SIMPLIFIED EVALUATION OF RESIDUAL DISPLACEMENT IN SEISMIC BASE - ISOLATED BUILDING STRUCTURE

PHƯƠNG PHÁP ĐÁNH GIÁ ĐƠN GIẢN HÓA CHUYỂN VỊ DƯ TRONG KẾT CẤU NHÀ NHIỀU TẦNG SỬ DỤNG GỐI CÁCH CHẤN

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Abstract: *Since excessive permanent deformation may affect post-earthquake function and make realignment more challenging, residual displacement is a crucial performance measure for assessing the seismic resistance of base-isolated structures. While nonlinear time-history analysis (NTHA) provides accurate estimates, its computational intensity often limits its utility during preliminary design phases. This study proposes a simplified approach to evaluate residual displacement by idealizing base-isolated buildings as equivalent single-degree-of-freedom (SDOF) systems. The nonlinear response of the isolation system is characterized using a bilinear hysteresis model, allowing residual displacement to be expressed through constitutive mechanical parameters, including characteristic strength (Q_d), post-yield stiffness (K_d). The authors examined the relationship between restoring force thresholds and the formation of residual displacement. Results demonstrate the restoring force capacity exhibits a linear correlation with the post-elastic stiffness ratio (K_d/K_u), while residual displacement follows a stable first-order inverse analog relationship with the recovery force, whereas the influence of the normalized characteristic strength (Q_d/W) remains relatively modest. Furthermore, current regulatory limits for restoring forces appear to be overly conservative, potentially restricting the selection of optimal seismic isolation components.*

Keywords: *Residual displacement; seismic base isolation; bilinear hysteresis model; nonlinear time-history analysis; base-isolated building.*

Tóm tắt: *Các biến dạng quá mức có ảnh hưởng nhất định đến khả năng làm việc sau động đất của kết cấu công trình, làm cho việc khôi phục kết cấu trở nên khó khăn, do dó chuyển vị dư là yếu tố quan trọng để đánh giá khả năng chống động đất của kết cấu nhà cách chấn. Mặc dù phương pháp phân tích phi tuyến theo lịch sử thời gian cung cấp các đánh giá chính xác, nhưng yêu cầu hiệu năng tính toán lớn là rào cản quan trọng, đặc biệt là trong giai đoạn thiết kế sơ bộ. Nghiên cứu này trình bày phương pháp đơn giản hóa đánh giá chuyển vị dư bằng cách mô hình kết cấu nhà cách chấn đáy bằng hệ một bậc tự do tương đương. Phản ứng phi tuyến của hệ cách chấn đáy được mô tả bằng mô hình song tuyến tính, cho phép biểu thị chuyển vị dư thông qua các tham số cấu thành gồm độ bền đặc trưng ban đầu (Q_d) và độ cứng sau đàn hồi (K_d). Mối quan hệ giữa giới hạn lực hồi phục và chuyển vị dư được nhóm tác giả xem xét đánh giá. Kết quả cho thấy, lực hồi phục của hệ kết cấu có mối quan hệ tuyến tính với tỷ lệ độ cứng sau đàn hồi (K_d/K_u), chuyển vị dư có quan hệ ổn định dạng đường cong nghịch đảo bậc nhất với lực hồi phục, trong khi ảnh hưởng của độ bền đặc trưng ban đầu được tìm thấy không đáng kể. Hơn nữa, các quy định hiện hành đối với lực hồi phục tỏ ra quá chặt chẽ dẫn đến hạn chế việc lựa chọn các thông số cho gối cách chấn.*

Từ khóa: *Chuyển vị dư, gối cách chấn đáy, mô hình song tuyến tính, phân tích phi tuyến theo lịch sử thời gian, kết cấu nhà cách chấn.*

1. Introduction

Earthquakes remain among the most unpredictable and destructive natural hazards, capable of causing significant loss of life and severe economic disruption. Recent events, such as the 2025 Myanmar earthquake, have underscored the urgent need for infrastructure systems that not only ensure life safety but also maintain functionality after strong ground motions. While conventional seismic design primarily emphasizes ductility and controlled inelastic behavior to prevent collapse, modern performance-based approaches increasingly focus on structural resilience and post-earthquake reparability.

In this regard, seismic base isolation (SBI) has become an effective strategy for protecting critical and multi-story building structures [1-3]. By introducing a flexible interface between the foundation and the superstructure, SBI systems decouple the building from ground motion, thereby lengthening the fundamental period and significantly reducing the seismic forces transmitted to the structure [4]. As a result, both structural components and non-structural elements experience lower damage levels.

Despite these advantages, the nonlinear hysteretic behavior of isolation devices introduces important challenges, particularly in terms of large lateral drift and residual displacement. Unlike peak displacement, which governs design clearance, residual displacement represents the permanent offset of the isolation layer after the earthquake. Excessive residual displacement can lead to sustained internal stresses, damage to utility systems, and costly or impractical repair, even when overall structural stability is preserved. Therefore, a detailed assessment of this response parameter is essential to ensure post-earthquake functionality and rapid recovery.

Currently, the most reliable method for assessing residual displacement is nonlinear time-history analysis (NTHA). While accurate, NTHA is computationally intensive, requires specialized expertise, and necessitates a suite of carefully selected ground motion records to yield statistically significant results. This complexity often precludes its use during the preliminary design phase, where engineers must rapidly evaluate various isolation configurations.

To overcome these limitations, this study implements a simplified analytical framework for preliminary assessment of residual displacement of foundation isolation structures. The system is idealized as an equivalent single-degree-of-freedom (SDOF) model, in which the superstructure is represented as a lumped rigid mass, and the isolation layer is described by a bilinear hysteretic force–displacement relationship [5].

A comprehensive parametric analysis was performed by systematically varying the key constitutive parameters, namely the characteristic strength (Q_d) and post-elastic stiffness (K_d), to evaluate their influence on restoring-force capacity and re-centering performance [4]. The seismic response was obtained through nonlinear time-history analysis using recorded earthquake ground motions, with the governing equations solved via the Newmark integration method combined with a Newton–Raphson iterative scheme to capture nonlinear behavior [6, 7].

For the purposes of this study, residual displacement is defined as the permanent displacement of the isolation layer after the cessation of ground motion. Based on an extensive parametric study involving 400 combinations of isolation properties affected by various seismic recordings, this work contributes critical insights into the complex relationship between restoring force, residual displacement, and the constituent parameters of the bilinear model. These results establish a rigorous basis for evaluating residual displacement efficiency and support the design of base-isolated structures with enhanced self-centering capabilities and overall seismic resilience.

2. Nonlinear effects in base-isolated building structures

2.1 Hysteretic behavior and energy dissipation

Seismic base isolation (SBI) systems are engineered to decouple a superstructure from ground motion by introducing a flexible, energy-dissipative interface at the foundation level. By significantly increasing the fundamental period of the structure, these systems shift the structural response away from the high-energy frequency range of typical earthquake spectra.

In addition to period elongation, isolators provide critical energy dissipation through various mechanisms depending on the device type [4]:

Elastomeric Bearings: Dissipate energy through material damping and shear deformation of rubber layers.

Lead-Rubber Bearings (LRBs): Utilize the yielding of a lead core under cyclic loading to absorb seismic energy.

Friction-Based Systems (e.g., FPS): Dissipate energy via controlled sliding friction while providing a restoring force through geometric curvature.

These mechanisms are inherently nonlinear, arising from material yielding, frictional sliding, and large shear deformations. Under seismic impacts, this nonlinearity results in hysteretic force–

displacement loops, where the area within the loop represents the energy dissipated during each cycle.

2.2 The bilinear hysteresis model

To achieve a balance between computational efficiency and analytical accuracy, the nonlinear behavior of isolators is commonly represented using a bilinear hysteretic model. The mechanical response in this model is governed by several constitutive parameters, as shown in Figure 1, are defined as follows:

- Characteristic Strength *(Q_d)*: The yield force at which the system transitions from high initial stiffness to a post-elastic state;

- Initial Elastic Stiffness *(K_u)*: The slope of the initial linear segment, providing rigidity against non-seismic loads like wind;

- Post-Elastic Stiffness *(K_d)*: The reduced stiffness after yielding, which acts as the primary restoring force required to re-centre the structure;

- Elastic Limit *(F_y)*: This is the force corresponding to the point of yielding. It is mathematically derived from the other parameters, such as:

$$F_y = Q_d \times \frac{K_u}{K_u - K_d}$$

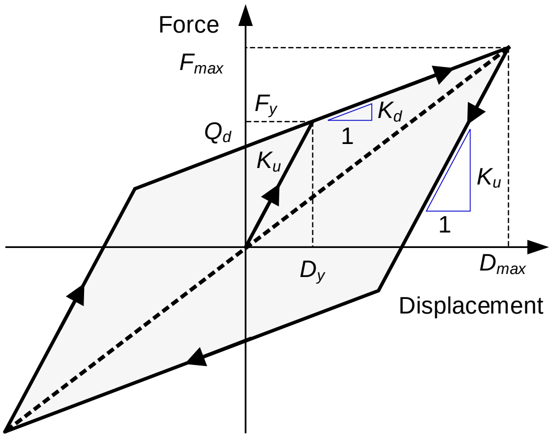

Figure 1. *Bilinear hysteresis model*

Among these parameters, the characteristic strength and the post-elastic stiffness are the most critical parameters. They directly influence the isolator's effectiveness and the structure's overall performance during a major earthquake. These two values are essential for ensuring the system dissipates energy correctly and extends the building's natural period as intended.

An important consequence of this bilinear behavior is the potential for residual displacement. If the restoring force provided by Kd is insufficient to overcome the inelastic deformation or frictional resistance during unloading, the system will fail to return to its original equilibrium position.

2.3 Impact of residual displacement on structural resistance

Although the nonlinear hysteretic behavior of isolation systems is essential for reducing seismic force transmission to the superstructure, it may also result in incomplete re-centering after strong ground motions. As a consequence, the isolation layer may not return to its original equilibrium position, leaving a permanent lateral offset after the seismic excitation ceases. This phenomenon, referred to as residual displacement, plays a critical role in assessing the post-earthquake condition and functionality of base-isolated structures.

Residual displacement can adversely affect structural performance in several ways:

- Structural integrity: Permanent offsets may induce sustained internal stresses in structural components such as columns, beams, and shear walls, potentially altering load paths and compromising long-term durability;

- Non-structural damage: Residual deformations can lead to cracking, misalignment, or detachment of partition walls, façades, and architectural finishes;

- System functionality: Utility systems crossing the isolation interface, including plumbing and electrical conduits, are particularly vulnerable to damage due to deformation incompatibility.

Therefore, controlling and accurately predicting residual displacement is essential to ensure not only structural safety but also post-earthquake serviceability and rapid recovery.

3. Case study

To achieve the specified objectives of the research, a representative multi-story building is analyzed. The structure consists of 15 floors, comprising 14 stories above grade and one basement level. The story heights are 3.6 m for the typical floors and 3.3 m for the basement. The building plan dimensions measures 24 m by 30 m, organized into a grid of four bays in the X-direction and three bays in the Y-direction, as shown in Figure 2.

The force-resisting system is composed of a reinforced concrete (RC) frame and shear wall system with the following section properties: Primary beams are 30 cm x 60 cm, secondary beams are 25 cm x 45 cm; Column sections progressively reduced to optimize mass, with 80 cm x 80 cm sections (stories 1÷5), 70 cm x 70 cm (stories 6÷10), and 60 cm x 60 cm (story 11 to roof); Wall thickness is maintained at 25 cm, while floor slabs are 15 cm thick.

- Material: concrete grade #B25, reinforcement grade CB400-V [8];

- Loading: the floor loading: dead load 120 daN/m^2, live load 240 daN/m^2 (on the floor) and 90 daN/m^2 (on the roof); Figure 2 shows the 3D model of the building by using Etabs [9].

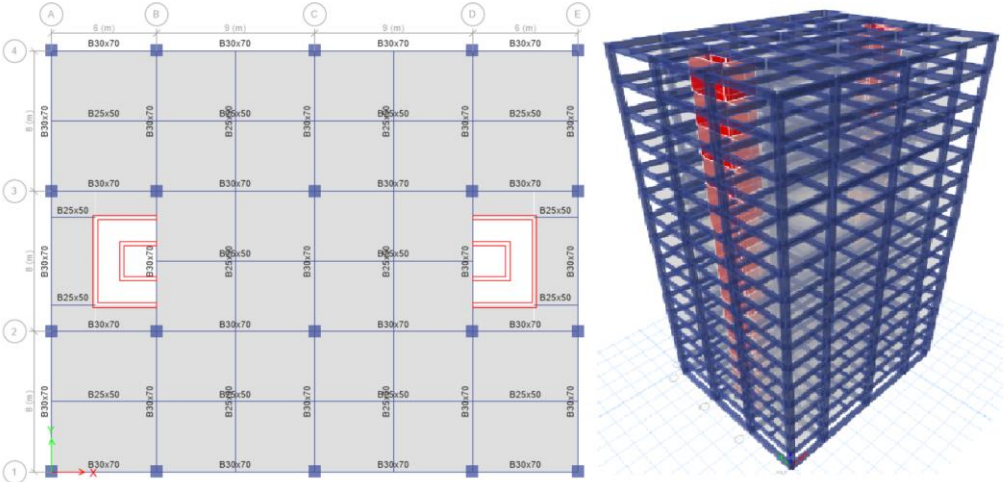

Figure 2. *Specific base-isolated multi-story building*

The building superstructure is idealised as a rigid lumped mass, all the isolation units experience the same displacement, and their properties can therefore be lumped into a single equivalent isolation unit representing the SIS. The building model serves as the benchmark to verify the accuracy of the simplified single-degree-of-freedom system (SDOF), as show in Figure 3. The nonlinear behavior of the isolation interface at the base is explicitly modeled to capture the hysteretic energy dissipation and the resulting residual displacements under time-history records.

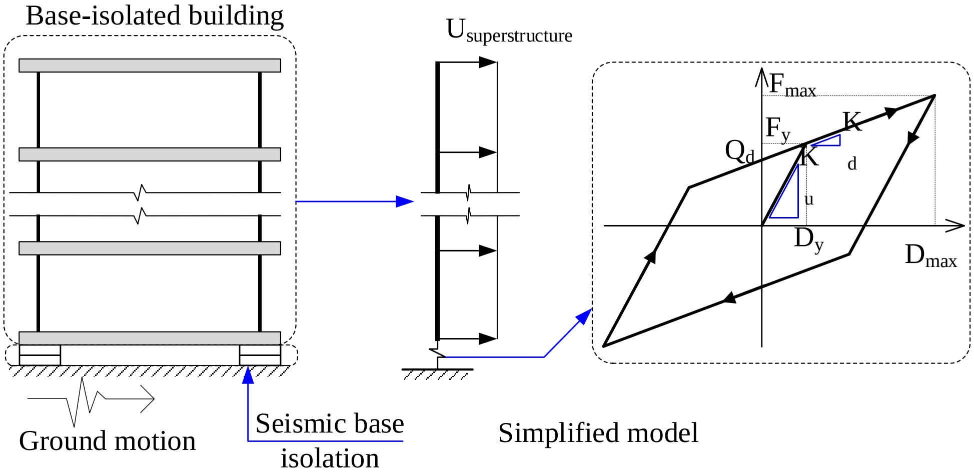

Figure 3. *Simplified model of base-isolated building structure*

The total mass of building is approximately assumed to be M=11474 (Ton), the non-isolated period of the system is assumed to be T_e = 0.4s.

The representative building is supported on the soil class B, located Son La, Viet Nam with the elastic response spectral acceleration according to TCVN 9386:2025 [10], representative by a_{gR} = 0.1893g [10] (g=9.81 m/s^2). To perform the nonlinear response history analysis, three historical ground motion records, including El Centro (USA), Kobe (Japan), and Northridge (USA) [11], were selected. These records were scaled using the linear scaling method [12, 13] to match the target elastic response spectrum, as shown in Figure 4.

Table 1. *Earthquake records used for response history analysis*

Earthquake	Station	Mw	R (km)	PGA (g)
El Centro, 1940-05-19	302 Commercial, Imperial Valley Irrigation District, CA, USA	6.9	12.2	0.355
Kobe, 1995-01-16	Nishi-Akashi, Japan	6.9	19.9	0.509
Northridge, 17-01-1994	Castaic-Old Ridge Rte, CSMIP station 24278	6.7	41	0.568

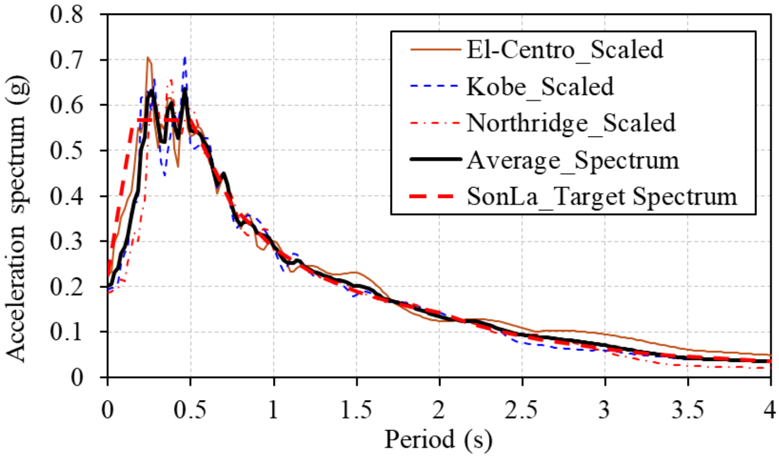

Figure 4. *Acceleration spectrum of scaled ground motion used for study*

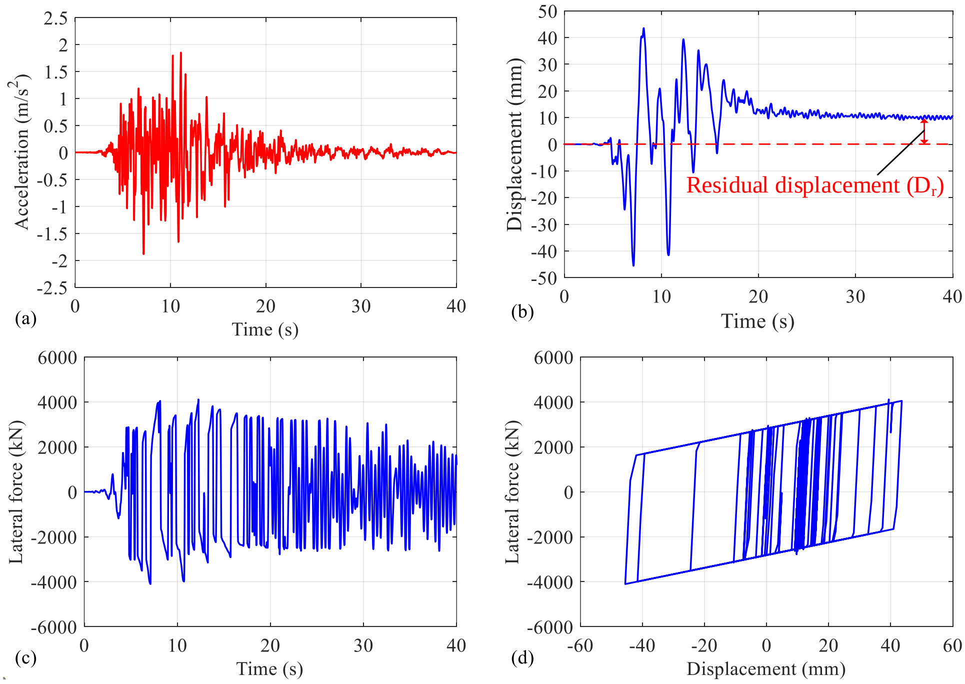

Figure 5. *Nonlinear response of base-isolated building structure subjected to Kobe scaled-ground motion*

The nonlinear behavior of the isolation is represented by a bilinear hysteretic model. For this specific case, the characteristic strength is set to 2% of the seismic weight, and the post-elastic stiffness is defined as 1% of the initial elastic stiffness.

The results of the nonlinear analysis, specifically under the scaled Kobe ground motion, are presented from Figure 5(b) to (d). A critical observation from the force-displacement response is the emergence of residual displacement. This permanent lateral offset remains at the isolation after the ground motion has ceased and the system has undergone unloading. The presence of residual displacement after unloading can adversely affect the normal operational state of a structure. Therefore, reliable estimation of residual displacement during the design phase is essential for anticipating structural response under seismic loading and for developing appropriate performance and recovery scenarios following an earthquake.

A critical requirement for the "normal operating state" of a base-isolated structure is its capacity to re-centre following a major seismic event. According to the provisions in TCVN 9386:2025, the isolation system must provide a minimum restoring force to mitigate excessive permanent offsets. Specifically, the standard mandates that the increase in restoring force for displacements between 0.5 and 1.0 times the design displacement must not be less than 2.5% of the total gravity load above the isolation interface. More specifically,

$$\begin{cases} F_{resto} = F(D_{\max}) - F(\frac{D_{\max}}{2}) = K_d \frac{D_{\max}}{2} \Rightarrow \frac{K_d D_{\max}}{W} \geq 5\% \\ F_{resto} \geq 2.5\% W \end{cases}$$

Mechanically, this restoring force acts as the primary antagonist to residual displacement. As the restoring force capacity decreases, the system's ability to overcome internal hysteretic friction and inelastic deformation is diminished, leading to a higher probability of significant permanent lateral drift.

To evaluate this relationship, a representative analysis was conducted using the specified building model subjected to the scaled Kobe earthquake record. Figure 6 illustrates the correlation between the restoring force and the resulting residual displacement.

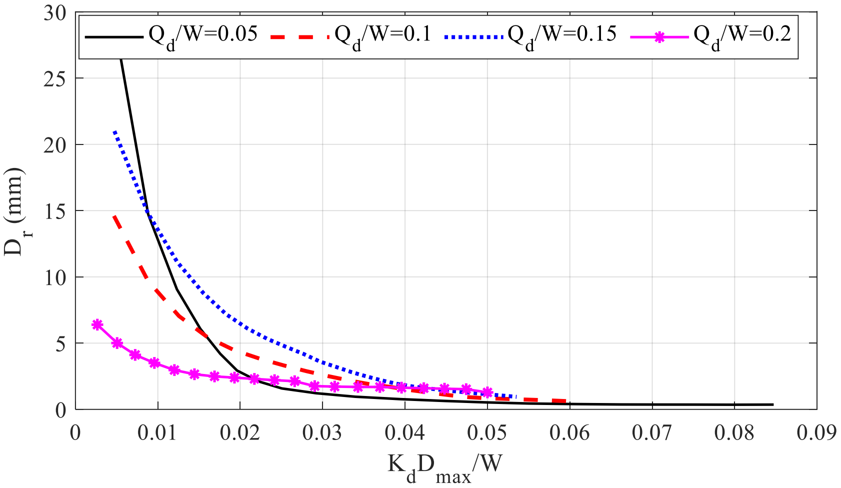

Figure 6. *Residual displacement as function of restoring force of building subjected to Kobe scaled ground motion*

The numerical results indicate that structures not satisfying the 2.5% gravity load threshold exhibit a pronounced and nonlinear increase in residual displacement. In contrast, systems that comply with the requirements of TCVN 9386:2025 maintain residual displacements within a range generally considered repairable and/or continuously operational. These findings highlight the importance of evaluating residual displacement during the design stage. By ensuring that the restoring force meets the prescribed criteria, engineers can establish reliable response scenarios and enhance the post-earthquake serviceability of base-isolated structures.

To further investigate these effects, a more comprehensive analysis was carried out to systematically evaluate the influence of the constitutive parameters of bilinear model on the residual displacement response of the base-isolated system. Two key dimensionless parameters were considered: the normalised characteristic strength ratio Q_d/W ranging from 0.01 to 0.2, and the post-elastic stiffness ratio K_d/K_u ranging from 0.005 to 0.10.

4. Results and discussion

4.1 Influence of restoring force on residual displacement

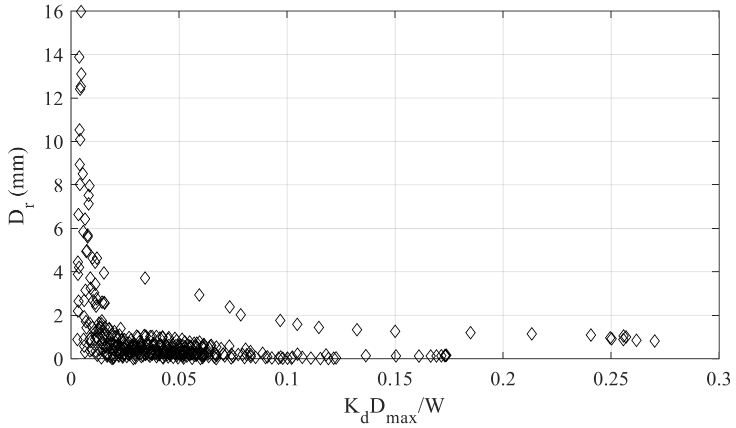

Figure 7. *Residual displacement of building subjected to El-Centro scaled accelerogram*

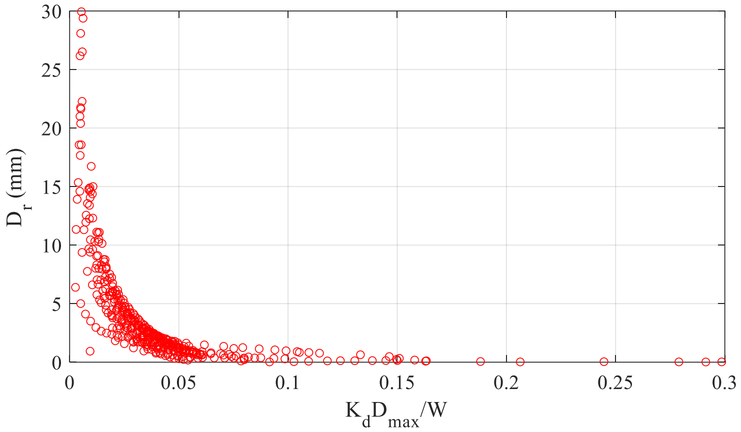

Figure 8. *Residual displacement of building subjected to Kobe scaled accelerogram*

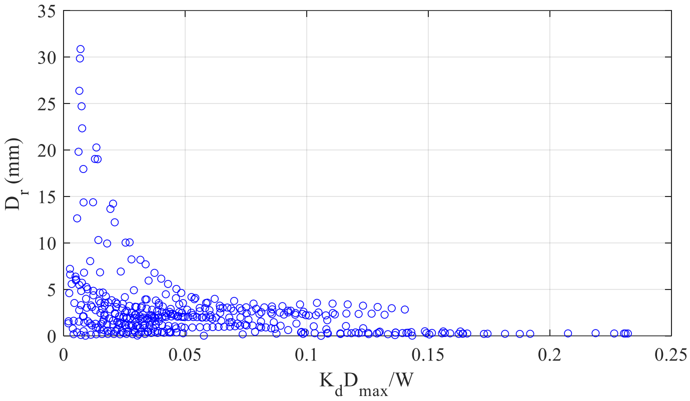

Figure 9. *Residual displacement of building subjected to Northridge scaled accelerogram*

The results of the parametric study provide a basis for re-examining the conservatism of the 2.5% restoring-force requirement specified in TCVN 9386:2025. While this limit is intended to ensure adequate restoring capability, the numerical results indicate that it may be conservative for certain structural configurations.

As shown in Figure 7 - 9, a substantial number of analysed cases exhibit residual displacements of less than 5 mm, even when the restoring-force capacity is below the 2.5% gravity load threshold. For a representative 15-story building, such a residual displacement corresponds to a negligible drift ratio and is unlikely to affect the operational condition of the structure or the performance of non-structural components.

These findings suggest the presence of an inherent safety margin within the current provisions, which may lead to over-conservative design. Increasing the restoring-force requirement typically necessitates higher post-yield stiffness or larger characteristic strength, both of which reduce the flexibility of the isolation system. This, in turn, may increase floor accelerations and base shear demands, thereby diminishing the primary objective of seismic isolation-namely, the reduction of seismic forces transmitted to the superstructure.

Based on these observations, it is proposed that the current 2.5% threshold could be refined into a performance-based, multi-level criterion. For structures where small residual displacements (e.g., less than 10 mm) do not compromise functionality or critical systems, a lower restoring-force requirement may be acceptable. Such an approach would provide greater design flexibility, enable optimisation of isolation performance while maintain satisfactory post-earthquake serviceability.

4.2 Influence of Q_d/W and K_d/K_u on restoring capacity

The re-centring capability of a base-isolated structure is fundamentally governed by the restoring force developed within the isolation interface at peak displacements. To evaluate the sensitivity of this capacity, a parametric study was conducted focusing on the normalized characteristic strength and the post-elastic stiffness ratio.

As illustrated in Figure 10, the restoring capacity of the isolator exhibits a strong and approximately linear correlation with the post-elastic stiffness ratio. From a mechanical perspective, K_d represents the effective stiffness of the system beyond the yield point and governs the slope of the hysteretic response in the inelastic range. As K_d/K_u increases, the tangent stiffness of the hysteresis loop remains positive and steep, ensuring that a significant restoring force is stored at the maximum displacement.

The results indicate that increasing the post-yield stiffness ratio is an effective means of enhancing restoring capability and ensuring compliance with the 2.5% gravity load requirement specified in TCVN 9386:2025. Structures with higher post-elastic stiffness ratios exhibit a stronger restoring mechanism, which facilitates the recovery of displacement after unloading and counteracts the residual effects associated with hysteretic energy dissipation.

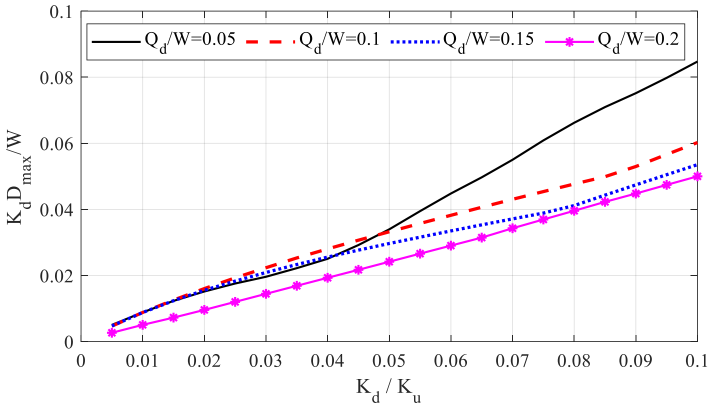

Figure 10. *Restoring capacity of isolator as function of post-elastic stiffness ratio*

In contrast, Figure 11 demonstrates that the characteristic strength ratio (Q_d/W) has a more complex and less dominant effect on the restoring capacity. While Q_d is the primary parameter for energy dissipation, it can actually act as a resistance to re-centring. A higher Q_d/W increases the force required to initiate movement back toward the equilibrium position (e.g., $K_d/K_u = 0.01$, as shown by black line). Therefore, if the strength is increased without a proportional increase in post-elastic stiffness, the system's restoring reliability may actually decrease. The results suggest that for optimal performance, Q_d/W should be carefully calibrated alongside K_d/K_u to ensure that the stored elastic energy at peak displacement is sufficient to overcome the characteristic yield strength of the bearings.

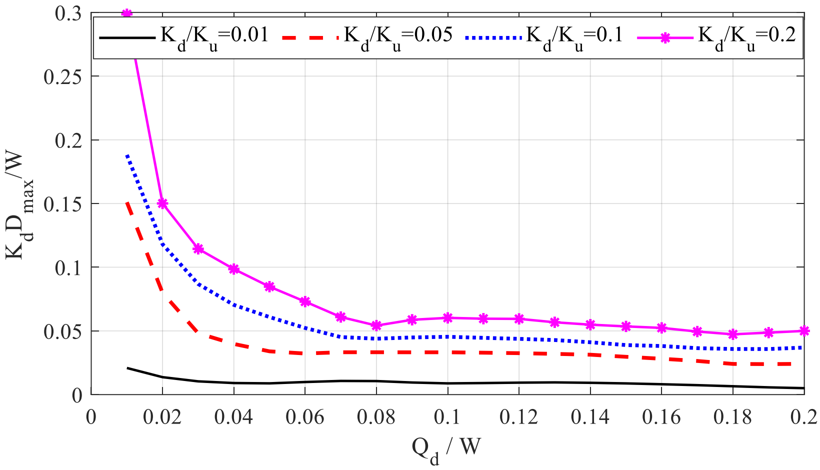

Figure 11. *Restoring capacity of isolator as function of characteristic strength*

4.3 Discussion and predictive modeling

The parametric analysis demonstrates a clear and consistent correlation between the post-elastic stiffness ratio and the magnitude of residual displacement. As observed in the comparative results, residual displacement decreases markedly with increasing restoring force. This trend is mechanically consistent, as K_d governs the restoring-force capacity of the isolation system in the inelastic range; a higher stiffness ratio enhances the ability of the system to overcome permanent offsets accumulated during strong seismic cycles.

From a design perspective, however, increasing K_d reduces the effective flexibility of the isolation layer, thereby limiting its ability to lengthen the fundamental period of the structure - key features of seismic isolation technique. Consequently, the selection of K_d requires a careful balance between improving re-centring capability and preserving the primary objective of seismic isolation, namely the reduction of force and acceleration demands.

In contrast, the influence of the normalised characteristic strength ratio Q_d/W on residual displacement is found to be less pronounced. While Q_d plays an important role in energy dissipation and in controlling peak response, it does not appear to be the dominant factor governing the system's ability to return to its original equilibrium position.

The parametric results highlighted in Figures 10 and 11 provide critical evidence that the 2.5% restoring force requirement specified in TCVN 9386:2025 is significantly conservative. Nevertheless, the relationship is not uniform across all cases. In several instances, negligible residual displacements (less than 5 mm) were achieved even when the restoring force fell slightly below this threshold, provided that sufficient post-yield stiffness was maintained.

These findings suggest that the current regulatory limit may impose undue constraints on the selection of seismic isolation bearings. There are grounds to propose a performance-based approach instead of rigid regulations, optimizing the selection of seismic isolation bearings to ensure both self-centering capability and maximum damping efficiency. Spefically, a more refined, performance-based approach-one that considers the specific interaction between post-elastic stiffness ratio and the allowable operational tolerances of the building-would enable more efficient optimization, allowing for superior seismic isolation performance without compromising structural restoring.

5. Conclusion

This study investigated the residual displacement response of base-isolated structures by utilizing a simplified single-degree-of-freedom (SDOF) analytical framework. By idealizing the isolation system with a bilinear hysteretic model, the research evaluated the sensitivity of permanent offsets to key constitutive parameters under diverse seismic excitations. The following conclusions are drawn from the analytical and numerical results:

- Primary driver of re-centring: The post-yield stiffness ratio (K_d/K_u) is identified as the most critical factor influencing residual displacement via restoring force. An increase in this ratio consistently enhances the system's restoring force, effectively overcoming inelastic offsets developed during intense seismic cycles;

- Secondary influence of yield strength: The normalized characteristic strength ratio (Q_d/W) exhibits a relatively modest and inconsistent influence on residual displacement. While Q_d is essential for energy dissipation and peak displacement control, it serves as an unreliable predictor for the system’s ability to return to its original equilibrium position;

- Critical evaluation of TCVN 9386:2025: Numerical evidence suggests that the current regulatory requirement, mandating a restoring force of at least 2.5% of the gravity load, is overly conservative. Many cases demonstrated negligible residual displacements (less than 5 mm in this case study) even when the restoring force fell below this threshold;

- Feasibility of simplified prediction: The restoring force capacity exhibits a linear correlation with the post-elastic stiffness ratio, while residual displacement follows a stable first-order inverse analog relationship with the recovery force. These consistent physical trends enable the development of regression-based predictive functions that accurately capture the primary characteristics of the permanent seismic response.

REFERENCES

[1] Morgan, T.A. (2007), *The Use of Innovative Base Isolation Systems to Achieve Complex Seismic Performance Objectives*. University of California, Berkeley.

[2] Ismail, M., J. Rodellar, and F. Ikhouane (2010), *An innovative isolation device for aseismic design.* Engineering Structures. 32(4): p. 1168-1183.

[3] Cheng, F.Y., H. Jiang, and K. Lou (2008), *Smart structures: innovative systems for seismic response control*. CRC press.

[4] Naeim, F. and J. M. Kelly (1999), *Design of seismic isolated structures: from theory to practice*. the United States of America: John Wiley & Sons.

[5] Xuan Dai, N., N. Van Tu, and P. Nam Phong (2020), *Evaluation of equivalent linearization analysis methods for seismically isolated building using Lead-Rubber Bearing.* Journal of Science and Technique-Section on Special Construction Engineering, 3(02).

[6] Chopra, A.K. (2017), *Dynamics of structures: Theory and Applications to Earthquake Engineering*. Pearson Education India: Prentice-Hall international series in civil engineering and engineering mechanics.

[7] Paultre, P. (2005), *Dynamique des structures.* Editions Hermes Lavoisier, Paris, France.

[8] TCVN-5574:2018 (2018), *Vietnam national standard - Design of concrete and reinforced concrete structures*. Ministry of Science and Technology.

[9] CSI (2020), *CSI analysis reference manual for SAP2000, ETABS, SAFE, CSiBridge, and PERFORM 3D*. Computers and Structures Berkeley, CA.

[10] TCVN-9386:2025, *Vietnam national standard - Design of structures for earthquake resistances*. Ministry of Science and Technology.

[11] PEER. *https://www.strongmotioncenter.org/*. 2021.

[12] Nguyen, X.D., et al. (2024), *Automated calibration of recorded ground motions for nonlinear response history analysis of isolated bridges.* International Journal of Structural Engineering, 14(4): p. 437-460.

[13] Dai Nguyen, X. (2022), *A proposed method for selecting and scaling recorded seismic accelerations according to TCVN-9386:2012.* Journal of Science and Technology in Civil Engineering (STCE)-HUCE. 16(1): p. 100-112.