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Comparative Analysis and Design of Flat and Waffle Slab System in Multistory Building under Seismic Condition

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Abstract: *A grid slab or two-way joist slab is a concrete slab made up of reinforced concrete with concrete ribs running in two directions on its under side. Grid slabs are preferred for spans greater than 40 feet (12 m), as they are much stronger than flat slabs, flat slabs with drop panels, two-way slabs, one-way slabs, and one-way joist slabs. Grid floor system consisting of beams spaced at regular intervals in perpendicular direction, monolithic with slab. The proposed construction site is for urban homeless at Sitaburdi market near Buty hospital, Nagpur. The length of the slab of 23.40 m and width of 8.82 m total area of the slab is 206.38 sq.m. It is design by using M25 grade concrete and Fe415 steel. Flat slab and grid slab has been analyzed by using STAAD PRO software under seismic condition of zone 3. Rates have been taken according to N.M.C. C.S.R.*

Keywords: *Analysis And Design Of Flat And Grid Slab system, Staad Pro Vi8, grid slab with drop, flat slab with drop, seismic condition.*

I. Introduction

Waffle slab consists of beams spaced at regular intervals in perpendicular directions which are monolithic with slab. These slabs are generally used for architectural purpose for large spans such as public assembly halls, auditoriums; show rooms were the slab has to cover a large column free space is required. Since gird slab offers more stiffness the rectangular voided pattern is used in present study. In the present study G+4 building is considered, analysed and designed for seismic conditions as per IS 1983-2002. The structure is analysed using STAAD Pro V8i software and design has been done manually.

An assembly of intersecting beams placed at regular interval and interconnected to a slab of nominal thickness is known as Grid floor or Waffle floor. These slabs are used to cover a large column free area and therefore are good choice for public assembly halls. The structure is monolithic in nature and has more stiffness. It gives pleasing appearance. In the present study, an attempt is made to compare the bending moment, shear force and displacement obtained from the dynamic analysis using STAAD Pro software for grid patterns. It is important to note that the grids are analysed for G+4 building. The main aim of the study is to compare the flat slab and waffle slab results obtained from the dynamic analysis of grid patterns and study the behaviour of various grids under dynamic loading.

An assembly of intersecting beams placed at regular interval and interconnected to a slab of nominal thickness is known as Grid floor or Waffle floor. These slabs are used to cover a large column free area and therefore are good choice for public assembly halls. The structure is monolithic in nature and has more stiffness. It gives pleasing appearance. The maintenance cost of these floors is less. However, construction of the grid slabs is cost prohibitive. By investigating various parameters the cost effective solution can be found for the grid slabs, for which proper method of analysis need to be used. There are various approaches available for analysing the grid slab system. They are generally employed for architectural reasons for large rooms such as auditoriums, vestibules, theatre halls, show rooms of shops where column free space is often the main requirement. The rectangular or square void formed in the ceiling is advantageously utilized for concealed architectural lighting. The sizes of the beams running in perpendicular directions are generally kept the same.

II. Objective

The objectives of present study can be shortening as follows:

1] To analysed flat and grid slab system in multi-storeyed building under seismic condition. 2] To design a flat and grid slab system in multi-storeyed building under seismic condition.
3] To compare the STAAD Pro result of flat and grid slab system in multi-storeyed building under seismic condition.
4] To study the provision of IS 1893:2002 and IS 875.
5] Study of earthquake design methods for flat slab and grid slab as per Indian standard building code (IS code 1893-2002)

6] Flat slab will be designed using direct design method. 7] Grid slab will be designed using approximate method

II FLAT SLAB

Flat Slab Floor System

A flat slab is a one-way or two-way system with thickenings in the slab at the columns and load bearing walls called 'drop panels'. Drop panels act as T-beams over the supports. They increase the shear capacity and the stiffness of the floor system under vertical loads, thus increasing the economical span range.

This form of construction has become less popular in recent years because of the limit on economical spans of about 9.5 m for reinforced slabs and about 12 m for prestressed slabs. Reinforced flat slabs may need to be sensibly pre-cambered (not overdone) to control deflection.

The plan dimensions of the drop panels are a minimum of 1/3 of the span in the direction under consideration, usually rounded to the nearest 100 mm. The overall depth of the drop panel is typically taken as 1.75 to 2 times the depth of the slab, again rounded to suit timber sizes or the nearest 25 mm.

Figure1:Flat slab

Advantages of flat slab

In the slab system Simple formwork is required. In this no beams simplifying under-floor services outside the drops. Minimum structural depth is required. Usually does not require shear reinforcement at the columns It reduces the overall height of the structure. Flat slabs are capable to carry concentrated loads. Requires less formwork.As reinforcement detailing of flat slabs is simple it is easy to place.Better quality control.Installation of sprinkler and other piping and utilities are easier due to absent of beams.It gives a better appearance and better diffusion of light.Better fire resistant than other floor systems.In this Fast construction is done.

Design of flat slab

Multitudes of process and methods are involved in designing flat slabs and evaluating these slabs in flexures. Some of these methods are as following:

i] The empirical method ii] The sub-frame method
iii] The yield line method

iv] Finite –element analysis

For smaller frames, empirical methods are used but sub-frame method is used in case of more irregular frames. The designs are conceptualized by employing appropriate software but the fact is using sub-frame methods for very complicated design can be very expensive.

The most cost effective and homogenous installation of reinforcements can be achieved by applying the

yield line method. A thorough visualization in terms of complete examination of separate cracking and deflection is required since this procedure utilises only collapse mechanism.
Structures having floors with irregular supports, large openings or bears heavy loads, application of finite-element analysis is supposed to be very advantageous. Great thought is put into choosing material properties or installing loads on the structures. Deflections and cracked width can also be calculated using Finite- element analysis.

III. Grid Slab

A waffle slab is flat on top, while joists create a grid like surface on the bottom. The grid is formed by the removal of molds after the concrete sets. This structure was designed to be more solid when used on longer spans and with heavier loads. This type of structure, because of its rigidity, is recommended for buildings that require minimal vibration, like laboratories and manufacturing facilities. It is also used in buildings that require big open spaces, like theatres or train stations. Waffle slabs are composed by intricate formwork, and may be more expensive than other types of slabs, but depending on the project and the quantity of concrete needed it may be cheaper to build.

Advantages of grid slab

The waffle slab floor system has several advantages:
Better for buildings that require less vibrations this is managed by the two way joist reinforcements that form the grid. Bigger spans can be achieved with less material, being more economical and environmentally friendly. Some people find the waffle pattern aesthetically pleasing. Greater load capacity than traditional one-way slabs. Forms can be implemented with wood, concrete or steel. If holes are provided between the ribs, building services can be run through them. One proprietary implementation of this system is called Hole deck.

Figure 2: Grid slab

Design of grid slab

Different guides have been made for architects and engineers to determine various parameters of waffle slabs, primarily the overall thickness and rib dimensions. The following are rules of thumb, which are explained further in the accompanying diagrams:

Diagram shows slab and rib width with rules of thumb formula

i] Slab depth is typically 75 mm (3 in) to 130 mm (5 in) thick. As a rule of thumb, the depth should be1⁄24 of the span.
ii] The width of the ribs is typically 130 mm (5 in) to 150 mm (6 in), and ribs usually have steel rod reinforcements.
iii] The distance between ribs is typically 915 mm (3 ft).
iv] The height of the ribs and beams should be 1⁄25 of the span between columns.
v] The width of the solid area around the column should be 1⁄8 of the span between columns. Its height should the same as the ribs.

IV. Literature Review

Harish M. K.(2017) analyzed the grid slab of G+4 building using response spectrum method by ETABS software and design is done by manually. In this paper analysis is done by equivalent static method, nonlinear method, response spectrum method and time history method in this structural elements like Slabs, Beams, Columns, Staircase and Shear Walls are assumed and modeled. Based on the assumed dimension of elements dead load Self weight are determined.

Amit A. Sathwanestudied that the among flat slab , flat slab with drop and grid slab which is economical for the nexus point opposite to vidhanbhavan and beside NMC office. The analysis of flat slab, flat slab without drop and grid slab done both manually by IS 456-2000 and by STAAD PRO V8i. It is found in the study that flat slab with drop is economical then rest of other considered slab for the nexus point. It is also revealed in the study that concrete required for grid slab is more than the flat slab with and without drop and steel required for the flat slab without drop is more than the flat slab with drop and grid slab.

Navjot Kaur Bhatia (June 2016) studied that dynamic performance of flat slab and grid slab in compare to conventional slab. In the study of the project the writer perform the dynamic analysis for seismic and wind forces of multistory reinforced concrete building with different plan like square, hexagonal, orthogonal for flat slab , grid slab and conventional slab. The above analysis done for different story like 10, 20 and 30 and also for the different earthquake zone as per the Indian standard code of practice is 1893 – 2002. They made the relation between earthquake responses and intensities. It is revealed from the study that the performance and structural behavior of flat slab & grid slab is superior in compare to conventional slab. It is show in term of deflection and cost of material.

D. Ramya (October 2015) analyzed the multi-story (G+10) building by both STAAD PRO V8i and ETABS software. In the study comparison between these two software is done to find out which give economy of multi storied (G+10) building. It is show that in the study STAAD PRO is much simple to work with as compare to ETABS software. It is also show that quantity of steel given by the ETABS is 9.25% less than by STAAD Pro when analyzed G+10 multistory building. The quantity of concrete show by both the software's is found same for multistory building. In the study it is revealed that the most economical section given by ETABS.

K.N.Mate (June 2015) analyzed the flat slab .Flat slab system is simple structure of RCC which provide long clear space, a good height, simple formwork and no delay time in construction. It is shown that why the flat slab is more feasible and flexible in comparison to other slab. This study includes complete analysis and design of flat slab as per Indian code of practices IS456:2000. Flat slab is more flexible and economical as compare to conventional slab. This paper guide us how to select drop, panel width, thickness of slab and detailing of reinforcement.

V. Models Of Building

Flat slab without drop with perimeter beams (G+5) Building configuration, loading data and earthquake data

Design data of building	Dimension
Plan of dimension	27.2x9.48
No. of storey	G+5
Typical storey height	3.5 m
Bottom storey height	3.5 m
Thickness of slab	150mm for commercial RC frame building
Column size	600 mm x 600 mm
Beam size	350 mm x 600 mm
Wall thickness	230 mm for external wall & 115 mm for internal wall
Live load	4.5 kN/m2 for typical floor & 2 kN/m2 for terrace
Floor finish	1 kN/m2
Earthquake data	Zone III type II medium soil Importance factor=1 Response reduction factor = 5 Damping ratio = 0.05
Grade of concrete	M 25
Grade of steel	Fe 415

Design data of building	Dimension
Plan of dimension	23.40x8.82
No. of bays in X direction	7 bay
No. of bays in Y direction	4 bay
No. of storey	G+5
Typical storey height	3.5 m
Bottom storey height	3.5 m
Thickness of slab	150 mm
Column size	600 mm x 600 mm
Beam size	450 mm* 450 mm
Wall thickness	230 mm
Live load	4.5 kN/m2
Floor finish	1 kN/m2
Earthquake data	Zone III type II medium soil Importance factor=1 Response reduction factor = 5 Damping ratio = 0.05
Grade of concrete	M 25
Grade of steel	Fe 415

VI. Methodology

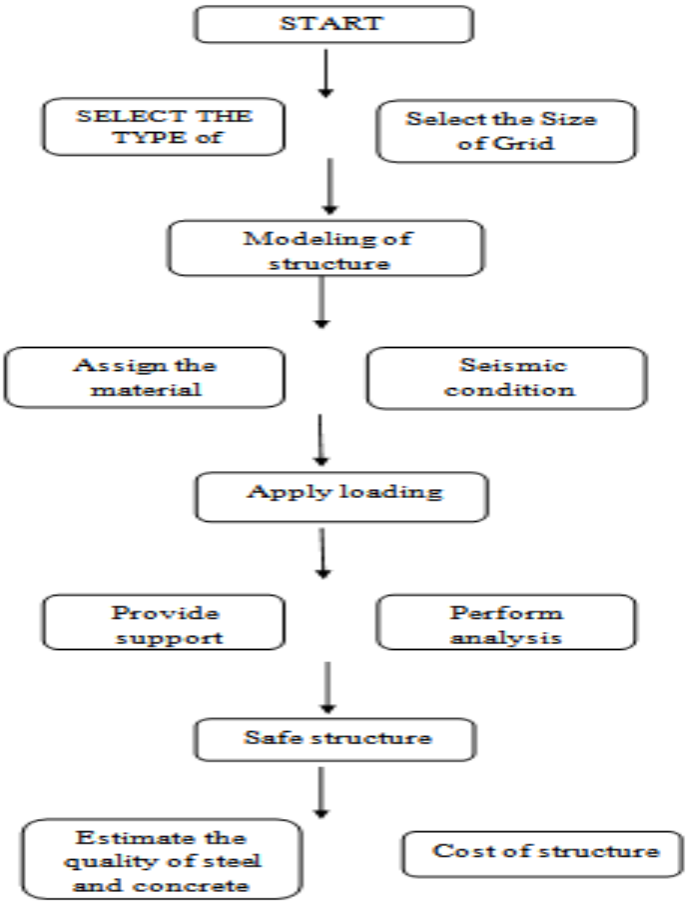

Figure 3:*Block*diagram *showing the process of analysis and design of structure performed on STAAD-Pro*

VII. Conclusion

From all the above summery of project work it is conclude that the quantity of concrete increase with increase the size of span and grid size of structure for the same slab system. The quantity of steel and concrete required for flat slab is minimum but for the grid slab system is maximum. Flat slab system is more economical than grid slab. In flat slab system it is found from the study that maximum displacement, maximum forced and maximum bending moment is found to be maximum.

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