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Analysis and Design of Building and Cost Optimization with Different Floor System

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Abstract - Earthquakes play an important part in the analysis and designing of structures. The analysis is a technique for determining the ways of a structure under various load combination. Design is the way of achieving convenient description for a structure. It takes a long time to manually plan and analyze a structure. The analysis and construction of structure can be done easily with the use of software. This project aims to analyze and design a building with different floor systems and cost comparison of floor systems. viz., Flat slab with drop panels, Flat slab, Conventional slab, Grid slab, and ribbed slab. The effects of seismic forces on buildings with different slab structures were investigated by using ETABS tools. ETABS stands for Extended Three-Dimensional Analysis of Building System. IS 456-2000 is used for design and analysis. Fe-500 steel and M40 grade of concrete were used. Load combinations are taken as per IS 1893-part 1 (2016). Live loads are taken according to IS 875 (part 1). Earthquake zone 2 has been adopted for analysis. Axis force, shear force, bending moment, storey drift, base shear, Storey shear, and storey displacement all affect the structure's output when it comes to seismic loads. After the design of these mentioned five cases, a comparative study concerning the economy is carried out. The results are presented using tables and bar charts

***Key Words*:** storey displacement, drop panel, grid slab, ribbed slab, axis force, base shear, bending moment. storey drift

1. INTRODUCTION

In this present developing industrial period, we can see the vast construction activities taking place all over the world-wide. The human being needs a better lifestyle the essential requirement of a human is shelter [1]. Due to the rise in population development of high-rise buildings and structures is a necessity [2]. Hence land space will be insufficient. So, the construction of high-rise structures is the solution to overcome this problem there are several modification techniques used to make work faster and economical [3]. In the past few years, many high-rise building structures have been constructed and many more are being planned in the world [4]. Construction of high-rise buildings requires a long period but now day skilled manpower and modern techniques are used to construct tall buildings and structures [5]. So a load of a high-rise building is an important factor that should be keeping in mind while constructing the building and structures. The load on various elements of structures such as columns, beams, walls, and slabs is reduced which decreases the load on the structure. Like other components floor (slab) is a very important structural element [6].

1.1 FLOOR SYSTEM

A floor system (slab) is a planar structural element and is used to provide a flat surface (floors/ceilings) in buildings. Based on reinforcement provided, beam support, and the ratio of the spans. Slabs are a quite common and important structural element, its horizontal structure component [7]. There are myriad types of a slab which are used in the construction of high-rise building. For instance

1.1.1 Conventional slab

In conventional structures slab is resting on the beams, forces are transferred from slab to beams, and then beams to columns. Conventional slabs are generally rectangular, but they also take place in any irregular shape such as triangular, circular, trapezoidal, etc. [8].

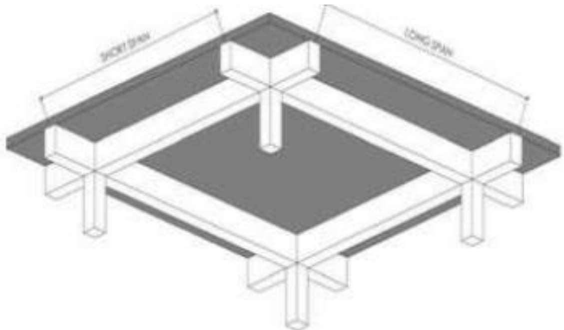

Fig -1.1: Conventional Slab System

1.1.2 Flat slab

A flat slab is a reinforced concrete slab supported directly on columns without the use of a beam. The load from the slab is directly transmitted to the columns and then to the foundation. In building construction, Flat slabs have been generally used due to their advantages in reducing story height and construction period. In this type of construction, a plain ceiling is obtained thus giving an attractive appearance from the architectural point of view [9].

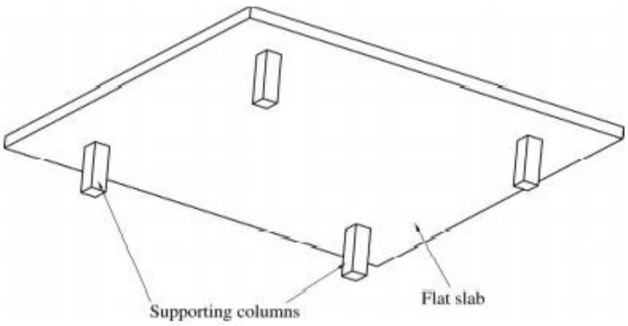

Fig -1.2: Flat Slab System

1.1.3 Grid slab

A grid slab is a kind of floor system consisting of beams placed at equal intervals forming oblong or square or rhombus-shaped grids connected monolithically with the slab to form a large column-free space. The sizes of all the beams in the grid slab are kept an equivalent. The area in the slab within the beams helps in providing architectural lighting and air conditioning for the area covered by the grid floor. Also, it improves the aesthetics of the structure. This type of construction is commonly used in concrete, wood, and metal construction [9].

Fig -1.3: Grid Slab System

1.1.4 Ribbed Slab

Ribbed floors consisting of equally spaced ribs are usually supported directly by columns. A ribbed slab also called a waffle slab is a two-way joist or coffered slab, essentially consisting of thin top slab acting compositely with a closely spaced orthogonal grid of beam ribs. A rib thickness of greater than 125 mm is typically required to accommodate tensile and shear reinforcement. Ribbed slabs are suitable for medium to heavy loads, can span reasonable distances are very stiff, and particularly suitable where the soffit is exposed [10].

Fig -1.4: Ribbed Slab System

2. Methodology and Building Analysis

A RCC medium rise building of G+15 stories with floor height 3m subjected to earthquake loading in Zone II has been considered. In order to study, the comparison of conventional slab, flat slab and grid slab, ribbed slab structural system. Analysis & design the structural system to check the behavior of the structure after acting the load. In the structure dead and live load are applied, the structure showing various behaviors. The structure is analyzed & design in the software. Selection and design of the building frames as per the design code procedure. The design frame modeled for analysis using ETABS software. It is necessary to develop a computation model to perform any kind of analysis. The parameters defining the building model, the basic assumptions and the geometry of the selected building for the study discuss.

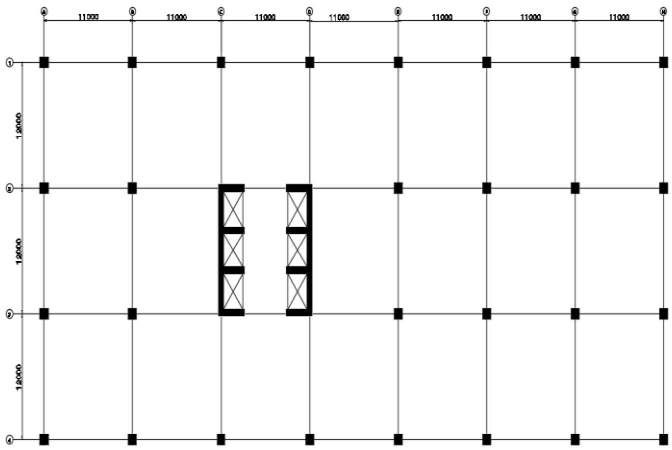

Fig -2.1: Plan of a building

2.1 Building Analysis

The plan of the building as shown in Fig.1 has been considered to carry out the study. Axial forces, shear force, bending moment shear have been calculated for three different columns (C1, C2, and C3) as shown in fig 4.2. to find out the effect in the building. The constraints are drawn and seen in the following fig.4.1 after evaluating all five cases structures in the ETABS. 1.2(DL + LL + EQX) and 1.2(DL + LL + EQY) is preferred from all the load combination considered. The structural configuration and dimension of the building structure are 77m x 36m. In these cases the earthquake force is predominant hence the structure is analyses for the seismic loading only. RCC building has been studied with the help of five different cases.

Case1- Flat Slab
Case2- Flat Slab with Drop
Case3- Conventional Slab
Case4- Grid Slab
Case5- Ribbed Slab

SPECIFICATION	DIFFERENT TYPES OF SLAB SYSTEM				
	Flat slab	Flat slab with drop	Conventional slab	Grid slab	Ribbed slab
Plan dimension	77X36 m	77X36 m	77X36 m	77X36 m	77X36 m
Floor to floor height	3.5	3.5	3.5	3.5	3.5
No. of stories	G+15	G+15	G+15	G+15	G+15
Seismic zone	II	II	II	II	II
Slab thickness (mm)	350	325(Drop 500)	300	100	100
Size of beam	0.3 X0.8 m	0.3 X0.8 m	0.3 X0.8 m	0.3 X0.55 m	0.3 X0.55 m
Size of column	1mx1m	1 mX1 m	1mx1m	1mx1m	1mx1m
Type of soil	Type I, rocky or hard soil	Type I, rocky or hard soil	Type I, rocky or hard soil	Type I, rocky or hard soil	Type I, rocky or hard soil
Seismic Zone	0.1	0.1	0.1	0.1	0.1
Importance Factor	1.2	1.2	1.2	1.2	1.2
Response Reduction	5	5	5	5	5
Grade of concrete	M-40	M-40	M-40	M-40	M-40
Grade of reinforcement	Fe-500	Fe-500	Fe-500	Fe-500	Fe-500

Table -2.1: Building Description

2.2 Material Properties

Elastic material properties of these materials are taken as per Indian Standard IS 456: 2000.

A) Concrete:
Concrete with following properties is considered for study.

- ✓ Characteristic compressive strength of concrete(fck) = 40 N/mm2
- ✓ Density = 25KN/m3
- ✓ Modulus of elasticity(E) = 5000 x √fck = 31622 N/mm2

fck is the characteristic compressive strength of concrete cube in MPa at 28-day

B) Steel:
Steel with following properties is considered for study.
Yield stress (fy) = 500 N/mm

3. Structural Modeling

ETABS software is used to model and analyze all five cases of buildings. Table no.1 gives all of the specifications. According to Indian criteria, both models are analyzed for gravity loads and lateral loads (Seismic) with various load combinations. Both the gravitational and lateral loads are measured according to Indian specifications. All the calculated loads are shown in load calculation. The amounts of reinforced steel and concrete needed for the floor structure have been measured for the five cases above and are presented in table no. 2 in tabular form

4. Result and Discussions

The constraints are drawn and seen in the following figures after studying all five cases structures in the ETABS. The two load combinations preferred from all of load combinations considered are EQX and EQY. Displacement, Drift, Base Shear, Shear Force have been calculated to find out the effect in the building.

4.1 Storey Displacement

It is the total displacement of a storey concerning the structure's bottom. It is inversely proportional to stiffness and therefore depends on the building structure's slenderness [10].
The following are the storey displacements of different categories of takes in the X and Y directions.

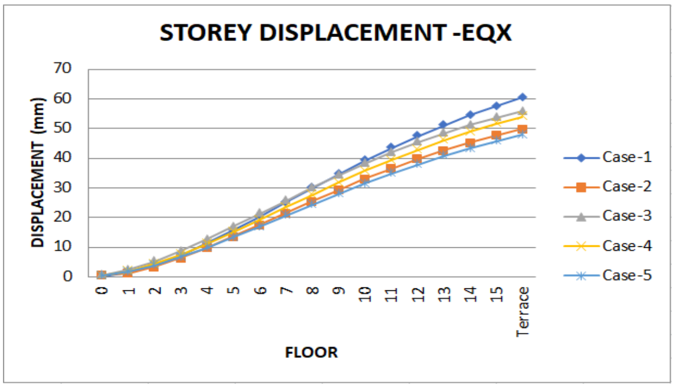

Fig -4.1.1: Storey Displacement in X Direction

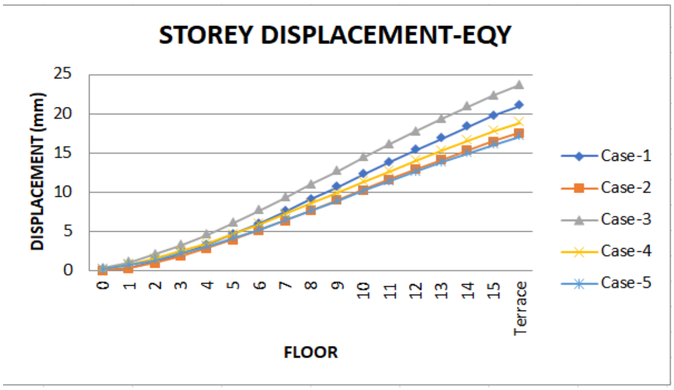

Fig -4.1.2: Storey Displacement in Y Direction

From the above table and graph, it can be easily observed that as the height of the building increases, the storey displacement gets increased. In the case of a conventional slab (case 3) structure, the lateral displacement is greater. The storey displacement was minimized to a greater extent when the flat was incorporate with a drop panel.

4.2 Storey Drift

It refers to the displacement of one storey compared to the other [10]. According to IS 1893 (Part1): 2016, storey drift in every storey must not exceed 0.004 times the height of storey It's a crucial concept in earthquake engineering. The following are the storey drift of different categories of takes in the X and Y directions.

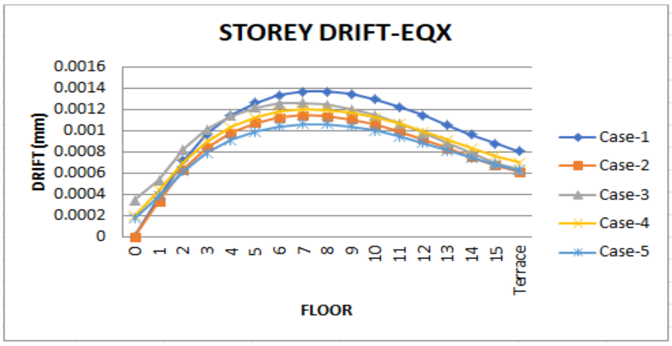

Fig -4.2.1: Storey Drift in X Direction

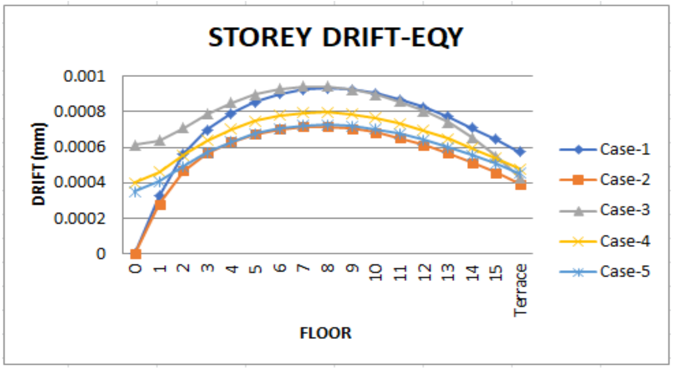

Fig -4.2.2: Storey Drift in Y Direction

According to the storey drift profiles seen in the graphs above, storey drift is greatest for conventional slabs (case 3) and lowest for flat slabs with drops (case2). For a conventional slab structure, it is highest on the 7th storey of a building.

4.3 Storey Shear

It's the total of all design lateral forces above the storey mentioned consideration [10].

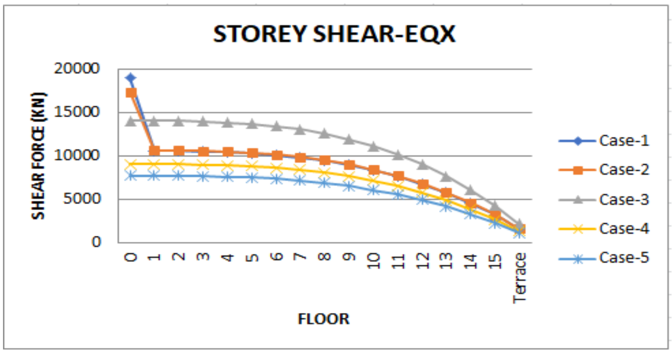

Fig -4.3.1: Storey Shear in X Direction

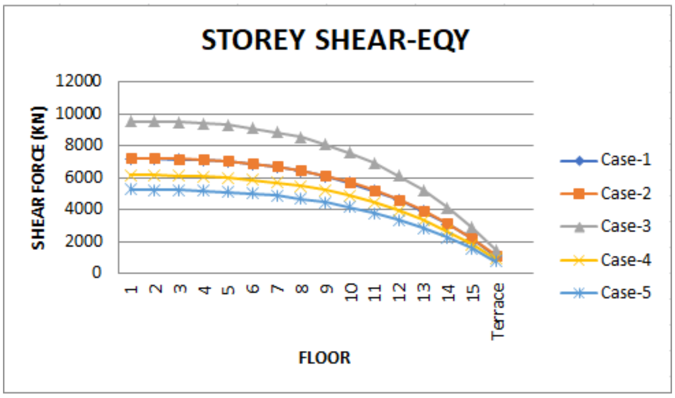

Fig -4.3.2: Storey Shear in Y Direction

4.4 Base Shear

The weight of the structure is directly proportional to the base shear [10]. It refers to the overall lateral force acting on the building at its base, which is equivalent to the bottom story's storey share.

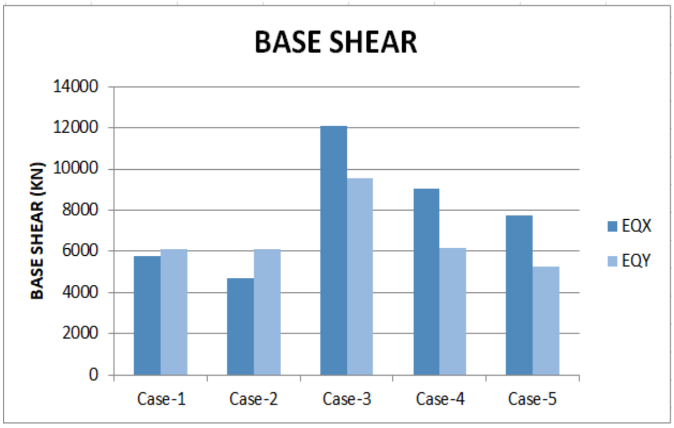

Fig -4.4.1: Base Shear in X and Y Direction

From the above graphs base shear profiles, it has been noticed that minimum base shear occurs in flat slab with drop (case 2) because flat slab is a beamless slab due to this dead load of building decrease so base shear for flat slab with drop is minimum.

5. Economics of Slab Construction

The cumulative estimation of the amounts for a standard floor is determined from the high-rise building's study and construction data. Table 7.1 shows the quantity of concrete and reinforced steel, as well as their costs at the present rate (excluding labor charges) for each of the five cases. The rate per square meter for a standard building floor (including slab and beam) is determined based on the values calculated from the detailed calculation in each case.

Slab	Concrete (m3)	Reinforcing steel (Kg)	Rate per sq. m
Case 1	995	124560	5299.13
Case 2	952	89770.96	4327.54
Case 3	1124	152500.332	6285.13
Case 4	1445.8	87375	5334.4
Case 5	1336	90450	5175.86

Table -5.1: Analysis for the Cases Considered

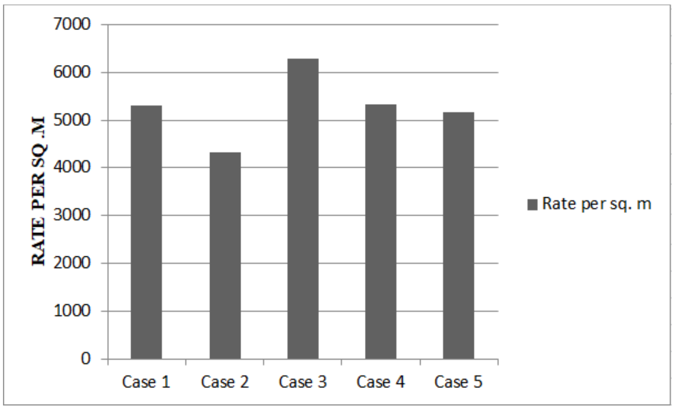

Fig -5.1: Rate variation for each floor system

6. CONCLUSIONS

1. In the case of conventional slab (case3) base shear is maximum as compared to other slab systems, the base shear increasing with an increase in mass.
2. In case (2) flat slab with drop panel, storey displacement considerably reduced. Drop panel increases the lateral stiffness of the building, measured in terms of first storey displacement thereby reducing displacement in all storey levels compared to other cases.
3. A flat slab with a drop panel (case 2) significantly increases stiffness.it considerably reduced the storey displacement and show a smooth drift profile as compared with other cases.
4. In the case of ribbed slab and grid slab, the shear force is reduced by approx. 30-70% as compared to other two cases from a strength point of understanding the performance of these cases is better.
5. In the case of grid slab and ribbed slab is focused to be very effective in reducing shear force and bending moment in columns, as the force is distributed in proportion to the stiffness of the member.
6. The amount of concrete required for a floor is more in the case of Conventional slab (case 3) with reinforced concrete beams while it is least for the flat slab with a drop (case 2).
7. The reinforcing steel required for the Conventional slab (case 3) and flat slab with drop (case 2) slab with the reinforced concrete beam is 55.01 Kg/m 2 and 32.38 Kg/m 2 respectively.

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