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# Comprehensive Structural Analysis and Design of an Auditorium using E-TABS.

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**ABSTRACT:** The structural study and design of an auditorium using the potent software program ETABS are the main objectives of this project. As a typical structural design structure, the auditorium needs careful engineering to guarantee its operation, safety, and aesthetic appeal. A well-known program for finite element analysis and design, ETABS has extensive features for modelling intricate structures and carrying out structural studies. The project starts with a study of the auditorium's functional needs, considering things like occupancy levels, acoustics, and spatial configurations. The structural system is then conceived while taking the site's characteristics, seismic concerns, and architectural vision into account. The program makes it easier to apply diverse loading circumstances, including as live loads, dead loads, wind loads, and seismic loads, allowing for a detailed examination of how the structure might react in various situations. In order to balance aspects like structural efficiency, cost-effectiveness, and adherence to building norms and standards, parametric studies are carried out to optimize the design. In order to find the best solution that satisfies all performance requirements, the project highlights the value of iterative analysis and design refinement. The auditorium's seismic performance and dynamic behaviour are assessed by the project by integrating sophisticated analysis tools found in ETABS. This project shows how useful ETABS is when it comes to structural analysis and amphitheatre design. The project's goal is to provide a safe, effective, and visually beautiful auditorium that meets the functional and engineering goals of its stakeholders by utilizing cutting-edge computational tools and engineering skills.

**KEYWORDS:** Auditorium Structures; E-Tabs; static analysis; dynamic analysis; response spectrum analysis.

## I. INTRODUCTION

Auditoriums stand as architectural marvels, serving as hubs of cultural exchange, artistic expression, and communal gatherings. These iconic structures, however, demand meticulous engineering scrutiny to ensure not just their grandeur but also their structural integrity and safety. There are several types of auditoriums, each designed for a specific purpose and use. The types of auditoriums include Conventional Auditorium, Multi-Purpose Auditorium, Black Box Auditorium, Acoustically Engineered Auditorium, Experimental Auditorium, Cinema Auditorium, and Lecture Hall.

This project focuses on the dynamic analysis and designing of auditorium utilizing the powerful software such as ETABS. The auditorium, as a common structure in structural design, requires meticulous engineering to ensure its safety, functionality, and aesthetic appeal. ETABS, a renowned finite element analysis and design software, offers comprehensive capabilities for modelling complex structures and performing structural analyses. The project begins with an exploration of the functional requirements of the auditorium, considering factors such as occupancy loads, acoustics, and spatial arrangements. Subsequently, the structural system is conceptualized, considering the architectural vision, site conditions, and seismic considerations. Using ETABS, the auditorium's structural model is developed, incorporating detailed geometrical and material property. ETABS facilitates the generation of comprehensive design reports and construction drawings. Overall, this project demonstrates the effectiveness of utilizing ETABS for the structural analysis and design of auditoriums. By leveraging advanced computational tools and engineering expertise, the project aims to deliver a safe, efficient, and aesthetically pleasing auditorium that fulfils the functional and engineering aspirations of its stakeholders. The auditorium is 20meters by 30 meters and has a rectangular shape. This covers designing structural elements that sustain various loading situations, organizing seating arrangements, ventilation, and load analysis.

## II. OBJECTIVE

- Exploring the suitable materials through examination of their sizes and types.
- Analysing in Dynamic analysis techniques for optimizing the structural design of columns and beams in compliance with IS codes.

- Analysing the auditorium model in zone 2,3,4 and 5.
- Evaluate the structural performance of auditorium with reference to parameters such as base shear, storey shear and displacement through ETABS.

### III. REVIEW OF LITERATURE

#### **Sri Priya et. al., 2018:**

The paper carries out the structural analysis and design for multipurpose auditorium in the state of Kerala municipality in Pathanapuram, with seating for 900-1000 people. This study describes in detail the analysis and the design of an auditorium carried out using the ETABS software tool. The acronym for "Extended 3D Analysis of Building System" is ETABS. This project showcased the use of ETABS software in the study and design of a multifunctional auditorium at the Pathanapuram municipality. Using AutoCAD, introductory planning were made. In order to be thorough, a cost calculation for the building was also done, and the result was an anticipated Rs 1,22,00000.

#### **Sachin P Dyavappanavar et.al., 2017:**

In addition to creativity and intellectual thinking, a solid understanding of structural engineering science is necessary for the structural planning and design process. Practical expertise is also important. Standards are meant to guarantee and improve safety while carefully balancing finance and protection. The G+1 building is developed using ETAB software in the current study. Getting the building plan is crucial for designing them since it shows where the rooms are located and ensures that they fulfill their intended functions while also being comfortable for the users.

Thus, the arrangement of the beams and the placement of the columns are set, contingent upon appropriateness. After that, the loads are computed: the live loads, which are based on Indian Standards. And the loads, are determined in unit weight of the materials used for construction. The soil's safe bearing capability is 140 KN/m<sup>2</sup>.

#### **Sindupriya B et. al., 2018:**

The journal is focused on constructing an indoor stadium which was proposed at the engineering college in Bangalore, Saphthagiri. It involves the use of software AUTOCADD and ETABS. The standard design principles required for achieving suitably high-quality Stadium are used in the designing process. All the Indian Standard codes that are mandatory to follow for the construction of a G+2 building are used. The journal focuses in how to design multistory building by the means of Limit state method. The focus of the journal is on analysis and design of indoor stadium which is a different type of auditorium system.

#### **Rupeesh S et. al., 2021:**

The journal gives us insight on the components of the Auditorium, the structural design components that are the main load bearing components such beams, columns, slabs, roof truss. It also gives us the seismic design standards that are to followed for the structure to withstand the loads that act on the auditorium. The key aspects like soil-foundation interaction, earthquake prone zones in India and so on.

The journal gives us a brief insight on the type of soil that are available in India (i.e. type A: Rock or hard soil, type B: medium or stiff soil, type C: soft soil). The soil type influences the structures compatibility differently in different seismic zones. Hence different type of foundations have to used depending on the seismic zones.

#### IV. METHODOLOGY

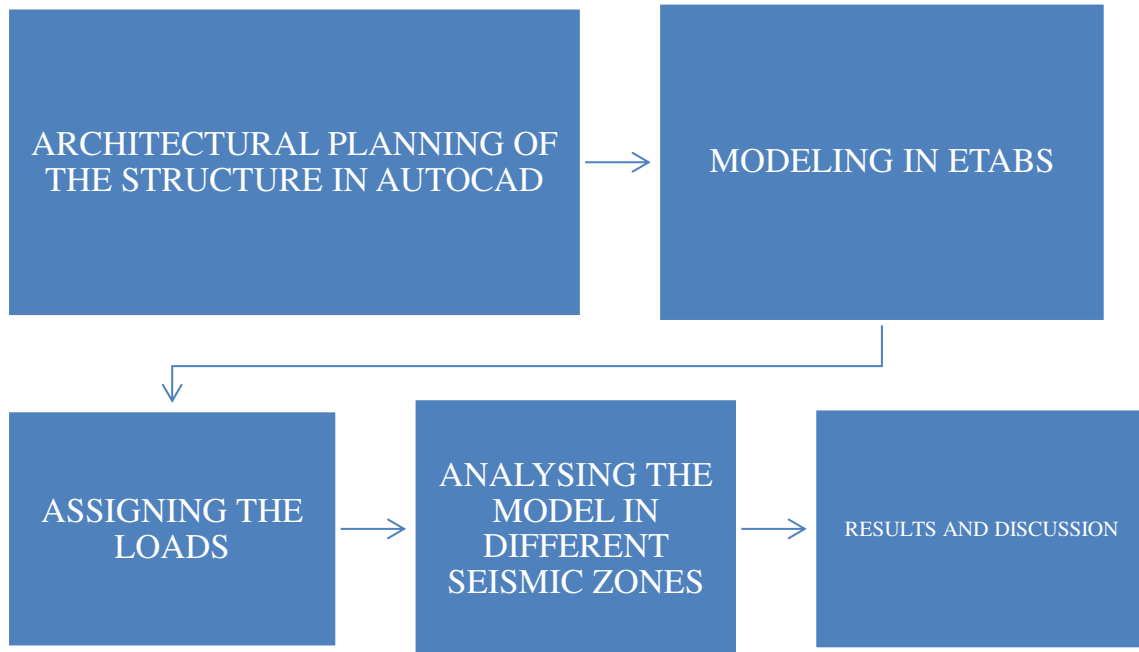


FIG.1:FLOW CHART OF METHODOLOGY.

#### 1. Architectural Plan in AutoCAD

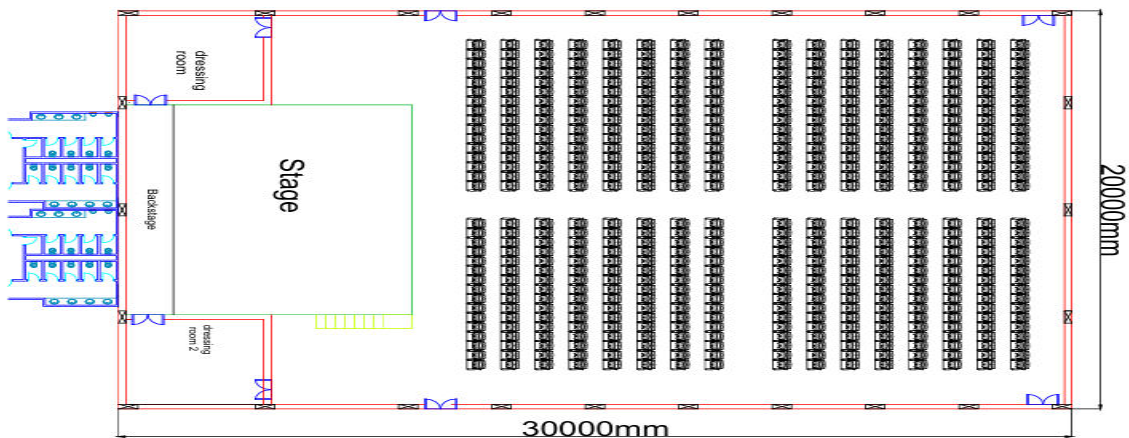


Fig.2: Architectural Plan in AutoCAD.

#### 2. Modeling in E-TABS

1. Start by defining the grid system data shows overall geometry of the structure, this consists of 20m width and 30m length.
2. Then defining story data with number of story and their heights of 3m considered.
3. Once the basic geometry is established, the individual structural elements created using appropriate commands or tools. This includes defining properties such as section sizes, materials, and connectivity.
4. Specifying the properties of each structural element, such as section properties for beams and columns, thickness for slabs, and material properties for all elements.

Member	Section	Material
Column	900mm x 900mm	M30
Beam1	230mm x 450mm	M25
Beam2	900mm x 1500mm	M25
Slab	250mm	M30

Table 1.: Section property data

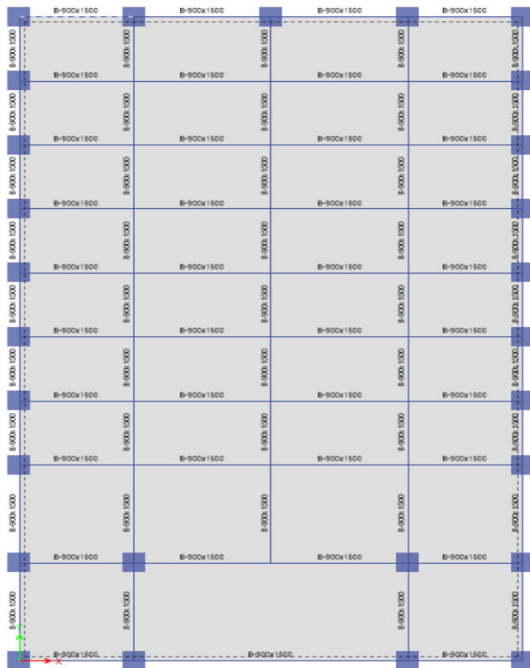


Fig 3: Plan view of Auditorium in E-TABS

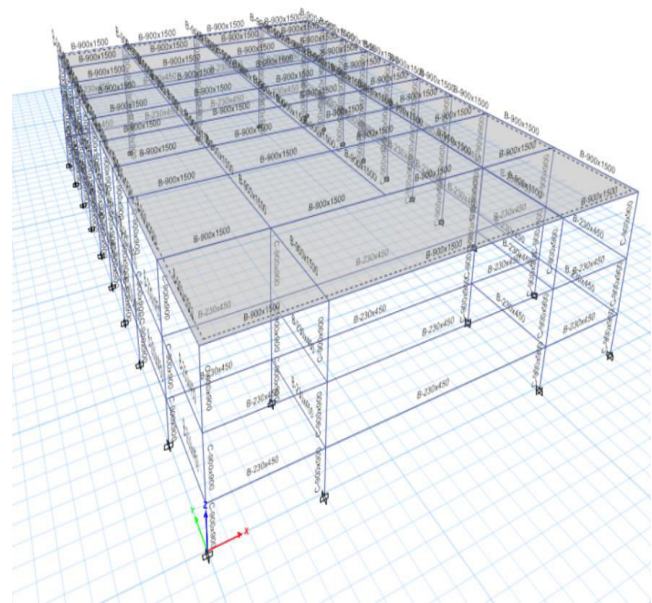


Fig 4: 3-D view of Auditorium in E-TABS.

### DYNAMIC ANALYSIS IN ETABS

Dynamic analysis in ETABS is a critical aspect of assessing the behavior of building structures under dynamic loading conditions, such as seismic events or wind-induced vibrations. Dynamic analysis in ETABS is an essential tool for us to evaluate the dynamic behavior and response of building structures accurately, ensuring their safety, stability, and resilience against dynamic loading events.

#### i. Response Spectrum Analysis (Rsa) (Is 1893:2016)

Response Spectrum Analysis (RSA) is a method of dynamic analysis used in structural engineering to evaluate the seismic response of buildings and other structures exposed ground motions during seismic activities. Response Spectrum Analysis is a significant method for assessing the seismic reaction of structures and designing them to withstand earthquake forces effectively. It delivers valuable insights into the dynamic behavior of buildings and helps us optimize their seismic design for safety and resilience.

#### ii. Defining load patterns

Defining load patterns for Response Spectrum Analysis (RSA) involves specifying the seismic loads to be applied to the structural model and configuring the parameters associated with these loads. By defining load patterns in ETABS for RSA Method, you can accurately simulate the seismic loads acting on your structure and assess its response and performance under seismic events.

#### iii. Defining load cases

Load cases for RSA (Response Spectrum Analysis) method are defined similarly to load cases for other analysis methods, but with specific consideration for seismic loads.

By defining load cases for RSA method in ETABS, you can accurately simulate the seismic loads acting on your structure and assess its response and performance under seismic events.

**iv. Assigning restraints**

Assigning restraints in RSA (Response Spectrum Analysis) method in ETABS involves defining how the structure is constrained against certain degrees of freedom during the seismic analysis. Restraints are essential for accurately modeling the behavioral changes of the structure when exposed to seismic loads. By means of assigning restraints in RSA method in ETABS, you can accurately model the reaction of the structure’s response to seismic loads and obtain meaningful results for seismic design and evaluation.

**v. Assigning diaphragms**

Assigning diaphragms in RSA (Response Spectrum Analysis) method in ETABS is crucial for accurately modelling the lateral load distribution within a structure. Diaphragms help to transmit lateral loads such as seismic forces between the lateral elements of the structure, such as walls and frames. By assigning diaphragms in RSA method in ETABS, you can accurately model the lateral load distribution within your structure and obtain meaningful results for seismic design and evaluation. After assigning diaphragms, you can proceed to perform the response spectrum analysis. During this analysis, ETABS considers the assigned diaphragms along with the seismic loads to calculate the structure's response under seismic excitation.

**V. RESULTS AND DISCUSSIONS**

**1. STOREY DISPLACEMENT**

Seismic zone	Maximum Displacement(mm) along Y-Y direction			
	Base	Plinth	Tie	Roof
2	0	0.0045	0.0182	0.0306
3	0	0.0100	0.0399	0.0679
4	0	0.0150	0.0599	0.1019
5	0	0.0555	0.2231	0.3453

TABLE 2: MAXIMUM DISPLACEMENT IN Y-DIRECTION

Seismic zone	Maximum Displacement(mm) along X-X direction			
	Base	Plinth	Tie	Roof
2	0	0.0058	0.0235	0.0390
3	0	0.0127	0.0515	0.0866
4	0	0.0191	0.0773	0.1299
5	0	0.0428	0.1765	0.3453

TABLE 3: MAXIMUM DISPLACEMENT IN X-DIRECTION

**2. STOREY SHEAR**

Sesmic zone	Mamimum storey shear (kN) along X-X direction			
	Base	Plinth	Tie	Roof
2	30.98	30.98	30.6	28.98
3	61.71	61.71	61.04	57.73
4	134.57	134.57	132.99	125.06
5	201.86	201.86	199.49	187.6

Table 4: MAXIMUM STOREY SHEAR IN X-DIRECTION DIRECTION

Sesmic zone	Maximum storey shear (kN) along Y-Y direction			
	Base	Plinth	Tie	Roof
2	31.05	31.05	30.65	29.05
3	62.01	61.01	61.29	57.78
4	135.35	135.35	133.61	125.023
5	203.02	203.02	200.42	187.85

Table 5: MAXIMUM STOREY SHEAR IN Y-DIRECTION

### 3. BASE SHEAR

Seismic zone	Storey Shear (kN) along X-X direction
	Base
2	30.98
3	61.71
4	134.57
5	201.86

Table 6: BASE SHEAR IN X-DIRECTION

Seismic zone	Storey Shear (kN) along Y-Y direction
	Base
Zone 2	31.05
Zone 3	62.01
Zone 4	135.35
Zone 5	203.02

Table 7: BASE SHEAR IN Y-DIRECTION

### VI. CONCLUSION

The dynamic analysis method is used in the seismic analysis of the auditorium structure in order to compare and measure the displacement, base shear, and storey shear. The research conducted using the Response Spectrum Method allows for the drawing of the following conclusions. As the number of storey level grows, storey shear continues to decrease. The location of the structure's lowest storey shear was at the roof, while its greatest storey shear was at the base. The difference in storey shear at the base and at roof varies from 6% to 8% depending on the seismic zone. It is found that when the structure was subjected to more seismic activity, the storey shear of the structure increased relatively. Zone 2 has the lowest storey shear count which is 85% lesser than Zone 5. In comparison to model's response in all the seismic zones, it is found that zone 5 has the largest base shear in both the longitudinal and transverse directions. According to dynamic analysis (response spectrum approach), the structure in zone 2 exhibits 85% less base shear in both directions compared to seismic zone 5. The storey drift in any story must not exceed 0.004 times the storey height, according to the Indian standard IS 1893(Part 1):2016, which outlines criteria for the earthquake-resistant design of structures. Comparing the analysis of the models in different seismic zones, we find that model 2 has displayed least displacement along both axis compared to other models response in other seismic zones and the model in seismic zone 5 has shown highest storey displacement along both axis. Zone 2 is safer for the model. In comparison to other seismic zones, as the model in zone shows 89% lesser displacement compared to zone 5. Furthermore, the model is compactable in all the zones as the displacement is negligible (i.e. 0.345mm < 80mm).

Hence the auditorium Model is Compactable for all the seismic zones. To tackle the storey shear acting on the Auditorium model in higher seismic zones, the number of stirrups and reinforcement bars used. We also need to take into consideration of the type of soil present in the site as it influences the structure's load bearing capacity at the base.

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