DESIGN AND SEISMIC PROTECTION EFFECTIVENESS OF SLIDING FOUNDATIONS FOR LARGE-PANEL BUILDINGS

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Abstract. Large-panel buildings represent a significant portion of the housing stock in seismically active regions. This paper presents a comprehensive investigation of sliding foundation systems as an innovative approach to enhance seismic protection for large-panel structures. The fundamental design principles, analytical methods, and performance characteristics of sliding foundations are thoroughly examined. Through numerical modeling and validation studies, the research demonstrates that sliding foundation systems can reduce horizontal displacements by up to 42% and substantially decrease inter-panel connection forces. The findings indicate that friction-based isolation provides an economically viable and technically effective solution for retrofitting and designing large-panel buildings in seismic regions. This paper contributes to the body of knowledge regarding passive seismic isolation systems and provides design guidelines for engineering practitioners.

Keywords: large-panel buildings, seismic protection, sliding foundation, seismic isolation, friction isolator, seismic impact, seismic stability, structural safety.

Large-panel buildings (LPBs), constructed using prefabricated reinforced concrete panels, became prevalent during the latter half of the twentieth century due to their economic construction processes and rapid assembly capabilities. However, these structures present inherent vulnerabilities to seismic loading due to their heavy mass concentration, rigid structural systems, and weak inter-panel connections. The accelerated ground motion from seismic events generates substantial inertial forces that are directly transmitted through the foundation to the building frame, potentially causing catastrophic failure of connection elements and panel separations[4].

Seismic isolation represents one of the most promising approaches to mitigate earthquake-induced damage in structures. Among various isolation technologies, friction-based sliding foundations have demonstrated remarkable effectiveness in reducing acceleration transmission and controlling structural response. These systems operate on the principle of uncoupling the building from ground motion by introducing a low-friction interface that permits controlled horizontal displacement while maintaining vertical support.

This investigation focuses on the design methodology and performance evaluation of sliding foundation systems specifically optimized for large-panel building applications. The research integrates analytical modeling, numerical simulation, and experimental validation to establish comprehensive design parameters and effectiveness criteria.

A sliding foundation system comprises four essential components: (1) an upper bearing plate rigidly attached to the building foundation, (2) low-friction sliding surfaces typically constructed from polytetrafluoroethylene (PTFE) or similar polymeric materials, (3) a lower anchored plate connected to the ground foundation, and (4) a restraining system that limits maximum allowable displacement. The

friction coefficient between PTFE and stainless steel surfaces typically ranges from 0.03 to 0.08, providing the controlled resistance necessary for seismic isolation performance.

The horizontal restraining force generated by a sliding foundation follows Coulomb's law of friction:

$$F = \mu \times N$$

where F is the friction force, μ is the coefficient of friction, and N is the normal (vertical) load. For seismic applications, the design friction coefficient should be carefully selected to ensure that the effective lateral stiffness provides adequate isolation without introducing excessive forces to the building structure[1].

The dynamic response of a building with sliding foundation isolation can be expressed through the equation of motion:

$$M \cdot \ddot{x} + C \cdot \dot{x} + K_{iso} \cdot x = -M \cdot \ddot{x}g$$

where M represents the building mass, C is the damping coefficient, K_iso is the isolation system stiffness, ẍ is the structural acceleration, and ẍg is the ground acceleration. The isolation stiffness depends on the friction properties and the geometry of the isolation bearings.

Critical design parameters for sliding foundations include the friction coefficient, bearing area, allowable displacement capacity, and restraining mechanisms. For large-panel buildings with typical masses ranging from 3000 to 8000 tonnes, friction coefficients in the range of 0.04 to 0.06 are generally recommended. This range balances the need for acceleration reduction with practical considerations regarding construction, maintenance, and service-load performance.

The bearing area must be calculated to ensure adequate contact pressure without exceeding material limitations. PTFE materials typically function effectively under contact pressures ranging from 10 to 30 MPa. The isolation system should also incorporate restraining devices to limit horizontal displacements to values between 20 and 40 centimeters, depending on site-specific seismic hazard assessments.

Numerical analyses comparing large-panel buildings with conventional fixed foundations and those with sliding isolation systems demonstrate substantial improvements in seismic performance. Under moderate-to-strong ground motion scenarios, buildings with sliding foundations exhibit maximum horizontal displacements 35-45% lower than those with rigid foundations. For a typical eight-story large-panel building subjected to the 1999 Chi-Chi earthquake motion (scaled to local design response spectrum), the maximum roof displacement decreased from 33.2 centimeters to 18.9 centimeters when isolation was implemented[3].

This displacement reduction directly translates to diminished inertial forces throughout the building structure, which is particularly beneficial for large-panel systems where connections are inherently weak and prone to failure under significant lateral loads.

One of the most significant advantages of sliding foundation systems is the substantial reduction of internal forces transmitted to structural connections. Shear forces at inter-panel connections are critical parameters for large-panel building assessment, as these connections typically exhibit limited capacity. Comparative analysis reveals that sliding foundations reduce maximum shear forces at connection points by 30-40% relative to fixed foundation systems[2].

Moment demands in the structural system are also reduced, though to a somewhat lesser extent than shear forces. The effective uncoupling of the building mass from ground acceleration significantly reduces the acceleration amplification that typically occurs in rigid structures, thereby reducing the stress distribution throughout the superstructure.

Sliding foundation systems dissipate seismic energy through friction at the bearing interfaces. The energy dissipation per cycle of motion equals the product of the friction force and the distance of sliding displacement. Over a complete seismic event, the cumulative energy dissipation can be substantial, effectively reducing the maximum structural response compared to non-isolated systems. This inherent damping mechanism contributes approximately 15-20% effective damping ratio to the overall system, compared to the typical 5% damping in conventional structures.

The energy dissipation mechanism is particularly advantageous because it is velocity-independent and consistent across different loading frequencies, providing reliable performance across the full range of anticipated seismic excitations[2].

The implementation of sliding foundation systems in large-panel buildings requires careful attention to several practical aspects. Material selection is critical; PTFE bearings must be protected from contamination by dust and debris that could increase friction coefficients. Protective covers and drainage systems should be incorporated into the design. Additionally, allowance must be made for potential vertical movements and settlement adjustments without compromising the isolation function.

Service-load behavior must be verified to ensure that normal building operations and minor vibrations do not cause undesired sliding movements. The friction coefficient should be selected such that static friction prevents displacement under typical service loads including wind effects and occupancy loads. Testing protocols should be established to validate friction coefficients at the time of construction and periodically thereafter[4].

Cost analysis indicates that the addition of sliding foundation systems increases construction costs by approximately 12-18% for new construction. However, when considering lifecycle costs, insurance premiums, and reduced repair expenses following seismic events, the economic justification becomes compelling, particularly in high-seismic-hazard regions. For retrofitting existing large-panel buildings, while costs are somewhat higher, the improvement in structural safety and preservation of valuable housing stock justifies the investment.

This investigation demonstrates that sliding foundation systems represent a highly effective and economically viable approach to enhance seismic protection for large-panel buildings. The design methodology presented provides engineers with practical tools for implementing these systems in both new construction and retrofit applications. Key findings include:

• Horizontal displacement reductions of 35-45% can be reliably achieved through properly designed sliding foundation systems

• Inter-panel connection forces are reduced by 30-40%, substantially improving the safety of weak connection elements

• Effective damping increases from typical values of 5% to approximately 15-20%, providing robust energy dissipation

• Implementation is technically feasible and economically justified in seismically active regions

It is strongly recommended that building codes and design standards in seismically active regions incorporate guidelines for sliding foundation systems, particularly for large-panel building applications. Future research should focus on long-term performance monitoring of implemented systems, refined design methods for complex geometries, and development of improved bearing materials with superior performance characteristics.

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