ISSN 2663-1563 Vol. 8, Issue 1: 145-152, DOI: 10.25236/AJAGE.2026.080118

Seismic Isolation and Energy Dissipation in Medical Buildings: Construction and Quality Control

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Abstract: *Medical buildings in high-seismic-intensity regions must maintain structural safety and essential functions while limiting damage to equipment and nonstructural components. This study examines the application of seismic isolation and energy dissipation technologies in medical public building projects, with emphasis on construction procedures and supervision-based quality control. Drawing on relevant standards, published studies, design and construction documents, and supervision records from representative projects, the study analyzes isolation mechanisms, bearing selection, construction procedures, and quality-control requirements across pre-construction, in-process, and post-construction stages. The analysis identifies five critical control points: incoming bearing inspection, positioning of embedded plates, bearing lifting and installation, protection of completed bearings, and deformation monitoring. Common risks include embedded-plate displacement, damage to bearing protection, blockage of isolation gaps, incomplete monitoring records, and excessive connection gaps. Corresponding measures include dual-person verification, continuous supervision at critical procedures, hierarchical acceptance, standardized documentation, and lifecycle maintenance planning. The findings provide practical guidance for construction supervision and quality management of isolated medical buildings in high-seismic-intensity regions.*

Keywords: *Lead-rubber Bearings, Hospital Resilience, Nonstructural Components, Structural Control, Quality Assurance, Construction Supervision, Post-earthquake Functionality*

1. Introduction

Southwestern China, including Sichuan and Yunnan, contains areas with seismic fortification intensities of 8–9 degrees [1]. Under the Regulations on the Administration of Seismic Resistance of Construction Projects, newly constructed key-protection public buildings such as hospitals and schools in these regions must adopt seismic isolation and energy dissipation technologies to maintain function under design-level earthquakes and avoid collapse under rare earthquakes [2].

Conventional rigid structures resist earthquakes through larger structural members and increased reinforcement, but interstory deformation can damage hospital equipment, pipelines, and other nonstructural components. Repairs may then delay the restoration of essential medical and emergency services [3].

Isolation bearings create a flexible layer that can reduce seismic action transmitted to the superstructure by approximately 60%–80% [4]. Japan and the United States adopted laminated rubber bearings in the 1970s and developed systems for testing, design, and construction [5, 6, 7]. Following the 2008 Wenchuan Earthquake, China expanded its use of isolation technology; Yunnan introduced local standards and regulations covering design, manufacturing, construction, and acceptance [8].

During the Lushan Earthquake, the isolated People's Hospital of Lushan County sustained minor wall-finish damage while its primary structure remained intact. Existing studies have emphasized structural simulation and bearing mechanics, leaving construction control and on-site supervision of large medical buildings in 9-degree fortification areas less examined. This study synthesizes literature, project documents, and supervision records to identify construction and quality-control requirements and propose engineering recommendations.

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2. Materials and Methods

2.1. Source Materials

The study draws on the Code for Acceptance of Construction Quality of Building Seismic Isolation Engineering (JGJ 360–2015), relevant local standards, published literature, and practical engineering experience. It also incorporates design documents, construction documents, and supervision documentation from representative medical building projects. These materials were used to identify technical requirements for isolation systems and recurring quality-control issues during construction.

2.2. Analytical Approach

The study adopts a practice-oriented review and case-informed technical synthesis. First, the working mechanisms and selection conditions of mainstream isolation bearings are examined. Second, the construction process is organized into key procedures from lower support-pier construction through bearing installation, superstructure construction, protection, and acceptance. Third, supervision requirements are analyzed across pre-construction, in-process, and post-construction stages. Finally, recurring quality problems are linked to corresponding optimization measures and future application recommendations. No new experimental dataset is introduced; the conclusions are derived from the cited literature, applicable standards, and the project documentation described above.

3. Results

3.1. Working Mechanism and Device Selection

During an earthquake, ground motion is transmitted from the foundation to the superstructure. Conventional rigid structures generally have short natural vibration periods and may therefore resonate with seismic waves, resulting in amplified structural forces. A seismic isolation system introduces an isolation layer between the foundation and the superstructure. This layer consists primarily of rubber isolation bearings, embedded components, seismic isolation gaps, and damping components and performs two principal functions.

(1) Period elongation through seismic isolation.

Rubber isolation bearings possess considerable horizontal deformation capacity. By extending the natural vibration period of the building away from the dominant-period range of the seismic excitation, the bearings substantially reduce resonance effects and decrease the seismic forces transmitted to the superstructure.

(2) Hysteretic energy dissipation for vibration mitigation.

Lead-rubber bearings (LRBs) incorporate lead cores. During repeated horizontal deformation, the lead core undergoes plastic shear deformation, thereby continuously dissipating seismic input energy. Lead-free natural rubber bearings (LNRs), in contrast, dissipate energy primarily through the inherent damping characteristics of rubber. These mechanisms jointly reduce the vibration response of the building.

Measured data reported in relevant standards indicate that the seismic shear force in the superstructure of a qualified isolated building may be only 20%–50% of that in a conventional seismic-resistant structure. Consequently, seismic isolation can provide simultaneous protection for the primary structure, medical equipment, and enclosure components, allowing the building to resume operation after an earthquake without extensive structural repair.

3.1.1. Main Types of Seismic Isolation Bearings and Their Applicable Conditions

Current projects commonly employ two major series of isolation bearings: lead-rubber bearings (LRBs) and lead-free natural rubber bearings (LNRs), together with modified R-type bearings. Different bearing types are selected according to the vertical loads carried by individual supports. Their principal characteristics are as follows:

(1) Lead-rubber bearings (LRBs).

LRBs are manufactured by vulcanizing alternating layers of steel plates and rubber, with a lead core embedded at the center. They simultaneously provide vertical load-bearing capacity, horizontal

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deformation capacity, and hysteretic energy dissipation. Owing to their high load-bearing capacity and stable damping characteristics, LRBs are suitable for primary frame columns subjected to relatively large loads.

(2) Natural rubber bearings (LNRs).

LNRs do not contain lead cores and dissipate energy through the inherent damping of natural rubber. They exhibit smooth deformation characteristics and relatively low costs and are therefore suitable for secondary column locations subjected to comparatively smaller loads.

(3) Bearing dimensions.

The bearing dimensions generally range from 700 to 1,500 mm. Bearing types are selected according to differences in axial forces at the column bases to satisfy the requirements for ultimate horizontal displacement and contact pressure under rare earthquakes corresponding to a seismic fortification intensity of 9 degrees.

3.1.2. Specific Advantages for Medical Buildings

Hospitals are classified as key-protection buildings and are characterized by three distinctive features: continuous 24-hour operation, a high concentration of precision medical equipment, and the need to provide emergency-response functions following earthquakes. Seismic isolation and energy dissipation technologies are therefore particularly well suited to medical buildings. During construction, these technologies can provide the following benefits:

(1) Reduction of damage to nonstructural components.

The technologies reduce the likelihood of damage to suspended ceilings, utility pipelines, glass curtain walls, and medical instruments, thereby substantially reducing post-disaster economic losses.

(2) Relaxation of structural detailing requirements for the superstructure.

Because seismic actions transmitted to the superstructure are reduced after isolation, the cross-sectional dimensions and reinforcement ratios of frame beams and columns may be optimized to an appropriate extent, thereby reducing civil construction costs.

(3) Enhancement of post-earthquake emergency response capacity.

By limiting severe damage to the primary structural system under design-level and rare earthquakes, isolation technology facilitates the rapid restoration of operating rooms, wards, and other essential medical spaces, thereby satisfying critical requirements for earthquake disaster response.

3.2. Construction Process and Key Procedures

Based on design documents, construction documents, and supervision documentation from representative projects, the construction process can be divided into four major stages: construction of lower support piers → installation of isolation bearings → construction of the superstructure → protection and acceptance of the isolation layer.

3.2.1. Reinforcement, Formwork, and Embedded Components for Lower Support Piers

(1) Reinforcement installation.

Reinforcement diameter, spacing, and anchorage length shall be strictly controlled in accordance with the design drawings. Supervisory personnel shall inspect the reinforcement individually to prevent insufficient reinforcement and inadequate anchorage.

(2) Formwork installation.

15-mm wood plywood combined with 100 × 100-mm timber members is used for reinforcement. Lateral supports are installed to prevent displacement during concrete placement. Concrete placement may commence only after the formwork alignment and cross-sectional dimensions have been verified.

(3) Positioning and fixing of lower embedded plates.

The centerline of the support pier is established on the base plate, while elevation control lines are marked on the surrounding walls. Short reinforcing bars are arranged at the four corners to level the embedded plate, and the reinforcement is welded and fixed to the sleeves and support-pier reinforcement cage. After installation, the center position, levelness, and elevation of the embedded

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plate are remeasured. Any deviation exceeding the allowable tolerance shall be corrected immediately.

3.2.2. Concrete Placement and Curing of Lower Support Piers

Ready-mixed concrete is used for placement. During vibration, direct interference with embedded components shall be avoided to prevent displacement of the embedded plates. After concrete placement, the flatness and coordinates of the embedded plates shall be rechecked, and any displacement shall be corrected promptly. Installation of the seismic isolation bearings may proceed only after the concrete has been cured until its strength reaches 75% of the design value.

3.2.3. Lifting, Positioning, and Installation of Seismic Isolation Bearings

(1) Lifting control.

The bearings shall be lifted using the manufacturer-specified two-point lifting method. Single-point lifting, inclined lifting, and loading of the bolt holes are prohibited. Bearings shall be lifted and placed gently to prevent impact damage to the rubber components.

(2) Positioning and installation.

Bearings shall be classified and positioned according to their designated models in the drawings. After lifting them onto the lower embedded plates, the upper and lower steel plates shall be aligned, ensuring that the bearing axis coincides with the structural axis. High-strength bolts shall then be tightened uniformly.

(3) Reinspection and acceptance.

After all bearings have been installed, their elevations and center coordinates shall be measured systematically, and installation measurement records shall be prepared. Construction of the upper formwork may proceed only after the supervising engineer has reviewed and approved the records.

3.2.4. Superstructure Construction and Bearing Deformation Monitoring

The upper frame is constructed floor by floor. After completion of each floor, vertical deformation of the isolation bearings shall be monitored, and settlement data shall be recorded and compared with the allowable deformation specified in the design. Stockpiling and impact by heavy objects are prohibited during construction. The seismic isolation gaps shall remain unobstructed, and construction waste shall not be stored within them because such obstructions may restrict horizontal displacement.

3.2.5. Protection of Completed Isolation Bearings

(1) Corrosion protection of metallic components.

Connection plates and exposed embedded plates shall receive two coats of anticorrosive paint. High-strength bolts shall be equipped with dedicated protective caps to prevent corrosion of the threads.

(2) Protection of rubber components.

The bearings shall be enclosed in protective wooden boxes fabricated from plywood. For particularly important buildings, fire-resistant cotton and fire-resistant blocks may also be used to provide enclosed protection. During anticorrosive coating operations, the rubber components shall be covered with plastic film to prevent paint contamination and rubber aging.

(3) Storage and handling protection.

Uninstalled bearings shall be stored in a dry, shaded, and well-ventilated environment and stacked according to type. Exposure to rain, direct sunlight, and scratches from sharp objects shall be avoided.

3.3. Quality-Control Measures for Supervision

In general, supervision and quality control can be divided into three stages—pre-construction, in-process, and post-construction control—covering documentation, materials, construction procedures, and acceptance.

3.3.1. Pre-Construction Control: Eliminating Quality Risks at the Source

(1) Review of qualifications and construction plans.

The qualifications of isolation-bearing manufacturers, testing agencies, and ready-mixed concrete suppliers shall be reviewed, and the certificates of personnel performing special operations shall be

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verified. Design review meetings and technical briefings shall be organized to identify potential issues concerning bearing parameters, support-pier configurations, and isolation gaps. The contractor's specialized construction plan for seismic isolation shall undergo rigorous review and approval; construction shall not commence without the required authorization.

(2) Incoming material inspection.

For all isolation bearings and embedded components, manufacturers' certificates of conformity and mechanical-performance test reports shall be checked upon delivery. Model numbers and technical parameters shall correspond precisely to the design drawings. Bearings shall undergo unpacking and visual inspection for defects such as bubbles, insufficient rubber, cracks, and exposed steel plates. Products exceeding the allowable limits specified in the applicable standards shall be rejected. Measuring and surveying instruments shall be accompanied by valid calibration certificates.

(3) Verification of surveying benchmarks.

Supervisory personnel shall independently verify the base-plate centerlines and elevation control points and establish a dual-control surveying system to minimize positioning deviations of the support piers.

3.3.2. In-Process Control: Dynamic Control through On-Site Supervision and Inspection

The in-process stage represents the core of quality control. Supervisory personnel shall adopt a combination of continuous on-site supervision and routine inspections, with dedicated inspection records prepared for critical procedures.

(1) On-site supervision of concealed works.

Continuous supervision is required for four critical procedures: reinforcement installation of lower support piers, fixing of embedded components, concrete placement, and lifting and positioning of seismic isolation bearings. Supervisory personnel shall monitor the displacement of embedded components, bolt tightening, and compliance with lifting procedures in real time.

(2) Sequential acceptance of construction procedures.

Each procedure—including reinforcement, formwork, embedded plates, and bearing installation—shall undergo contractor self-inspection before being submitted for supervisory inspection. Nonconforming work shall be rectified in accordance with supervisory notices and may proceed to the next procedure only after passing reinspection.

(3) Process monitoring and documentation.

Records of vertical bearing deformation and photographic documentation of concealed works shall be retained concurrently. The width of isolation gaps shall be inspected periodically, and construction waste shall be removed.

(4) On-site instruction and corrective-action control.

Minor problems shall be communicated verbally and corrected immediately. Batch defects shall be addressed through formal work coordination notices. Major quality risks shall result in the issuance of a supervisory engineer's notice, while serious violations shall result in an order to suspend construction.

3.3.3. Post-Construction Control: Hierarchical Acceptance and Documentation

(1) Hierarchical quality acceptance.

Quality acceptance shall be organized progressively at the levels of inspection lot, sub-item work, and seismic isolation sub-division. Representatives of the owner, designer, contractor, supervising organization, and bearing manufacturer shall participate jointly. Critical acceptance items include bearing performance, installation accuracy, and embedded-component quality, while general acceptance items include appearance, protection measures, and isolation-gap configuration.

(2) Collection of complete acceptance documentation.

The supervision organization shall uniformly review and archive all relevant documentation, including supplier qualifications, factory test reports, third-party testing reports, concealed-work records, installation measurement records, deformation-monitoring logs, and isolation-gap inspection records.

(3) Operation and maintenance handover.

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Upon project completion, the preparation of an operation and maintenance plan for the seismic isolation system shall be supervised. The plan shall specify requirements for periodic inspection, maintenance, and replacement of isolation bearings and shall be transferred to the owner for recordkeeping.

3.3.4. Supporting Supervision and Control Measures

(1) Technical measures.

Supervisory personnel shall receive specialized training in seismic isolation standards and design drawings. Dual-person verification shall be implemented for support-pier elevations, bearing center positions, and levelness.

(2) Organizational measures.

A dedicated seismic isolation supervision engineer shall be assigned to oversee bearing-related construction procedures and provide continuous on-site monitoring.

(3) Safety and site-management measures.

A safety management log shall be established for seismic isolation works. Risks associated with lifting operations and work at height shall be controlled, while orderly storage and site management of isolation bearings shall be standardized.

(4) Schedule-control measures.

Material deliveries and bearing installation progress shall be recorded monthly and compared with the project schedule. Delayed procedures shall be coordinated and addressed promptly through monthly supervision reports.

4. Discussion

4.1. Common Quality Problems and Optimization Strategies

Based on typical problems identified through supervision inspections and acceptance activities in selected projects, common industry defects and corresponding optimization strategies are summarized below.

4.1.1. Quality Defects in Incoming Isolation Bearings

Problem: Some bearings exhibit excessive bubbles or insufficient rubber, lack complete mechanical-performance test reports, or do not conform to the models specified in the design drawings.

Countermeasures: A dual-person joint inspection system shall be established for incoming bearings. Manufacturers shall provide a unique product identification code with each shipment. Nonconforming bearings shall be removed from the site immediately. Witnessed sampling and testing shall be conducted, and bearings may be used only after they pass the required tests.

4.1.2. Excessive Positioning Deviations of Lower Embedded Plates

Problem: Vibration during concrete placement may cause embedded plates to shift or develop excessive levelness deviations, resulting in uneven loading of the bearings during subsequent operation.

Countermeasures: The fixing procedure for embedded plates shall be optimized by installing multiple layers of limiting reinforcement. Dedicated personnel shall monitor the embedded plates during concrete placement. Immediately after placement, the plates shall be remeasured and corrected. Where deviations exceed the allowable limits, the plates shall be releveled and reinforced.

4.1.3. Inadequate Protection of Completed Isolation Bearings

Problem: During superstructure construction, rubber components may be scratched, contaminated by paint, or exposed to bolt corrosion because enclosed protective measures are not implemented.

Countermeasures: Enclosed plywood protection shall be installed immediately after bearing installation. Dedicated technical briefings on finished-product protection shall be provided, and designated workers shall be responsible for monitoring the isolation layer. Damage caused by noncompliance shall be subject to accountability and compensation.

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4.1.4. Blockage of Seismic Isolation Gaps

Problem: Construction waste and mortar may accumulate within the isolation gaps, restricting horizontal displacement of the bearings and compromising the isolation function.

Countermeasures: Supervisory personnel shall inspect and clean the isolation gaps weekly. Protective barriers shall be installed, and construction waste shall be placed at designated locations. Before final acceptance, the isolation gaps shall be comprehensively cleaned and photographic records retained.

4.1.5. Incomplete Construction Monitoring Records

Problem: Vertical deformation monitoring may be omitted on certain floors, resulting in missing data and making it impossible to evaluate the long-term loading condition of the bearings.

Countermeasures: The supervision organization shall establish a mandatory monitoring log. Measurements shall be completed within 24 hours after each floor is completed, and the data shall be entered in real time. Abnormal settlement shall immediately trigger joint verification and corrective analysis with the design organization.

4.1.6. Excessive Gap between the Upper Flange Plate and Structural Steel

Problem: Because of the relatively large dimensions of the bearings, the bottom of the structural steel member may not fit tightly against the flange plate. However, the gap may remain within the allowable design range, which is specified as 5‰.

Countermeasures: All connections shall be inspected. Where the gap exceeds 5 mm, high-strength cement mortar shall be injected under pressure to fill the gap.

4.2. Development Trends

(1) Integrated product development.

High-damping rubber bearings and friction-pendulum bearings are expected to become increasingly prevalent. These systems combine load-bearing capacity with energy dissipation under large deformation and are suitable for buildings with extremely high seismic demands and large spans.

(2) Digitalized quality control.

Full-life-cycle coding and traceability of isolation-bearing products are expected to become standard practices. BIM technology can be used to simulate bearing layouts, while automated monitoring equipment can continuously collect deformation and stress data from isolation bearings.

(3) Application of combined seismic isolation systems.

Large and complex medical buildings may adopt combined systems consisting of seismic isolation bearings and viscous dampers, thereby further improving multidirectional seismic energy dissipation capacity.

4.3. Recommendations for Engineering Application and Quality Control

(1) Policy level.

High-seismic-intensity regions should strictly implement mandatory seismic isolation requirements for hospitals and schools, improve local specialized acceptance procedures, and strengthen dedicated supervision of seismic isolation projects by construction quality supervision authorities.

(2) Design level.

Design documentation should specify isolation-bearing models, support-pier configurations, isolation gaps, and protective measures in greater detail, while clearly defining requirements for deformation monitoring and operation and maintenance.

(3) Construction and supervision level.

Dedicated construction and supervision procedures shall be established. Continuous on-site supervision shall be implemented during bearing installation, and a joint five-party final acceptance system shall be adopted.

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(4) Operation and maintenance level.

A long-term inspection system for building seismic isolation systems should be established. The appearance, deformation, and corrosion-protection condition of isolation bearings should be inspected periodically, and timely assessment and replacement should be conducted when the service life is reached.

5. Conclusion

Seismic isolation should be treated not only as a structural design choice but as a lifecycle quality-management system for medical buildings in high-seismic-intensity regions. The practical value of the technology depends on maintaining the intended mechanical behavior of the isolation layer throughout construction, acceptance, and subsequent operation. Accordingly, supervision should prioritize traceable control of bearing quality, geometric accuracy, protection, deformation monitoring, and isolation-gap clearance. A coordinated management framework linking design requirements, construction procedures, supervision records, and operation and maintenance can improve the reliability of post-earthquake building functionality. The case-informed findings also indicate that future implementation should place greater emphasis on digital traceability, continuous monitoring, and integrated isolation and damping solutions where project conditions justify their use.

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