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ACTIVE SEISMIC PROTECTION SYSTEMS IN LARGE-SPAN BUILDINGS: THEORETICAL AND PRACTICAL ASPECTS

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https://doi.org/10.5281/zenodo.23064618

Annotatsiya. Ushbu maqolada yirik panelli binolarda aktiv seysmik himoya tizimlarini qo‘llashning nazariy va amaliy jihatlari tahlil qilinadi. Binolarning zilzila ta’siridagi dinamik xususiyatlari, konstruktiv elementlarda yuzaga keladigan inertsiya kuchlari va tebranishlarni kamaytirish imkoniyatlari o‘rganiladi. Aktiv seysmik himoya tizimlarining ishlash prinsipi, boshqaruv mexanizmlari hamda konstruksiyaning seysmik barqarorligini oshirishdagi ahamiyati yoritiladi. Shuningdek, sirpanish poydevorlari, ishqalanishli izolyatorlar va boshqa seysmik himoya vositalaridan foydalanish imkoniyatlari ko‘rib chiqiladi. Tadqiqot natijalari yirik panelli binolarning zilzilabardoshligini oshirish, konstruktiv shikastlanishlarni kamaytirish va foydalanish xavfsizligini ta’minlashga qaratilgan amaliy tavsiyalar ishlab chiqish uchun asos bo‘lib xizmat qiladi.

Kalit so‘zlar: yirik panelli binolar, aktiv seysmik himoya, seysmik izolyatsiya, sirpanish poydevori, ishqalanishli izolyator, zilzila ta’siri, dinamik yuklama, seysmik barqarorlik.

Abstract. This article examines the theoretical and practical aspects of applying active seismic protection systems in large-panel buildings. Particular attention is given to the dynamic behavior of buildings under earthquake excitation, inertia forces arising in structural elements, and approaches to reducing seismic vibrations. The operating principles and control mechanisms of active seismic protection systems are considered, with emphasis on their potential to improve the seismic stability of large-panel structures. The study also discusses the application of sliding foundations, friction-based isolators, and other seismic protection technologies. The obtained results provide a basis for developing practical recommendations aimed at improving earthquake resistance, reducing structural damage, and increasing the operational safety of large-panel buildings under seismic loading.

Keywords: large-panel buildings, active seismic protection, seismic isolation, sliding foundation, friction isolator, earthquake excitation, dynamic loading, seismic stability.

Large-span buildings present unique structural challenges when subjected to seismic events. The extended unsupported lengths create greater flexibility and susceptibility to resonance phenomena, requiring innovative protection strategies beyond conventional base isolation or damping techniques. Traditional passive systems, while effective for smaller structures, often prove insufficient for controlling the excessive displacements and accelerations inherent in large-span configurations.

Active seismic protection systems address these limitations through dynamic response mechanisms. By continuously monitoring structural behavior and applying corrective forces through actuators, these systems can significantly reduce motion amplitudes and damage potential. The primary objective of this thesis is to evaluate the efficacy, implementation challenges, and practical viability of active systems in the context of large-span structures, bridging the gap between theoretical models and real-world applications.

Active seismic protection systems operate on the principle of counteracting ground-induced motion through controlled structural intervention. The fundamental architecture comprises three

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integrated components: sensing, computation, and actuation. Accelerometers and displacement sensors continuously measure structural response in real time. This data feeds into a computational controller that executes predefined or adaptive algorithms to determine optimal force generation. Hydraulic, pneumatic, or electromagnetic actuators then apply these forces to critical structural elements[1].

The mathematical foundation rests on optimal control theory. For large-span buildings modeled as multi-degree-of-freedom systems, the equation of motion becomes:

$M \cdot \ddot{u} + C \cdot \dot{u} + K \cdot u = -M \cdot \ddot{ig} + F(t)$

where M is the mass matrix, C is the damping matrix, K is the stiffness matrix, u represents displacement, ïg is ground acceleration, and F(t) represents the actively applied control forces. Various control strategies exist: linear quadratic regulators minimize the weighted sum of structural response and control effort; semi-active systems modulate damper properties without energy input; and adaptive algorithms adjust control parameters based on real-time performance metrics[3].

Implementing active systems in large-span buildings requires careful consideration of multiple technical and practical factors. System reliability becomes critical, as any component failure could compromise structural safety. Redundancy in sensors and actuators is essential, with failsafe mechanisms that allow graceful degradation to passive behavior if active control fails. The power supply infrastructure must be sufficient to operate actuators continuously; uninterruptible power supplies ensure functionality during electrical outages that may coincide with seismic events.

Large-span buildings present particular challenges regarding sensor placement and data communication. Extensive structural dimensions require distributed sensor networks with wireless or hardwired communication systems. Signal latency becomes a critical concern; even milliseconds of delay in the control loop can significantly reduce effectiveness. Processing speed of computational systems must be sufficient to analyze multi-channel sensor data and execute control algorithms within required timeframes.

Economic considerations substantially influence implementation decisions. Initial capital investment for active systems typically exceeds that of passive alternatives by 15-30 percent. Operating costs include power consumption, maintenance of complex machinery, and periodic software updates. However, potential benefits—reduced structural damage, minimized downtime, and extended building lifespan—may justify the investment over the structure's service life. Cost-benefit analyses must incorporate probabilistic seismic hazard assessments specific to the building's location[4].

Several notable implementations demonstrate the practical viability of active seismic protection in large-span structures. Contemporary examples include large-span pedestrian bridges equipped with tuned mass damper systems integrated with active actuators, achieving simultaneous wind and seismic mitigation. Long-span roof structures spanning over 300 meters utilize active systems to control lateral movement during seismic events, maintaining structural integrity while minimizing acceleration-induced damage to building contents and occupants.

Industrial facilities with large clear-span requirements increasingly incorporate semi-active damping systems, which reduce power requirements while maintaining substantial protection. Monitoring data from deployed systems reveals effectiveness metrics: typical active systems reduce peak interstory drift by 30-50 percent and accelerations by 25-40 percent compared to uncontrolled structures subjected to equivalent seismic excitation. Response time analysis indicates modern systems achieve actuation latencies of 50-100 milliseconds, sufficient for effective control of building-period vibrations[5].

Emerging technologies are expanding the capabilities and applicability of active seismic protection systems. Artificial intelligence and machine learning algorithms are being integrated into

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control systems to enable real-time optimization beyond predetermined controller parameters. Advanced materials such as shape-memory alloys and magnetorheological fluids offer improved actuator efficiency and reduced power consumption. Hybrid systems combining active and passive elements represent a pragmatic approach to managing cost while maintaining enhanced protection.

Research continues on improving sensor technologies, particularly for large-span applications where distributed sensing networks are necessary. Wireless sensor networks show promise for reducing installation complexity and cost. Integration with structural health monitoring systems allows active protection systems to adapt to structural condition changes resulting from aging or previous seismic events.

Active seismic protection systems represent a significant advancement in structural engineering's ability to protect large-span buildings from seismic hazards. While implementation requires substantial technical expertise and initial investment, demonstrated effectiveness and reducing costs make these systems increasingly viable for critical infrastructure and high-value facilities. As technology evolves and case study evidence accumulates, active systems are likely to become more prevalent in seismically active regions where large-span structures are necessary. Future development should focus on standardizing design procedures, establishing maintenance protocols, and reducing costs through technological innovation, thereby facilitating wider adoption of these protective technologies.

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