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COMPARATIVE ANALYSIS AND DESIGN OF A MULTISTOREY AUDITORIUM WITH NORMAL SLAB AND WAFFLE SLAB USING ETABS

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Abstract : A slab is a crucial structural component that is used to build flat, practical surfaces like floors, roofs, and ceilings. It is a horizontal structural element with parallel or nearly parallel top and bottom surfaces. A waffle slab is a structural member that is plain on top and has a grid pattern on the bottom. Compared to a flat slabs, waffle slabs offer stronger and lighter slabs. When compared to a normal slab, this slab can be built more quickly. Compared to a raft slab, it utilises 20% less steel and 30% less concrete. And also waffle slabs are economical since it is quite light in weight. For a good visual view, this type of slab is typically utilised at hotels, malls, and restaurant entrances. In order to prevent several columns from obstructing space, it is typically utilised where large spans are needed (such as auditoriums and movie theatres). Our project is focused on the analysis and design of a G+1 multi-storied Auditorium building with waffle slab by utilising ETABS software. The main aim of this research is to analyse and utilise ETABS to build a structure with a waffle slab and compare it with a normally used slab.

IndexTerms **– Slab,Waffle ,Analysis,ETABS**

1.INTRODUCTION

In civil engineering, the phrase "building" refers to a structure made up of many parts, such as walls, columns, floors, roofs, doors, windows, ventilators, stair lifts, foundations, and different kinds of surface finishes. An auditorium is a multipurpose building with a space designed for an audience to hear and see performances. An auditorium can be found in theatres, community centres, other public spaces, and it can be used for classes, presentations, performances, and other activities. The primary focus of structural engineers is determining how a structure will respond to horizontal forces, and high-rise structures need to be sufficiently stiff to withstand the horizontal forces produced by wind and earthquakes. The development of science and technology had made it possible to erect tall buildings even in earthquake and cyclone-prone regions. As a result, lateral loads such as wind loads and seismic forces are becoming more and more significant, and practically every designer is challenged with providing sufficient strength and stability against lateral loads. These lateral forces may cause the structure to sway laterally as well as create critical stresses and unfavourable vibrations.

Grid or Waffle slab are constructed from a group of crossing beams that are spaced regularly apart and joined to a nominally thick slab. Beams comprise the waffle slab. These slabs are a fantastic option for public assembly rooms since they may cover a huge area that is devoid of columns. There is increased rigidity and the construction is monolithic in nature. Aesthetic attractiveness is another benefit. The use of structural design and analysis results in a structure with features like the ability to withstand all applied loads without failing for the duration of its intended life. All the relevant soil information must be gathered through geotechnical research prior to the design and analyses of any structure. In order to plan and build the foundation for the project, a geotechnical site investigation is a way of gathering data and assessing the site's conditions. Structural engineers continuously search for the most accurate, cost-effective, and efficient design while also making sure that the finished product will be usable for the intended purpose for the duration of the design life. Here, A G+1 building is taken into consideration in this project. The design was carried out manually and the structure was analysed using ETABS software. The basic goal in designing a reinforced concrete structure is to create a building that is safe, functional, long-lasting, and visually beautiful. In addition, the building should be affordable in terms of both construction and maintenance costs.

2.NEED OF THE STUDY.

A waffle slab, also known as a ribbed slab, is a structural member that is plain on top and has a grid pattern on the bottom. The top of a ribbed slab is often thin, and the bottom grid lines are typically ribs that are laid perpendicular to each other with equal depth. Two directions of reinforcement are present in waffle slab. These have a uniform rib look and are set out at an equal depth. It is known as waffle because it is plain and upright and has holes underneath that give the impression of waffles. In order to prevent columns from obstructing space, it is typically employed where large spans are necessary. These are also utilised to provide a clear height when the depth of the beams is restricted. Compared to other slab kinds, waffle slabs are stiffer and lighter. Due to its stiffness, this sort of structure is suggested for buildings that call for expansive open areas, such as theatres or halls etc. For a good visual view, this type of slab is typically utilised at hotels, malls, and restaurant entrances. In order to prevent several columns from obstructing space, it is typically utilised where vast spans are needed (such as auditoriums and movie theatres etc).

3.1DESCRIPTION OF SOFTWARE USED

3.1.1Auto CAD 2021

The computer-aided design software AutoCAD was created and developed by the business Autodesk. It allows for the creation and editing of digital 2D and 3D drawings faster and easier than by hand. Additionally, the data can be simply saved and kept in the cloud, enabling access from anywhere at any time. It is a programme used to create vector graphics. It bases complex objects on simple ones like text, polygonal lines, circles, arcs, and lines. For the exchange of CAD data, the DWG file format for Auto CAD and, to a lesser extent, the DXF interchange file format, have become the standards. Auto CAD 2021 is utilised throughout our project for all of the drawings and details.

3.1.2 ETABS 18

Extended three-dimensional analysis of building systems is known as ETABS. Structural design and analysis are the primary uses of ETABS. In this project, ETABS 2018 Ultimate 18.1.0 is being used. The features of ETABS include modelling, designing, and analysis of a structure. Along with accurately analysing and creating simple structures, ETABS is capable of managing the largest and most complex structural model buildings. The ETABS is well renowned for its modelling tools, templates, and analysis technique. The ETABS Software also assists in comprehending static and dynamic studies of multi-story structures and shear wall construction.

3.1.3 SketchUp

SketchUp is a collection of subscription products that includes SketchUp Pro Desktop, a 3D modelling Computer-Aided Design (CAD) programme for a variety of drawing and design applications, such as architectural, interior design, industrial and product design, landscape architecture, civil and mechanical engineering, theatre, film, and video game development.

3.2 OBJECTIVES

- To develop the drawings of the proposed auditorium.
- Analysis and design of an auditorium with conventional slab.
- Analysis and design of same auditorium with waffle slab.

3.3 RESEARCH METHODOLOGY

3.3.1 Site plan & building plan

In this initial stage, a site has to be visited and then a plan or map is prepared for the area showing topographical details related to design of structure etc. Then based on those data a suitable site plan and building plan has to be drawn using AUTODESK AUTOCAD software

3.3.2 Soil investigation & foundation selection

The application of a geotechnical site investigation is necessary to obtain sufficient site information for designing a structure in the proper time with minimum cost. Engineering and Index Properties of the soil has to be tested and also based on the loading conditions a suitable foundation has to be selected.

3.3.3 Structural planning & designing of building

Here the Manual and Software Analysis and Design has to take place. Manual Analysis of the beam, column, slab, foundation etc is done according to IS 456: 2000. Then the structural plan of the auditorium prepared using AUTOCAD is analysed and designed using ETABS software.

3.3.4 Analysis of auditorium with normal slab using ETABS

The proposed auditorium with normal slab is fully analysed using ETABS Software.

3.3.5 Analysis of auditorium with waffle slab using ETABS

The proposed auditorium is modelled with waffle slab and is fully analysed using ETABS Software.

3.3.6 3D model using sketchup

The 3D model of the proposed auditorium is drawn using sketch up software.

3.3.7 Comparative analysis

In this final stage, Auditorium with waffle slab and the same Auditorium with conventional slab is compared and the results are anlaysed.

3.4 DETAILS OF PROPOSED AUDITORIUM

District/state	Ernakulam/kerala
Municipality/taluk	Paravur
Type of auditorium	Multipurpose
Type of soil in the site	Laterite soil
Type of structure	Rcc
Estimated area	1016m^2
Estimated area of auditorium	8000-10,000 sq.ft

3.5 ANALYSIS OF AUDITORIUM WITH NORMAL SLABS USING ETABS.

For analysis, the dead loads, live loads and wind loads were calculated from IS: 875 (Part I ,II and III) seismic load was calculated by referring IS 1893 (Part I):2016 and their combinations were applied on the model of the space frame. From the analysis various load combinations were considered to obtain the maximum design loads, moments and shear on each member. The design was carried out as per IS code for the critical load combinations. The concrete mix used was M 25 for beams , foundation and slabs. Steel used is of Fe 415 grade for stirrups. Then the structure is analysed with normal slab and waffle slab.

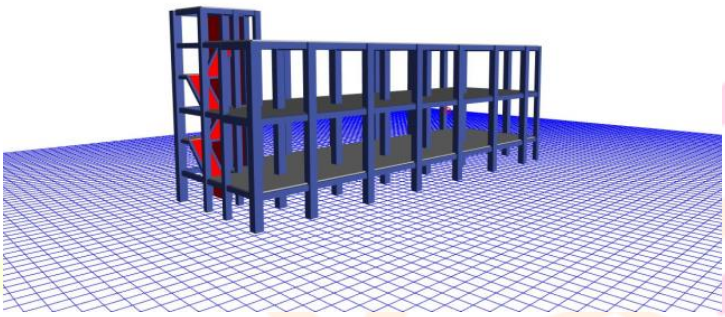

Fig 3.5 : 3D rendered view

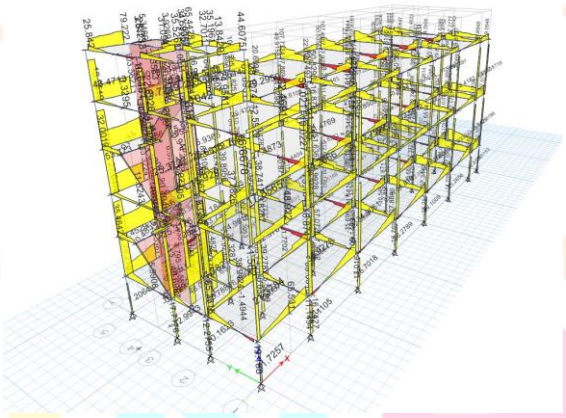

Fig 3.5 : Shear force diagram

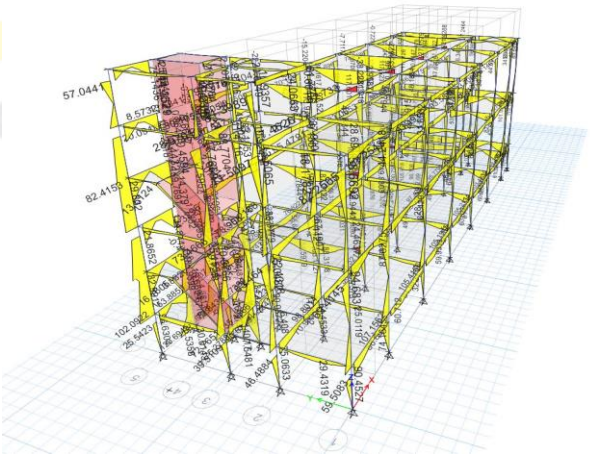

Fig 3.5 : Bending moment diagram

3.6 Analysis of Auditorium with Waffle Slabs using ETABS

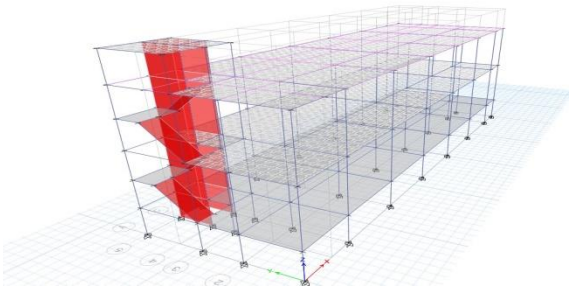

Fig 3.6: 3 D view of the building with waffle slab

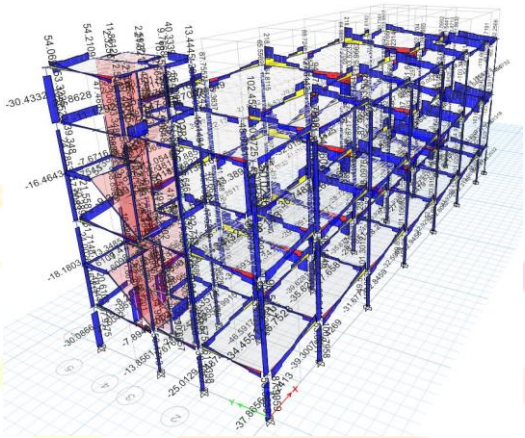

Fig 3.6: Shear force diagram

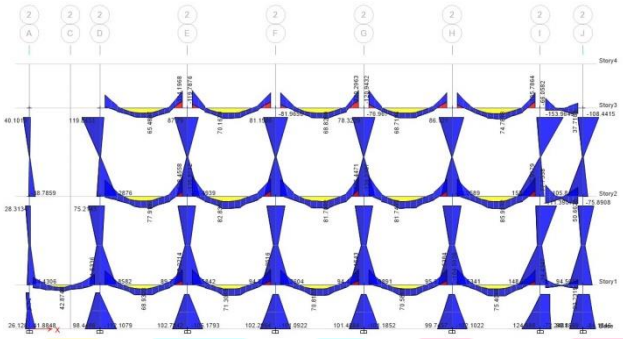

Fig 3.6: Bending moment diagram

3.7 3D MODEL

Fig 3.7 : 3D Model using SketchUp Software

4. RESULTS AND DISCUSSION

Result Analysis and Comparison between Normal slab and Waffle slab

In this final stage, Auditorium with waffle slab and the same Auditorium with conventional slab is compared and the results are anlaysed.The comparison of the auditorium building with waffle slab and normal slab is done using two parameters.

a. Story displacement

b. Material consumption

4.1 STORY DISPLACEMENT

The deflection of a single story with respect to the foundation or ground level of the structure is known as story displacement. As we ascend the structure, we can anticipate seeing increasing total displacement numbers. As a result, a graph of the structure's height against the displacement of the storeys identically resembles a deflected shape. The graph showing the story displacement can be obtained directly from E TABS.As per IS:456-2000 the story displacement of the building shall not exceed H/500 for transient loads , where H is the total height of the building.

(a). Maximum storey Displacement of Normal Slab

The total height of the building , H = 15m

The permissible story displacement = $\frac{H}{500} = \frac{15000}{500}$ = 30 mm

Here, Story displacement = 2.5 mm

Story displacement is 2.5mm which is less than the permissible limit . Hence the structure is stable.

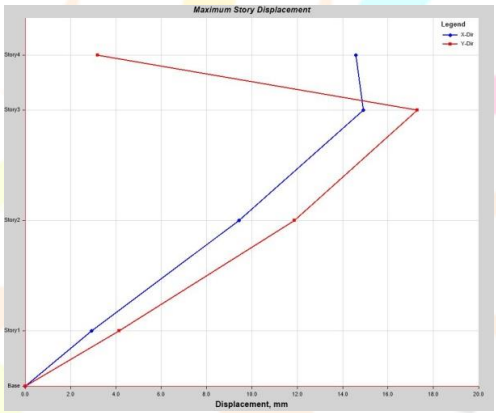

Fig 4.1 (a) : Maximum storey Displacement of Normal Slab

(b). Maximum storey Displacement of Waffle Slab

The total height of the building , H = 15m

The permissible story displacement = $\frac{H}{500} = \frac{15000}{500}$ = 30 mm

Here, Story displacement = 3.2 mm

Story displacement is 3.2 mm which is less than the permissible limit . Hence the structure is stable.

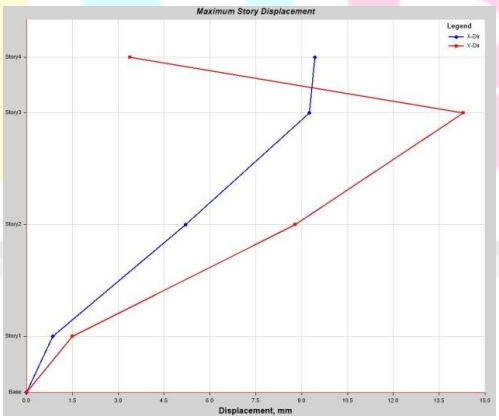

Fig 4.1 (b) : Maximum storey Displacement of Waffle Slab

4.2 MATERIAL CONSUMPTION

It refers to the amount of materials required for the construction of the structure. Here we consider the amount of concrete and steel required for the construction and then comparing the material consumption while using the normal slab and waffle slab. The bill of materials can be obtained from E TABS software. From these data we can find the quantity of concrete and steel required. By providing the mix ratio corresponding to the M 25 concrete we can calculate the amount of cement , fine aggregate & coarse aggregate.

Item	Beam	Column	Slab
Concrete (CU.M)	156.906	302.400	160.086
Steel (Kg)	14513	27710	9985

Table 4.2: Material consumption of waffle slab

Item	Beam	Column	Slab
Concrete (CU.M)	162.913	364.050	301.884
Steel (Kg)	19.004	53345	8591

Table 4.2: Material consumption of normal slab

5. CONCLUSION

- Analysis and design of auditorium with normal slab is done
- Analysis and design of same auditorium with waffle slab is done
- From comparative analysis we concluded that storey displacement is more for waffle slab when compared to normal slab
- And also material consumption is more for waffle slab when compared to normal slab

Therefore we came to the conclusion that the normal slab is more economical and have less story displacement while compared to waffle slab

Normal Slab	Waffle slab
Story displacement = 2.5 mm	Story displacement = 3mm
Quantity of concrete used=619.392 m^3	Quantity of concrete used=828.847 m^3
Quantity of steel used = 52208 Kg	Quantity of steel used = 61955 Kg

Table 5 : Comparison between waffle slab and normal slab

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