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IMPACT OF WIND AND SEISMIC LOADS ON VARIOUS BUILDING SYSTEMS

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Abstract - Buildings are constantly subjected to a variety of external pressures. The wind and seismic loads are acknowledged as the most significant due to their dynamic, unpredictable nature and substantial impact on structural performance and safety. Wind loads act externally on building surfaces, creating negative suction on leeward sides and positive pressure on windward faces. These lateral forces have a substantial impact on occupant comfort, serviceability, and structural stability, especially in tall and thin structures that are susceptible to vibration and aerodynamic instability. In contrast, seismic loads result from ground motion during earthquakes, creating inertial forces inside the structure that necessitate robust detailing, regulated energy dissipation, and ductile behavior in order to avoid catastrophic failure. The impact of these lateral forces on a variety of structural systems, such as moment-resisting frames, shear walls, braced frames, tube structures, and dual systems, is examined in this study along with an evaluation of each system's relative performance under both loading scenarios. The efficiency of the system is evaluated by looking at important factors such as lateral displacement, interstory drift, base shear, and structural ductility. The basic distinctions between wind and seismic load characteristics and their unique design requirements are highlighted by a comparative analysis.

Keywords: Wind loads; Seismic load; structural stability; energy dissipation; ductile behavior.

1. INTRODUCTION

As the foundation of organized society, buildings are essential pillars of human civilization. Buildings have always demonstrated humanity's inventiveness and drive to build secure, useful spaces, from the first mud-brick shelters of ancient Mesopotamia to the tall glass skyscrapers of contemporary cities. They guarantee human survival and comfort by offering vital defense against inclement weather, high temperatures, and environmental dangers [1]. Beyond providing a place to live, buildings perform a variety of functions: homes support families, school's foster knowledge, hospitals save lives, and workplaces stimulate economic growth. Communities' cultural identities are defined by their architectural styles, which reflect the story of civilization, values and history across many generations. Additionally, buildings promote social contact by uniting people in common areas for leisure, education, business, and worship. Buildings are not just practical constructions; they are essential to human existence because, without them, modern society as we know it would simply vanish [2].

Over the course of their existence, buildings are exposed to a variety of loads, including as dead loads, live loads, wind loads, and seismic loads. Because they are dynamic in character and have a substantial impact on the structural performance and safety of buildings, wind and seismic loads are regarded as the most important environmental loads [3]. Seismic loads result from ground vibrations produced during earthquakes, whereas wind loads are induced by the movement of air surrounding a structure. Both kinds of loads put structures under lateral forces, they must be carefully considered when designing [4]. Several variables, including building height, shape, structural system, material characteristics, and geographic location, affect how these loads are felt. For modern constructions to be safe, stable, and long-lasting, wind and seismic effects must be properly understood and analyzed during the construction of any building.

2. WIND LOADS ON THE BUILDINGS

Wind loads apply pressure to its external surfaces, producing negative suction on the leeward sides and positive pressure on the windward faces. Wind speed, building height, location, and surrounding topography all depend on the strength of these forces applied. Structures that are tall and thin are especially susceptible to flutter and vortex shedding caused by dynamic winds [5]. Building systems designed to properly withstand and disperse these stresses include diagrid structures, shear walls, moment-resistant frames, and lateral bracing. Long-term building performance, occupant safety, and structural stability are all guaranteed by proper wind load analysis, which is directed by codes such as ASCE 7 [1].

2.1 Nature of wind loads

The wind speed, topography, building height, shape, and neighboring structures are some of the variables that affect wind pressure intensity. Positive pressure is created on the windward side of a building when wind interacts with it, whereas suction or negative pressure is created on the leeward side [6]. The structure is subject to forces acting both vertically and horizontally as a result of these pressure variations. Wind loads often have little impact on the main structural system of low-rise buildings. However, wind effects become more noticeable as a building's height increases. Tall buildings are more vulnerable to wind-induced aerodynamic instability, vibration, and lateral movement [7].

2.2 Impact on structural system

The different structural systems are affected differently by wind loads. Rigid beam-column connections are used in moment-resisting frame systems to resist wind forces. The structure can withstand lateral loads because to these connections, which distribute bending forces throughout the frame. On the other hand, severe wind forces could cause significant lateral displacements, which would be uncomfortable for occupants and harm non-structural elements. By transferring lateral forces directly to the foundation through diagonal elements, braced frame designs increase rigidity. These methods successfully lessen wobble and increase the structure's overall stability. Shear wall systems, which are frequently built with reinforced concrete, also provide superior wind load resistance [8]. Shear walls greatly limit lateral movement and improve structural stability because of their high stiffness. Outrigger systems and tube structures are common in contemporary high-rise architecture. By effectively distributing wind stresses throughout the building's core and perimeter, these technologies lessen structural deformation and enhance overall performance under high wind situations.

In addition to the structural framework, non-structural components including roofing systems, glass facades, cladding panels, doors, windows, and mechanical equipment are also impacted by wind loads. Water penetration, broken windows, facade damage, and roof lifting can all result from strong wind pressures. In order to endure expected wind pressures, engineers must make sure that these components are appropriately constructed and anchored.

2.3 Wind-induced vibrations

Wind-induced vibration is one of the main issues with tall buildings. Excessive movement can make residents uncomfortable even in situations where a building's structural safety remains unaffected. Motion sickness, trouble carrying out regular tasks, and psychological discomfort can all be brought on by vibrations [9]. Aerodynamic adjustments, tuned mass dampers, and other vibration-control systems that lessen building motion during high wind events are frequently used by engineers to control these effects.

3. SEISMIC LOADS ON BUILDINGS

The seismic loads were produced during an earthquake due to ground motion. Seismic forces are inertia forces that develop inside a building, as opposed to wind loads, which act externally on a structure. The foundation moves with the ground, but because of inertia, the building's higher sections typically resist movement. Internal forces and strains are created throughout the structure as a result of this variation in movement [10]. The strength of the earthquake, the length of the shaking, the soil, the mass of the building, the stiffness of the structure, and the damping properties all affect the magnitude of seismic stresses. Buildings must be built to absorb and disperse massive amounts of energy without failing catastrophically since earthquakes happen quickly and without warning.

3.1 Structure response during earthquake

A building's dynamic characteristics, such as its inherent frequency, mode shapes, and damping ratio, affect how it reacts to an earthquake. Significant lateral displacements, interstory drift, torsional effects, and structural vibrations can all be caused by seismic forces. Structural components may fail, yield, or crack if these deformations go beyond allowable bounds [11]. Ensuring that structures stay stable and don't collapse during powerful earthquakes is one of the fundamental goals of seismic design. Energy dissipation systems, ductile design, and proper structural detailing all help achieve structural strength.

3.2 Impact on different structural systems

The moment-resisting frames can withstand without losing structural integrity and provide significant deformations. Hence, these are frequently utilized in earthquake-resistant design. These systems use controlled yielding of beams and columns to disperse seismic energy [12]. However, if sufficient stiffness is not given, they could suffer significant lateral drift. Shear wall systems' great strength and stiffness make them quite successful at withstanding seismic forces.

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During earthquakes, these walls increase structural stability and lessen lateral displacement. To guarantee ductile behavior and avoid brittle failure, proper reinforcement details are crucial [13].
Seismic loads are transferred via axial forces in diagonal braces in braced frame systems. These systems are appropriate for structures situated in seismic regions because they offer great stiffness and effective force dispersion [14]. To increase ductility and energy absorption, specific bracing arrangements are frequently employed. The benefits of shear walls or braced frames and moment-resisting frames are combined in dual systems. These systems, which are frequently utilized in high-rise structures, provide exceptional seismic performance by offering both stiffness and ductility.

4. COMPARISON BETWEEN WIND AND SEISMIC LOADS

While both seismic and wind loads act laterally on buildings, their impact and properties are very different. Wind loads are often long-duration forces that have a major impact on structural stability, occupant comfort, and serviceability. Seismic loads, on the other hand, can produce very strong forces that endanger structural safety during a brief period of time. Building shape, height, exposure conditions, and aerodynamic properties all have a significant impact on wind loads. However, the structure's bulk, stiffness, and dynamic reactivity are the main factors influencing seismic loads. Seismic design prioritizes ductility, energy dissipation, and collapse avoidance, whereas wind design concentrates on managing displacement and vibration. Choosing the right structural systems and design approaches requires an understanding of these distinctions.

CONCLUSION

Among the most significant environmental factors influencing building systems are wind and seismic stresses. Seismic loads control structural safety and collapse resistance in earthquake-prone areas, whereas wind loads primarily affect structural stability, serviceability, and occupant comfort, especially in tall buildings. To successfully withstand these dynamic stresses, a variety of structural solutions have been created, such as moment-resisting frames, shear walls, braced frames, dual systems, and base-isolated structures. A thorough grasp of load behavior, structural reaction, material qualities, and contemporary mitigating measures is necessary for the successful design of structures. By using cutting-edge engineering concepts and cutting-edge technologies, engineers can make sure that structures are resilient, long-lasting, and safe even when wind and seismic loads are mixed.

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