Analytical Study of Burj Khalifa for Seismic Loads

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***Abstract*—In this current modern construction era, most of the buildings are formulated in irregular manner both in plan and vertical configurations. Irregularities in lack of symmetry might imply vital eccentricity between the building mass and stiffness centers, give rise to damaging coupled lateral response. Irregular structural analysis is crucial because irregular building configurations can significantly increase the risk of damage and failure during seismic events. Besides, designing and analyzing an irregular building requires a high level of effort and knowledge whereas an inappropriate designer may design it without considering the effect, In other words, damages in those with irregular options are more than that of the regular one. Irregularities, such as variations in stiffness, mass, or geometry, can significantly affect a structure's response to loads, especially during earthquakes, potentially leading to failure. Understanding and accurately analyzing these irregularities is essential for ensuring the safety and stability of structures, particularly in earthquake-prone regions. Thus, irregular structures would require more careful structural analysis in the event of destructive earthquake As there is increase in population by which land deficit occurs and to overcome that, high-rise structure is opted. These types of high-rise structure are affected by the natural phenomena. Earthquake in the past decade is observed to be more devastating, so it is now important to consider the effect of earthquake for the construction of medium to high rise buildings. Earthquakes are the most dangerous by means of the damage and effect caused to the structural components and also that they can't be controlled. In the stability of these high rise buildings due to the different loads in tall buildings is comparatively high than in low buildings because they are exposed to the wind, the increase in the height of the building increases the impact of increased winds loads, causing safety concerns for the structure envelope and the integrity of the structural system. Tall buildings shook along the wind. The vibrations may be large to cause anxiety and discomfort for the people present, or by strong earthquakes. So designing the structure seismic loads is a crucial step .In this project, the Burj Khalifa which is a prime example of a high-rise building, specifically a skyscraper is analyzed for seismic behaviour .**

***Index Terms*—Burj Khalifa, Irregular structures, seismic behaviour , structural analysis , seismic design , ANSYS , displacement ,skyscraper, Seismic loads**

I. INTRODUCTION

As the world advances, it populates and grow, Consequently there is a need for modern technological advancements in the construction field and as a result the advancements and development in construction field occurs. Here in this project the world's tallest building The Burj Khalifa has been analyzed. It holds the title of the world's tallest building and is known for its impressive height and architectural design .It has been analyzed for seismic loads using ANSYS software.

The Burj Khalifa is the tallest structure ever built by man. This structure rises to 828 meters in Dubai skyline. It consists of 162 floors above grade and 3 basement levels. It was originally named Burj Dubai before its inauguration in 2010. The skyscraper serves as a mixed-use development, housing residential, commercial, and hospitality spaces, including the Armani Hotel. It's a global icon, a testament to architectural and engineering innovation, and a major tourist attraction.

The Burj Khalifa's design is a blend of aesthetic appeal, structural efficiency, and a nod to its cultural context, making it a true architectural marvel. While integrating wind engineering principles and aerodynamic shaping into the architectural design concept was an important consideration in mitigating and taming the dynamic wind effects, managing the gravity load flow to the building extremities was equally significant in overcoming the overturning moment due to extreme lateral loads .The Burj Khalifa's seismic design incorporates several key features that enhance its ability to withstand earthquakes, including a buttressed core system, a Y-shaped floor plan, and a robust foundation. These elements work together to provide stability against lateral forces and minimize the impact of seismic activity.

Most of the tower overturning resistance is managed mostly by the tower's own gravity loads. In addition, all the vertical members are proportioned to resist gravity loads on equal stress basis to overcome the differential column shortening issues that are generally difficult to manage in supertall buildings.

The structure of Burj Khalifa was designed to behave like a giant column with cross sectional shape that is a reflection of the building and mass profile. The wall thicknesses and column sizes were fine-tuned to reduce the effects of creep and shrinkage on the individual elements which compose the structure.

This system of arrangement in Burj Khalifa helps the structure in resisting lateral loads.

II. STRUCTURAL AND ARCHITECTURAL DESIGN

A. Structural and Architectural Design

The Burj Khalifa's architecture is characterized by a Y-shaped plan, inspired by the Hymenocallis flower, and a spiral, stepped-back design that reduces wind resistance and optimizes space. It incorporates Islamic architectural themes, particularly in the patterning and the spire at the top.

The structure is primarily reinforced concrete, clad in reflective glazing and precast concrete, enhancing its visual appeal and energy efficiency. The building's footprint is based on a three-lobed or Y-shaped plan, derived from the Hymenocallis flower, which allows for optimal residential and hotel space with maximized views.

The tower's design incorporates setbacks as it rises, creating a spiral effect. This design reduces wind loads and optimizes the building's structural mass. A hexagonal central core provides the primary structural support, with wings extending from it. The core also houses vertical transportation systems.

The design is derived from Islamic architecture. As the tower rises from the flat desert base, there are 27 setbacks in a spiral pattern, decreasing the cross section of the tower as it rises and creating convenient outdoor terraces.

These setbacks are arranged and aligned in a way that minimizes vibration wind loading from eddy currents and vortices. At the top, the central core emerges and is sculpted to form a finishing spire. At its tallest point, the tower sways a total of 1.5 m (4.9 ft).

III. ANSYS SOFTWARE

ANSYS is widely used for seismic analysis of various structures and components, enabling engineers to assess their behavior under earthquake loads. It allows for both linear and nonlinear dynamic analyses, including modal analysis, response spectrum analysis, and time-history analysis, to evaluate the structural response to seismic events.

This research uses the ANSYS general finite element software to have dynamic characteristics of this structure an also on dynamic characteristics of the auto oscillation characteristics of the overall structure and the dynamic characteristics under seismic wave functions, to obtain research fruits of the auto oscillation frequency and vibration form characteristics of this structure .

The structural deformation and internal forces, etc. under seismic response spectrum functions, providing valuable data for the structural design and reliable basis for ensuring the safe use of this structure.

IV. SEISMIC ANALYSIS

A .Seismic Analysis

Seismic analysis of Burj Khalifa in ANSYS typically involves a combination of modal analysis and response spectrum analysis or time history analysis to evaluate a structure's response to earthquake loads.

This process generally includes defining the structure, applying boundary conditions, performing modal analysis to find natural frequencies and the mode shapes, and then using these results in a response spectrum analysis (RSA) or time history analysis to determine the structure's response to a seismic event.

The initial step is creating the geometry of Burj Khalifa building and defining the support conditions to represent how the structure is connected to ground.

The next step of analysis is to discretize the geometry into finite element mesh for ensuring sufficient element density for accurate results.

The finite element mesh of Burj Khalifa is done. The final step of analysis involves modal analysis of structure.

The modal analysis of structure involves the inclusion of response spectrum data .The input of the response spectrum data was given ,which represents the expected ground motion characteristics (acceleration, velocity, or displacement) at different frequencies.

The displacement was taken for analyzing ground motion characteristics of Burj Khalifa building. Once the input data was applied, the modal analysis of Burj Khalifa is done based on frequencies. Here the seismic load is applied as time dependent displacement function at the base of the structure.

The Burj Khalifa is solved over time to capture the dynamic behaviour of the Burj Khalifa during earthquake. The modal combination method is used in order to combine all the responses due to different frequencies and the total response of Burj Khalifa is obtained.

V. RESULTS

A. Results

The resulting displacements, stresses, strains and other relevant quantities are examined to assess the structure's seismic performance.

The examined results are compared with the established design criteria and allowable limits of Dubai building code in order to determine whether the structure meets seismic safety requirements.

VI. CONCLUSION

The Burj Khalifa building which is the world's tallest skyscraper is taken for consideration for the purpose of analysis under seismic loads.

The maximum displacement occurs at top of the spire of Burj Khalifa. It can withstand upto maximum of 7 Richter scale earthquake which is much higher than the previous earthquakes that has occured in Dubai. The Burj Khalifa building has been analyzed using ANSYS software and results were found and the maximum displacement of building is found.

The Burj Khalifa building is designed and analyzed for seismic loads effectively. Any irregular structure involves same procedure and same method of seismic analysis using ANSYS From this any irregular structure can be designed and analyzed using same procedure in ANSYS software.

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