027
5	M25,Fe500	232.9091	0.027
6	M25,Fe550	215.0062	0.027
7	Column M25, Slab-Beam M20, Fe415	268.6346	0.027

8	Column M25, Slab-Beam M20, Fe500	229.3612	0.027
9	Column M25, Slab-Beam M20, Fe550	211.7635	0.027
10	Column M30, Slab-Beam M25, Fe415	263.2562	0.027
11	Column M30, Slab-Beam M25, Fe500	225.0009	0.027
12	**Column M30, Slab-Beam M25, Fe550**	**207.9966**	**0.027**
13	Ground to 5th floor M25, Other floor M20, Fe415	271.4567	0.027
14	Ground to 5th floor M25, Other floor M20, Fe500	231.6006	0.027
15	Ground to 5th floor M25, Other floor M20,Fe550	213.7975	0.027
16	Ground to 5th floor M30, Other floor M25,Fe415	266.6656	0.027
17	Ground to 5th floor M30, Other floor M25,Fe500	227.6944	0.027
18	Ground to 5th floor M30, Other floor M25,Fe550	210.3828	0.027

Table 6.2.2 - Values of Reinforcement and Concrete according to Variation in Grade of Concrete and Grade of Steel for Slab, Beam and Column by using Response Spectrum Method

Sr. No.	**Varying Grade of Concrete and Grade of Steel for Slab, Beam and Column**	**Response Spectrum Method**	
		Area of Reinforcement per Square Feet (mm^2)	**Volume of concrete per Square feet (m^3)**
1	M20,Fe 415	260.3515	0.027
2	M20,Fe500	222.1495	0.027
3	M20,Fe550	205.1007	0.027

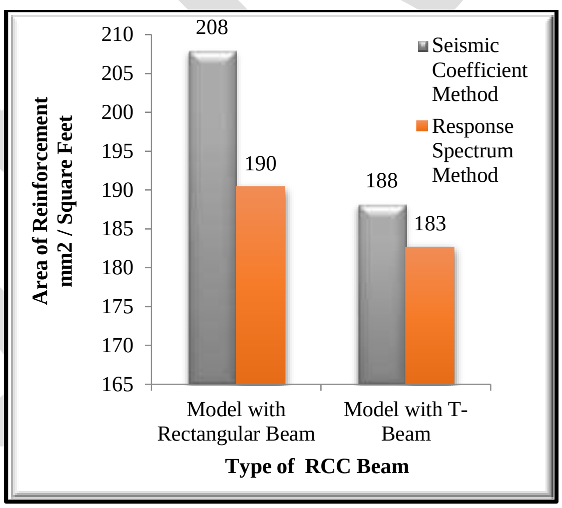
4	M25,Fe415	249.8384	0.027
5	M25,Fe500	213.5691	0.027
6	M25,Fe550	197.424	0.027
7	Column M25, Slab-Beam M20, Fe415	246.9655	0.027
8	Column M25, Slab-Beam M20, Fe500	211.4832	0.027
9	Column M25, Slab-Beam M20, Fe550	195.5109	0.027
10	Column M30, Slab-Beam M25, Fe415	239.9138	0.027
11	Column M30, Slab-Beam M25, Fe500	205.6609	0.027
12	**Column M30, Slab-Beam M25, Fe550**	**190.5009**	**0.027**
13	Ground to 5th floor M25, Other floor M20, Fe415	248.8155	0.027
14	Ground to 5th floor M25, Other floor M20, Fe500	212.8667	0.027
15	Ground to 5th floor M25, Other floor M20,Fe550	196.7669	0.027
16	Ground to 5th floor M30, Other floor M25,Fe415	242.6534	0.027
17	Ground to 5th floor M30, Other floor M25,Fe500	207.7657	0.027
18	Ground to 5th floor M30, Other floor M25,Fe550	192.2659	0.027

Table 6.3.1 - Values of Reinforcement and Concrete according to Types of RCC beams by using Seismic Coefficient Method

Sr. No.	Types of RCC beams	Seismic Coefficient Method	
		Area of Reinforcement per Square Feet (mm^2)	**Volume of concrete per Square feet (m^3)**
1	Rectangular Beam	207.9966	0.027
2	**T-Beam**	**188.2146**	**0.027**

Table 6.3.2 - Values of Reinforcement and Concrete according to Types of RCC beams by using Response Spectrum Method

Sr. No.	Types of RCC beams	Response Spectrum Method	
		Area of Reinforcement per Square Feet (mm^2)	**Volume of concrete per Square feet (m^3)**
1	Rectangular Beam	207.9966	0.027
2	**T-Beam**	**188.2146**	**0.027**



Graph 6.3.1: Total Area of Reinforcement for Types of RCC Beams

6.3.2 Optimization with Variation in Slab Thickness

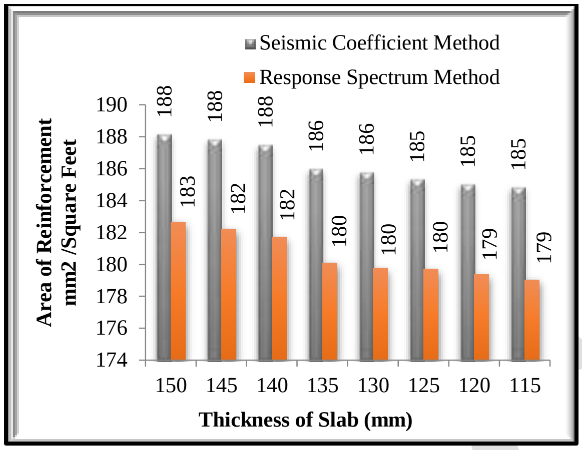
Variation of Total Area of Reinforcement and Concrete according to variation in thickness of slab for T-beam by Seismic Coefficient Method and Response Spectrum Method is given in Table 6.3.3 and 6.3.4.

Table 6.3.3 - Values of reinforcement and Concrete for models with variation in Thickness of Slab by using Seismic Coefficient Method

Sr. No.	Thickness of Slab (mm)	Seismic Coefficient Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	150	188.2146	0.0270
2	145	187.8917	0.0267
3	140	187.5533	0.0263
4	135	186.0463	0.0258
5	130	185.8274	0.0253
6	125	185.3835	0.0249
7	120	185.0810	0.0244
8	**115**	**184.8992**	**0.0239**

Table 6.3.4 - Values of reinforcement and Concrete for models with variation in Thickness of Slab by using Response Spectrum Method

Sr. No.	Thickness of Slab (mm)	Response Spectrum Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	150	182.6575	0.0270
2	145	182.2368	0.0267
3	140	181.7361	0.0263
4	135	180.0792	0.0258
5	130	179.7687	0.0253
6	125	179.7068	0.0249
7	120	179.3686	0.0244
8	**115**	**179.0429**	**0.0239**



Graph 6.3.2: Total Area of Reinforcement for Variation in Thickness of Slab

6.4 Model IV- Optimization using Dead Load Reduction

Variation of Total Area of Reinforcement and Concrete according to Models with different types of bricks (i.e. Conventional Bricks and Siforex Bricks) by Seismic Coefficient Method and Response Spectrum Method is given in Table 6.4 and 6.5.

Table 6.4 - Values of Reinforcement and Concrete for Model with Reduction in Dead Load of Structure by using Seismic Coefficient Method

Sr. No.	**Types of Models**	**Seismic Coefficient Method**	
		Area of Reinforcement per Square Feet (mm^2)	**Volume of concrete per Square feet (m^3)**
1	Model with Conventional Bricks (20 kN/m^3)	184.8992	0.0239
2	**Model with Siforex Bricks (6.5 kN/m^3)**	**183.4485**	**0.0239**

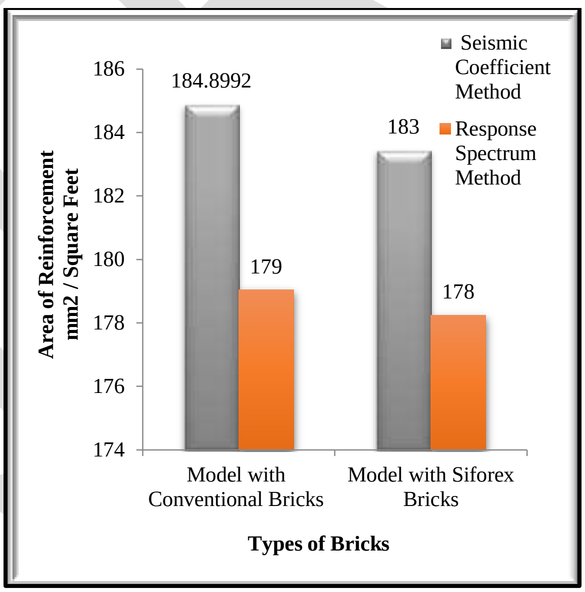
Table 6.5 - **Values of Reinforcement and Concrete for Model with Reduction in Dead Load of Structure by using Response Spectrum Method**

Sr. No.	Types of Models	Response Spectrum Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	Model with Conventional Bricks (20 kN/m^3)	179.0429	0.0239
2	**Model with Siforex Bricks (6.5 kN/m^3)**	**178.2432**	**0.0239**

Variation of Total Area of Reinforcement according to Models with different types of bricks (i.e. Conventional Bricks and Siforex Bricks) by seismic coefficient method and response spectrum method is given in Graph 6.4.

6.5 Model V- Optimization by Varying Diaphragm Action

Variation of Total Area of Reinforcement and Concrete according to different types of diaphragm action by Seismic Coefficient Method and Response Spectrum Method is given in Table 6.6 and 6.7.



Graph 6.4: Total Area of Reinforcement for Models with Material Density Variation

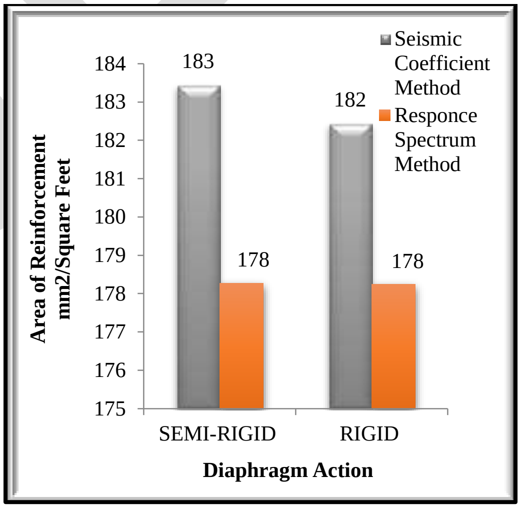
Table 6.5 - Values of Reinforcement and Concrete by Varying Diaphragm Action by using Seismic Coefficient Method

Sr. No.	Diaphragm Action	Seismic Coefficient Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	Semi-Rigid Diaphragm Action	183.4487	0.0239
2	**Rigid Diaphragm Action**	**182.4485**	**0.0239**

Table 6.6 - Values of Reinforcement and Concrete by Varying Diaphragm Action by using Response Spectrum Method

Sr. No.	Diaphragm Action	Response Spectrum Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	Semi-Rigid Diaphragm Action	178.2740	0.0239
2	**Rigid Diaphragm Action**	**178.2432**	**0.0239**

Variation of Total Area of Reinforcement according to different action of diaphragm by seismic coefficient method and response spectrum method is given in Graph 6.5.



Graph 6.5: Total Area of Reinforcement for Diaphragm Action

6.6 Model VI- Optimization Using Size Variation in Columns and Beams, Floor Wise Column Size Reduction, Column Orientation

6.6.1 Size Variation in Columns and Beams

Variation of Total Area of Reinforcement and Concrete according to trial variation in sizes of column and beam for a model by Seismic Coefficient Method and Response Spectrum Method is given in Table 6.6.1 and 6.6.2.

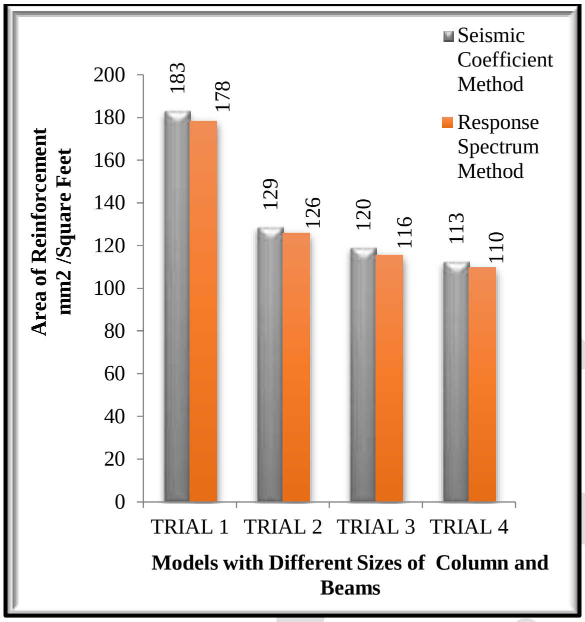
Table 6.6.1 - Values of Reinforcement and Concrete for Model with Varying Sizes of Column and Beam by using Seismic Coefficient Method

Sr. No.	Trials with Different Sizes of Column And Beam	Seismic Coefficient Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	Trial 1	183.4485	0.0239
2	Trial 2	129.1039	0.0200
3	Trial 3	119.5210	0.0186
4	**Trial 4**	**112.9934**	**0.0171**

Table 6.6.2 -Values of Reinforcement and Concrete for Model with Varying Sizes of Column and Beam by using Response Spectrum Method

Sr. No.	Trials with Different Sizes of Column And Beam	Response Spectrum Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	Trial 1	178.2679	0.0239
2	Trial 2	126.0028	0.0200
3	Trial 3	115.5769	0.0186
4	**Trial 4**	**109.7776**	**0.0171**

Variation of Total Area of Reinforcement according to Models with variation in sizes of columns and beams by seismic coefficient method and response spectrum method is given in Graph 6.6.1.



Graph 6.6.1: Total Area of Reinforcement for Variation

in Sizes of Column and Beams

6.6.2 Floor Wise Reduction in Column Sizes

Variation of Total Area of Reinforcement and Concrete for models with and without floor wise column size reductions by Seismic Coefficient Method and Response Spectrum Method is given in Table 6.6.3 and 6.6.4.

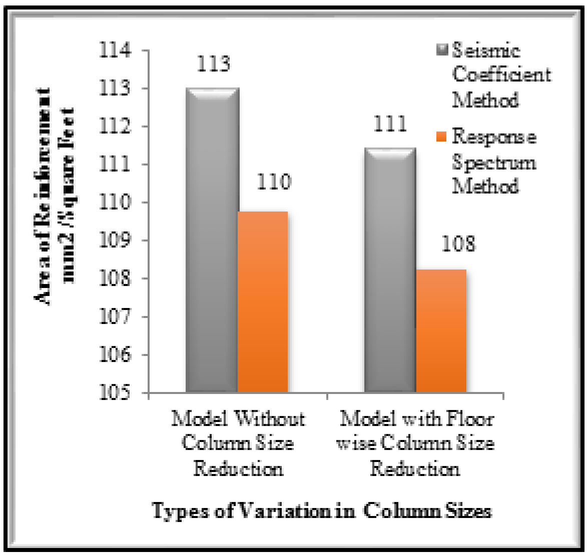
Table 6.6.3 - Values of Reinforcement and Concrete for Models with and without Column Size Reductions by using Seismic Coefficient Method

Sr. No.	Reduction in Column	Seismic Coefficient Method	
		Area of Reinforcement per Square Feet (mm^2)	**Volume of concrete per Square feet (m^3)**
1	Without floor wise Column Size Reduction	112.9935	0.0171
2	**With Floor wise Column Size Reduction**	**111.4205**	**0.0167**

Table 6.6.4 - Values of Reinforcement and Concrete for Models with and without Column Size Reductions by using Response Spectrum Method

Sr. No.	Reduction in Column	Response Spectrum Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	Without floor wise Column Size Reduction	109.7776	0.0171
2	**With Floor wise Column Size Reduction**	**108.257**	**0.0167**

Variation of Total Area of reinforcement for models with and without floor wise column size reduction by seismic coefficient method and response spectrum method is given in Graph 6.6.2.



Graph 6.6.2: Total Area of Reinforcement for Models

with variation in sizes of columns

6.6.3 Orientation of Columns

Variation of Total Area of Reinforcement according to models with orientation of Square Column and Rectangular Column in different directions by seismic coefficient method and response spectrum method is given in Table 6.6.5 and 6.6.6.

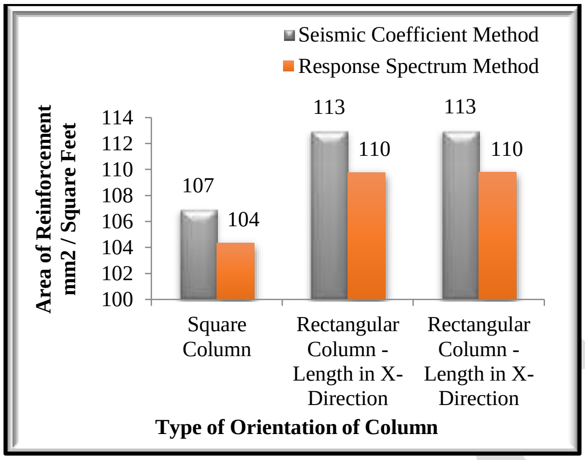
Table 6.6.5 - Values of Reinforcement and Concrete for Models with Orientation for Types of Column by using Seismic Coefficient Method

Sr. No.	Reduction in Column	Seismic Coefficient Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	**Square Column**	**106.9607**	**0.0179**
2	Rectangular Column Along X-Direction	112.9935	0.0170
3	Rectangular Column Along Y-Direction	113.0199	0.0170

Table 6.6.6 - Values of Reinforcement and Concrete for Models with Orientation for Types of Column by using Response Spectrum Method

Sr. No.	Reduction in Column	Response Spectrum Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	**Square Column**	**104.3412**	**0.0179**
2	Rectangular Column Along X-Direction	109.7776	0.0170
3	Rectangular Column Along Y-Direction	109.7834	0.0170

Variation of Total Area of Reinforcement according to models with orientation of Square Column and Rectangular Column in different directions by seismic coefficient method and response spectrum method is given in Graph 6.6.3.



Graph 6.6.3: Total Area of Reinforcement for Models

with Types of Orientation of Columns

6.7 Model VII- Placement of Reinforcement along Major and Minor Axis of Column

Variation of Total Area of Reinforcement and Concrete according to model with trial percentage of reinforcement by Seismic Coefficient Method and Response Spectrum Method is given in Table 6.7.1 and 6.7.2.

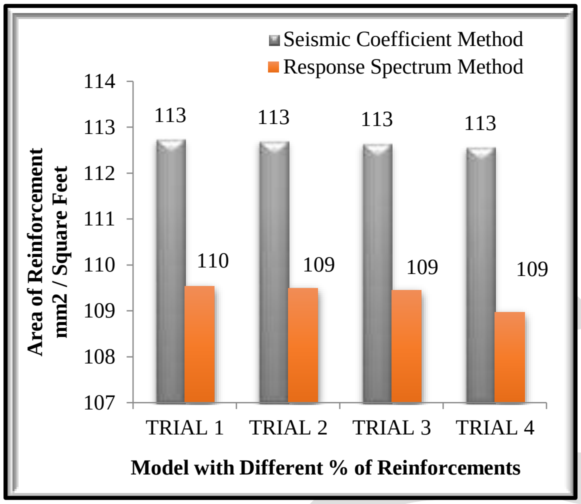
Table 6.7.1 - **Values of Reinforcement and Concrete by Varying Percentage of Reinforcement by using Seismic Coefficient Method**

Sr. No.	Percentage of Reinforcement	Seismic Coefficient Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	TRIAL 1	112.7525	0.0170
2	TRIAL 2	112.7148	0.0170
3	**TRIAL 3**	**112.6626**	**0.0170**
4	TRIAL 4	112.5769	0.0170

Table 6.7.2 - **Values of Reinforcement and Concrete by Varying Percentage of Reinforcement by using Response Spectrum Method**

Sr. No.	Percentage of Reinforcement	Response Spectrum Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	TRIAL 1	109.5367	0.0170
2	TRIAL 2	109.4989	0.0170
3	**TRIAL 3**	**109.4468**	**0.0170**
4	TRIAL 4	108.9687	0.0170

Variation of Total Area of Reinforcement according to according to model with trial percentage of reinforcement by seismic coefficient method and response spectrum method is given in Graph 6.7.



Graph 6.7: Total Area of Reinforcement for Models

with Trial Percentage of Reinforcement

6.8 Model VIII - Optimization using Bare Frame and infill frame

Variation of Total Area of Reinforcement and Concrete according to models equipped with bare frame and infill frame by Seismic Coefficient Method and Response Spectrum Method is given in Table 6.8.1 and 6.8.2.

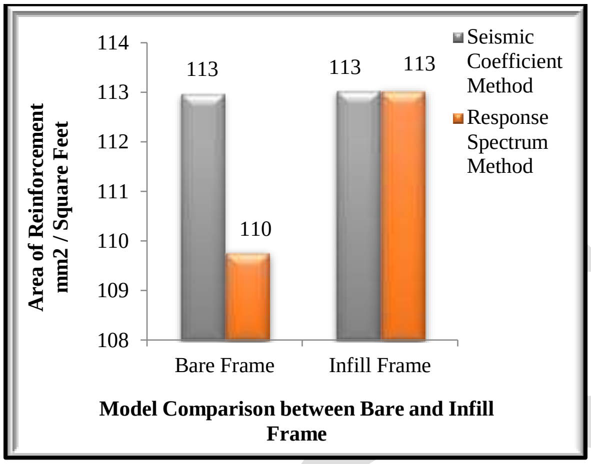
Table 6.8.1 - Values of Reinforcement and Concrete for models with bare and infill frame by using Seismic Coefficient Method

Sr. No.	**Comparison Between Frames**	**Seismic Coefficient Method**	
		Area of Reinforcement per Square Feet (mm^2)	**Volume of concrete per Square feet (m^3)**
1	**Bare Frame**	**112.9935**	**0.0170**
2	Infill Frame	113.0418	0.0170

Table 6.8.2 - Values of Reinforcement and Concrete for models with bare and infill frame by using Response Spectrum Method

Sr. No.	**Comparison Between Frames**	**Response Spectrum Method**	
		Area of Reinforcement per Square Feet (mm^2)	**Volume of concrete per Square feet (m^3)**
1	**Bare Frame**	**109.7776**	**0.0170**
2	Infill Frame	113.0373	0.0170

Variation of Total Area of Reinforcement according to models equipped with bare frame and infill frame by seismic coefficient method and response spectrum method is given in Graph 6.8.



Graph 6.8: Total Area of Reinforcement for Models with Types of Frames

6.9 Model IX -Optimization Using Prismatic or Non-Prismatic Section of Beam

Variation of Total Area of Reinforcement and Concrete according to models with Prismatic and Non-Prismatic Sections of beams by Seismic Coefficient Method and Response Spectrum Method is given in Table 6.9.1 and 6.9.2.

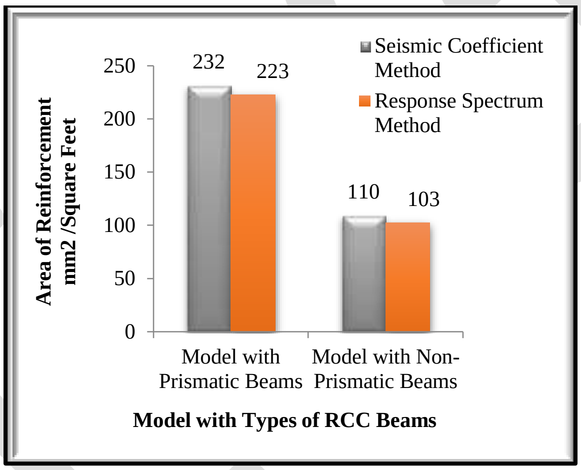
Table 6.9.1 - Values of Reinforcement and Concrete for Prismatic or Non Prismatic Section of Beam by using Seismic Coefficient Method

Sr. No.	Types of Beams	Seismic Coefficient Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	Model with Prismatic Beams	231.6930	0.0170
2	**Model with Non-Prismatic Beams**	**109.5946**	**0.0165**

Table 6.9.2 - Values of Reinforcement and Concrete for Prismatic or Non Prismatic Section of Beam by using Response Spectrum Method

Sr. No.	Types of Beams	Response Spectrum Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	Model with Prismatic Beams	222.8167	0.0170
2	**Model with Non-Prismatic Beams**	**102.5464**	**0.0165**

Variation of Total Area of Reinforcement according to models with Prismatic and Non-Prismatic Sections of beams by seismic coefficient method and response spectrum method is given in Graph 6.9.



Graph 6.9: Total Area of Reinforcement for Model with Types of RCC Beams

6.10 Model X - Optimization of model using OMRF and SMRF for ZONE II

Variation of Total Area of Reinforcement and Concrete according to OMRF and SMRF model equipped with bare and infill frame by Seismic Coefficient Method and Response Spectrum Method is given in Table 6.10.1 (a) and 6.10.1 (b).

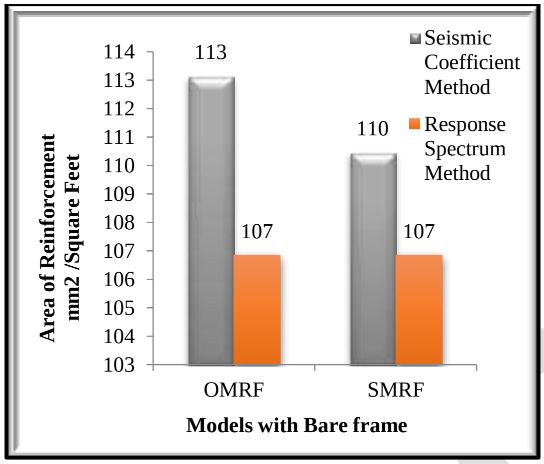
Table 6.10.1 (a) - Value of reinforcement and Concrete for Models with OMRF and SMRF for Zone II by using Seismic Coefficient Method

Sr. No.	Comparison for Zone II	Seismic Coefficient Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	OMRF Bare Frame	113.1553	0.0170
	OMRF Infill Frame	113.4021	0.0170
2	**SMRF Bare Frame**	**110.4729**	**0.0170**
	SMRF Infill Frame	**111.2229**	**0.0170**

Table 6.10.1 (b) - Value of reinforcement and Concrete for Models with OMRF and SMRF for Zone II by using Response Spectrum Method

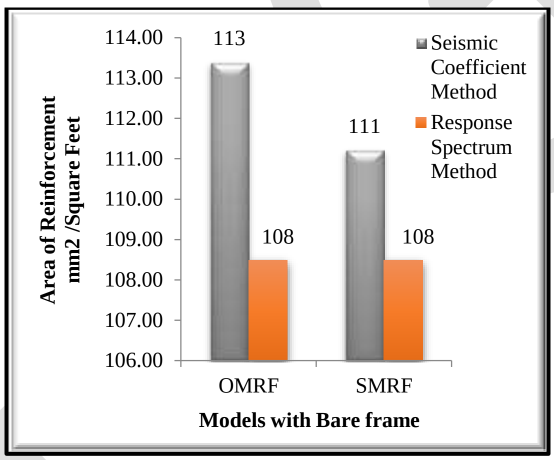
Sr. No.	Comparison for Zone II	Response Spectrum Method	
		Area of Reinforcement per Square Feet (mm^2)	Volume of concrete per Square feet (m^3)
1	OMRF Bare Frame	106.8612	0.0170
	OMRF Infill Frame	108.4888	0.0170
2	**SMRF Bare Frame**	**106.8612**	**0.0170**
	SMRF Infill Frame	**108.4888**	**0.0170**

Variation of Total Area of Reinforcement according to model equipped with bare frame by seismic coefficient method and response spectrum method is given in Graph 6.10 (a).



Graph 6.10 (a): Total Area of Reinforcement for Models with Bare Frame

Variation of Total Area of Reinforcement according to model equipped with infill frame by seismic coefficient method and response spectrum method is given in Graph 6.10 (b).



Graph 6.10 (b): Total Area of Reinforcement for Models with Infill Frame

6.11 Model XI- Optimization using Shear wall or Different Types of Bracings

Variation of Total Area of Reinforcement according to shear wall with types of frames by seismic coefficient method and response spectrum method is given in Graph 6.11 (a).

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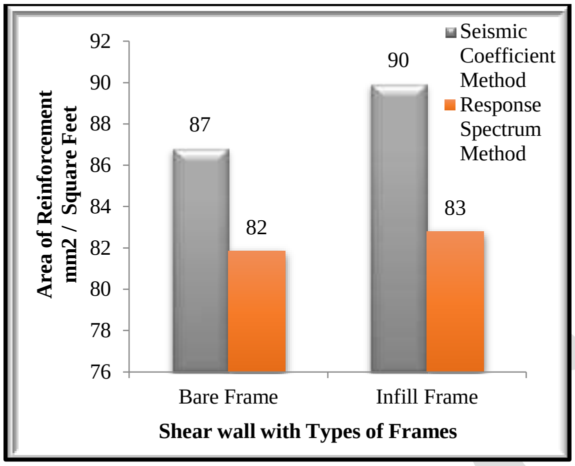
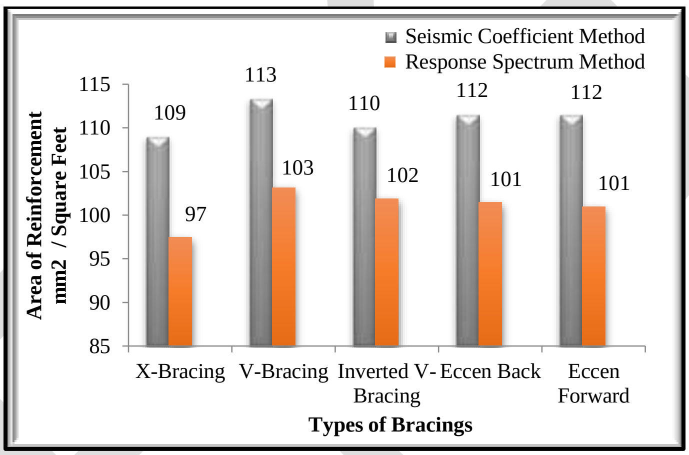


Graph 6.11(a): Total Area of Reinforcement for Shear wall with Types of Frames

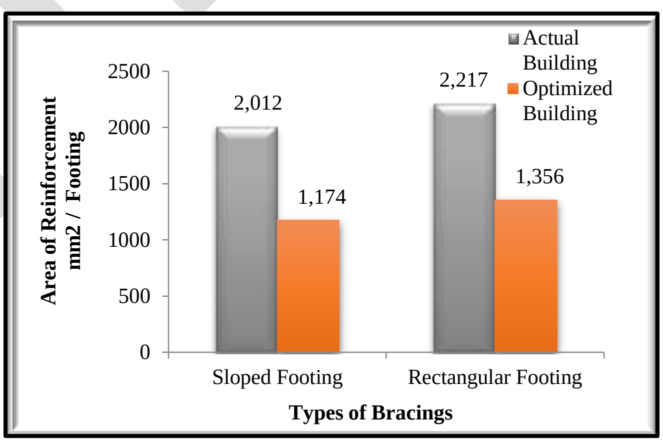
Variation of Total Area of Reinforcement according to types of bracing by seismic coefficient method and response spectrum method is given in Graph 6.11 (b).



Graph 6.11 (b): Total Area of Reinforcement for Types of Bracings

6.12 Model XII - Optimization by trial of different types of foundation

Variation of Total Area of Reinforcement according to types of foundation is given in Graph 6.12.



Graph 6.12: Total Area of Reinforcement for Types of Bracings

VIII. CASE STUDY

An existing (G+2) college main building of Nagesh Karajagi Orchid college of Engineering and Technology located in district Sholapur (Maharashtra) has been taken as case study for this project. This college main building is located in zone III having hard soil strata. An available data have been used in the case study. Analysis and design of existing building have been done in software ETABS. After this extensive analysis procedure, calculated quantity of steel was matched with the available amount of steel. For existing building two methods i.e. seismic coefficient method and Response spectrum method are used in order to obtain the values of base shear, area of reinforcement etc. Now in further step, various optimization techniques are adopted on college main building to reduce the overall cost of building. The value of area of reinforcement for actual building obtained by seismic coefficient method was to be 356.69 mm^2 per square feet and by response spectrum method it is 333.60 mm^2 per square feet. In further trials various optimization techniques have been applied in order to study the optimistic characteristics of this existing model.

A sample plan and 3D elevation of college main building have been shown in Figure 7.1 and Figure 7.2.

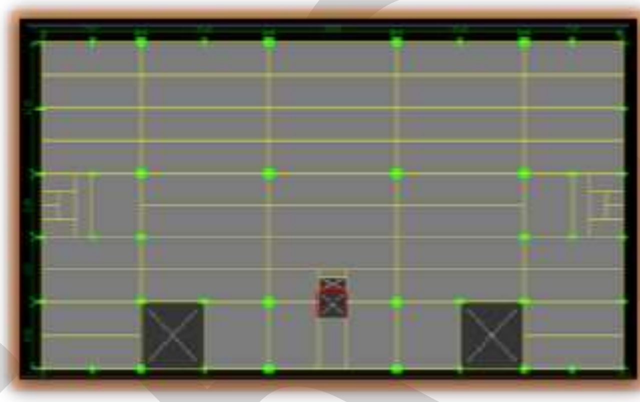


Figure 7.1: Plan of College Main Building

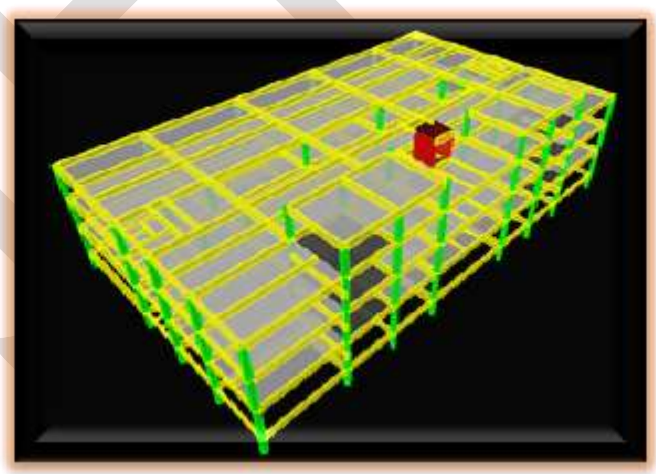
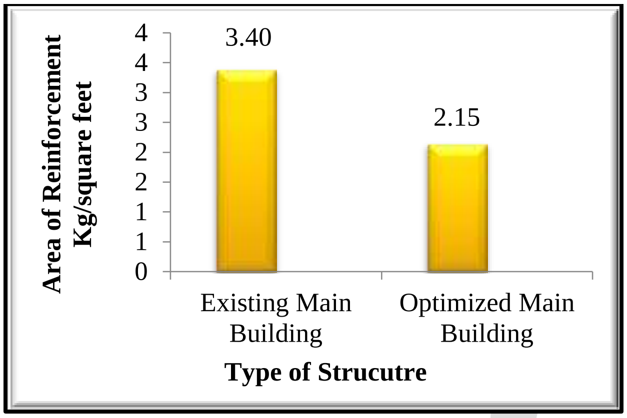


Figure 7.2: 3D Elevation of College Main Building

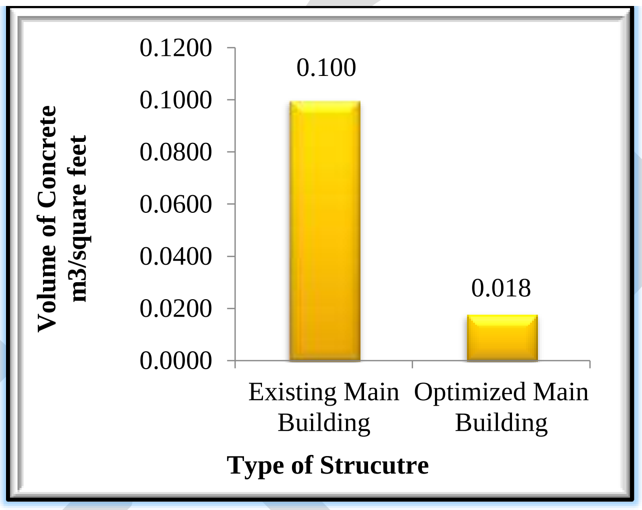
7.1 COMPARISON OF EXISTING STRUCTURE AND OPTIMIZED STRUCTURE

After extensive analysis of structures with all techniques comparison of parameters like area of reinforcement and volume of concrete required per square feet has been presented in Graph 7.1(a).



Graph7.1 (a): Area of Reinforcement for Existing Office Building

Variation of volume of concrete according type of structure is as shown in Graph7.1 (b).



Graph7.1 (b): Volume of Concrete for Types of Structure

VIII. CONCLUSIONS

10. For moderate span structure, if higher grade of concrete is used for column than slab-beam with grade of steel Fe-550 then the structure is economical.
11. When T-Beam action is considered and there is gradual decrease in slab thickness, stiffness and also rigidity is reduced, then
    e) Time period increases,
    f) Base shear decreases,
    g) Required area of reinforcement reduces and,
    h) Volume of concrete also reduces.
12. Use of Siforex bricks reduces dead weight of structure which helps in reducing seismic forces. Hence model with Siforex bricks is most the optimum solution as compared with conventional bricks.
13. When optimization is done by varying diaphragm action, rigid diaphragm action properly transfers forces to vertical system as a result of which, area of reinforcement required is less when compared with semi-rigid diaphragm action.
14. Due to variation in sizes of column and beams, floor wise reduction in sizes of column and different orientation of columns, the stiffness of structure gets reduced as a result time period increases, base shear reduces which affects the percentage of reinforcement.
15. It is observed that when structural models have been prepared by varying placement of reinforcement along with major and minor axis of column as mentioned in trials, the percentage of reinforcement gets reduced and structure gets optimized.

16. Model with Non-prismatic section of beams for larger span is a best solution as structures with prismatic sections of beams is not economical due to large cross sectional area of beams. Provision of Non-prismatic section in beams proves that
    d) Cross sectional area reduced so that stiffness of structure gets reduced and time period increases.
    e) Shear force and bending moment reduces at centre of span.
    f) Base shear decreases as a result of which, required area of reinforcement gets reduced.
17. According to IS 1893:2002 (Part-I) for buildings located in seismic zone II, buildings should be designed with Ordinary Moment Resisting Frame (OMRF). However study shows that Special Moment Resisting Frames (SMRF) is more economical even for seismic zone II.
18. After the analysis of models with different types of bracings, it has been concluded that a performance of cross bracing system (X-bracing) is better than the other specified bracing systems. The building frames with X-bracing system will have minimum possible bending moments in comparison to other type of bracing system. When X-Bracings is compared with shear wall, the model with shear wall is better and optimal one.

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