

Seismic Response Evaluation of Multistory Reinforced Concrete Frame Structures with Irregular Configuration

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DESCRIPTION

The structural behavior of multistory reinforced concrete frame systems subjected to seismic activity has remained a significant area of study in civil engineering due to the increasing construction of high-rise buildings in regions with moderate to severe earthquake risk. These structural systems are widely used in residential, commercial, and institutional developments because of their flexibility in architectural planning and their ability to accommodate varied functional requirements. However, when building configurations deviate from symmetry or exhibit irregular geometric distributions, their response under seismic excitation becomes more complex and less predictable.

Irregular configurations may arise from setbacks, unequal mass distribution, varying stiffness across floors, or asymmetric placement of structural elements such as columns and shear walls. These irregularities introduce non-uniform stress distribution during ground motion, resulting in torsional effects, localized deformation, and amplification of displacement in certain zones of the structure. Unlike regular structures where seismic forces can be distributed relatively evenly, irregular buildings tend to concentrate energy in specific regions, increasing the likelihood of structural damage. Reinforced concrete frame structures rely on the combination of concrete and steel reinforcement to resist applied loads. Concrete provides compressive strength, while steel reinforcement contributes tensile resistance and ductility. This composite behavior allows structures to absorb and dissipate energy during seismic events. However, the effectiveness of this system depends on proper detailing, material quality, and connection integrity between structural members. Poor detailing in beam-column joints or insufficient reinforcement anchorage can significantly reduce seismic resistance.

Dynamic analysis techniques are commonly used to evaluate structural response under earthquake loading. These techniques include response spectrum analysis and time history analysis. Response spectrum methods provide estimates of maximum structural response based on predefined seismic input parameters, while time history analysis simulates actual ground

motion records to observe real-time structural behavior. Both approaches assist engineers in identifying critical stress points and potential failure mechanisms within irregular configurations. Torsional behavior is a major concern in asymmetric structures. When the center of mass does not align with the center of stiffness, seismic forces generate rotational motion in addition to translational movement. This rotation leads to uneven distribution of lateral forces across structural elements, causing certain columns or frames to experience higher stress levels than others. Over time, repeated seismic loading may result in cumulative damage in these overstressed regions.

Material nonlinearities also influence seismic performance. Reinforced concrete exhibits nonlinear behavior under high stress levels, particularly during cyclic loading conditions. Cracking of concrete, yielding of reinforcement steel, and stiffness degradation contribute to changes in structural response during an earthquake event. These nonlinear effects must be considered in advanced simulation models to accurately predict displacement and energy dissipation behavior. Finite element modeling is widely used to simulate seismic performance of complex structural systems. By dividing a building into discrete elements, engineers can analyze stress distribution, deformation patterns, and failure progression under simulated earthquake conditions. This method allows for detailed assessment of how irregularities affect overall stability and helps in identifying weak zones that require reinforcement or redesign.

Base isolation techniques and energy dissipation devices are often introduced to improve seismic resistance in irregular structures. Base isolation systems reduce the transmission of ground motion to the building by introducing flexible layers between the foundation and superstructure. Energy dissipation devices such as dampers absorb seismic energy and reduce structural vibration. These technologies enhance safety but require careful integration into structural design to ensure compatibility with existing load paths. Soil-structure interaction also plays a significant role in seismic response evaluation. The behavior of foundation soil affects how seismic waves are

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transmitted into the structure. Soft soil conditions may amplify ground motion, while stiff soil may reduce certain vibration frequencies. Accurate modeling of soil conditions is essential for realistic seismic analysis, particularly in regions with variable geological characteristics.

Construction quality significantly influences seismic performance. Variations in material strength, improper curing of concrete, insufficient reinforcement placement, and construction defects can reduce structural capacity. Quality control measures during construction are therefore essential to ensure that design assumptions are reflected in actual structural behavior. Retrofitting strategies are commonly applied to improve the seismic resistance of existing irregular structures. These strategies may include adding shear walls, reinforcing columns, strengthening beam-column joints, or introducing external bracing systems. Retrofitting improves stiffness distribution and reduces structural vulnerability during seismic events.

CONCLUSION

Performance-based design approaches have gained importance in modern seismic engineering. Instead of relying solely on prescriptive design rules, performance-based methods evaluate how structures behave under different levels of seismic intensity. This allows engineers to design structures that meet specific performance objectives such as immediate occupancy, life safety, or collapse prevention. Continuous research in computational simulation, material behavior, and structural optimization continues to improve understanding of seismic response in irregular reinforced concrete systems. As urban development increases in seismic regions, ensuring structural safety through accurate analysis and improved design practices remains a central objective in civil engineering practice.