PRACTICAL APPLICATIONS OF DAMPERS TO HIGH-RISE BUILDINGS

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1. INTRODUCTION

Recent investigations have revealed that the damping ratios of tall buildings are typically only around 0.5% to 2%, significantly lower than previously assumed and generally decrease with building height [1]. This finding has important implications for the seismic and wind-resistant design of such structures. Across various regions, there have been reports of severe shaking in tall buildings caused by long-period ground motions and typhoons, resulting in damage to both structural and non-structural components, as well as adverse effects on habitability due to prolonged vibrations.

In Thailand, for instance, the earthquake that occurred in central Myanmar on March 28, 2025, caused prolonged shaking in many tall buildings throughout Bangkok. Damage to structural and non-structural elements was also reported, highlighting the vulnerability of these buildings to long-period seismic events.

To mitigate the effects of such shaking, dampers are increasingly being adopted as an effective solution. This paper presents case studies of tall buildings equipped with dampers in Japan and the Philippines, where seismic and wind demands are particularly stringent.

2. DAMPER APPLICATIONS IN JAPAN

1) Design Criteria

Table 1 presents the performance objective for tall buildings in Japan. In addition to these standard criteria, clients often impose even more stringent performance requirements depending on the building's intended use and importance.

Table 1: Performance objective for tall buildings in Japan

Items	Demand Levels	
	Rare Earthquake (RE) RP: 75 years	**Extremely Rare Earthquake (ERE) RP: 475 years**
Performance Objective	Operational	Limited Damage
IDR	1/200	1/100
Ductility factor of each component	Essentially elastic	4.0 or less

2) New Construction

In Japan, the use of dampers is a common strategy in the seismic and wind-resistant design of new tall buildings. Typically, a combination of velocity-dependent dampers (such as oil dampers and viscous damping walls) and displacement-dependent dampers (such as Buckling-Restrained Braces [BRBs] and friction dampers) are employed to optimize performance for various loading conditions.

Case Study – TOKYO TORCH Tokiwabashi Tower[2] (192m, Column: CFT, Girder: Steel)

In this project, oil dampers and viscous damping walls were installed from the first to the eighth floor to mitigate seismic effects. Above the eighth floor, BRBs were strategically concentrated to enhance seismic performance. Additionally, a hybrid mass damper (HMD) was installed at the rooftop level to reduce both wind-induced vibrations and seismic responses.

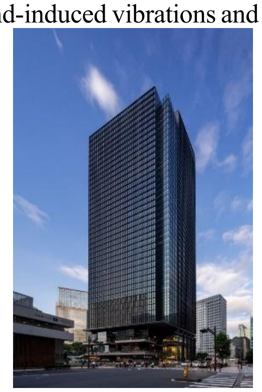

Figure 1. TOKYO TORCH Tokiwabashi Tower
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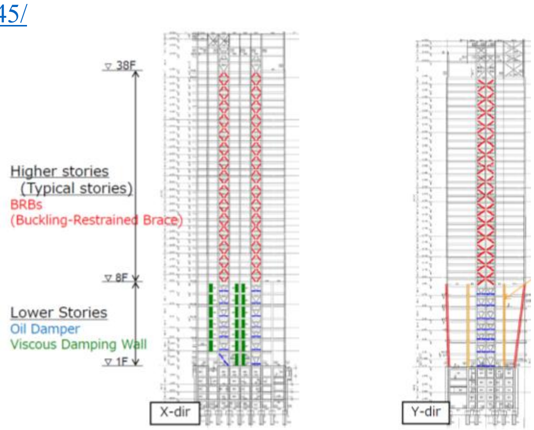


Figure 2. Damper layout

3) Seismic Retrofit against long-period earthquake

The Great East Japan Earthquake on March 11, 2011, brought significant attention to the effects of long-period ground motions in Japan. Even in areas far from the epicenter, buildings constructed on soft soil experienced prolonged shaking, revealing the vulnerability of tall buildings to such motions.
As a result, many existing tall buildings have undergone seismic retrofitting using dampers to address these issues.

Case Study – Sakishima Building, Osaka [3]
(256m, Steel structure)
Despite being located approximately 770 km from the epicenter of the 2011 earthquake, the upper floors of this building experienced prolonged shaking lasting nearly 600 seconds, with a maximum displacement of 1.3 meters and a peak acceleration of 1.3 m/s².
To address this, 140 oil dampers were installed in the short direction and 152 BRBs in the long direction. This retrofit successfully reduced deformation at the upper levels by 42% in the short direction and 56% in the long direction.

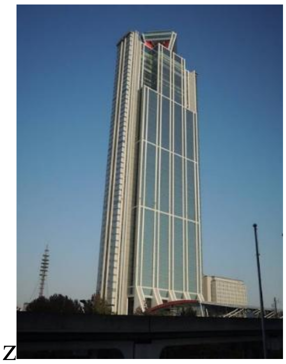
z 

Figure 3. Sakishima Building, Osaka
http://www.tanikenchiku.com/250.htm

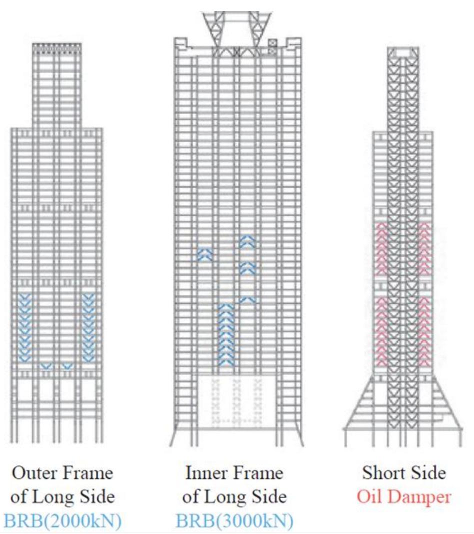


Figure 4. Damper Layout

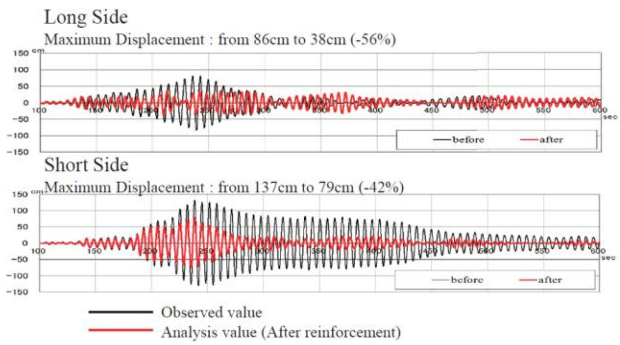


Figure 5. Effect of Dampers

3. DAMPING SYSTEMS FOR EARTHQUAKE AND WIND PROTECTION OF TALL REINFORCED CONCRETE BUILDINGS

1) Viscoelastic Dampers

Viscoelastic dampers were the first damping system used for tall buildings, with the first project in 1969 in North America and later in 1990s in Japan and Taiwan. Nippon Steel Engineering Co. has been supplying Viscoelastic dampers since the 1990s. Viscoelastic dampers consist of multiple layers of solid viscoelastic (VE) material sandwiched between and bonded to multiple steel plates. Each consecutive steel layer is extended out and then anchored to the structure. When the VE material is strained under dynamic loads there is a instantaneous viscous and elastic restoring force applied to the building structure.
A primary advantage of distributed VE dampers is that they add supplemental damping to the building structure immediately and for all amplitudes of vibration because they are configured rigidly. Furthermore, they can be used for all frequencies of vibration and all types of dynamic loads. This results in benefits for both service level and strength level wind and seismic loads. Furthermore, VE dampers do not require any maintenance or monitoring over the life of the building to ensure performance. Because tall buildings have such low levels of inherent damping this reliable instantaneous supplemental damping greatly reduces both service and strength level wind and seismic loads. The impact is that buildings with distributed viscoelastic deform less, come to rest quicker and are more resilient when properly implemented in design.
Distributed dampers have historically been configured in shear-type frame buildings either as braces or vertical damping panels, which are engaged by inter-story racking of the structure. This is efficient and practical for low rise steel frame buildings, but today's tall and slender reinforced concrete (RC) buildings behave more like cantilevers under lateral loads. The lateral load resisting systems of tall buildings are now primarily formed by vertical structural elements coupled together with coupling beams or outriggers, which are deformed and stressed in vertical shear. Those heavily stressed coupling members are ideal locations to configure dampers to add distributed damping to high-rise buildings
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2) Viscoelastic Coupling Dampers (VCDs)

These features led to the development of the Viscoelastic Coupling Dampers (VCDs) at the University of Toronto in collaboration with Nippon Steel Engineering and Kinetica (Figure 5) **[4]**.

Figure 5. VCD Schematics in core wall and outrigger configurations

When tall reinforced concrete buildings, equipped with VCDs, deform due to wind and earthquake dynamic loads they deform the VCDs in the vertical direction shearing the VE material providing instantaneous elastic and viscous forces (Figure 6).

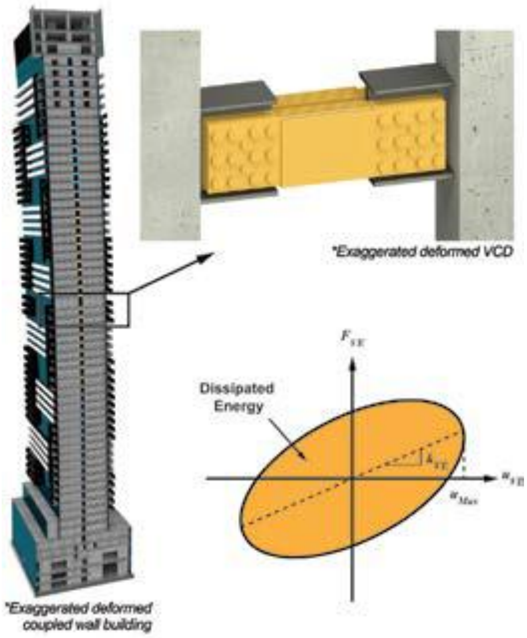


Figure 6. VCD Schematics in core wall and outrigger configurations

Over 10,000 tests have been conducted in full-scale and many more component and material level tests at the University of Toronto since early 2000s (see Figure 7) on the VCD system, with all samples were provided by Nippon Steel Engineering.

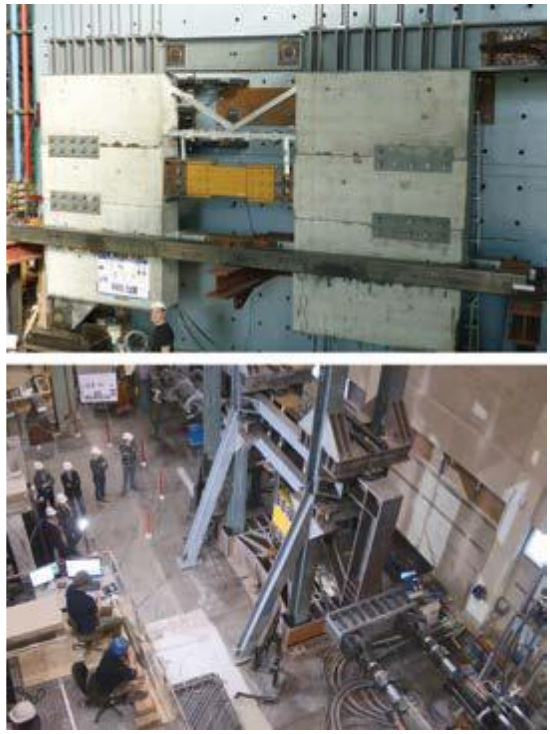


Figure 7. Full-Scale VCD Tests at the University of Toronto

3) VCD Project Applications in Philippines

In Philippines, the use of tall reinforced concrete buildings is commonplace. VCDs have recently become a high-performance choice for developers wanting to improve their performance in a cost-effective manner. The VCDs have been implemented in Connors at Greenhills, Park Central Towers 1 and 2 in Makati, Parklinks Towers 1 and 2, BWDC and The Seasons Residence 1, 2, 3 and 4 in the past five years in Metro Manila following the Philippines design code and a performance-Based Seismic design philosophy. Both core wall and outrigger VCD configurations have been used in Philippines.

Case Study – Park Central Towers 1 and 2
(260m and 210m, Reinforced Concrete)

Park Central Towers, located in Makati, consists of two towers connected by a shared podium (see Figure 8). Both towers utilized four levels of a flag wall damped outrigger configuration with VCDs spanning between the external columns and the concrete flag wall cantilevered off of the RC core. There are a total of 128 VE damper panels supplied by Nippon Steel Engineering. This configuration provided 2% supplemental damping in shorter building and 3% damping in the taller building for the primary sway modes of vibration.

Figure 8. Park Central Towers 1 and 2

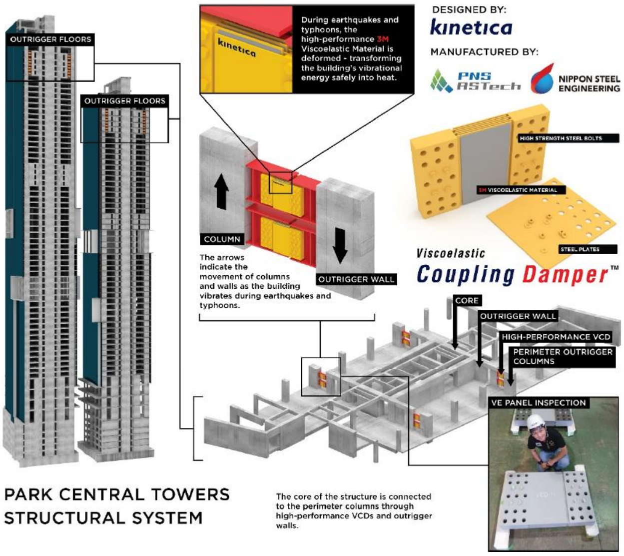
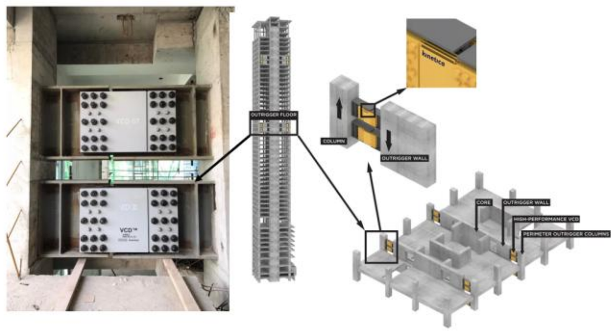


Figure 9. Schematics of the Outrigger Configuration in Park Central Towers 1 and 2

Case Study – The Seasons Residence Towers 1, 2, 3 and 4 (150 - 180m, Reinforced Concrete)

The Seasons Residence consists of four reinforced concrete towers connected by a four-story podium with the well-known Japanese department store Mitsukoshi. All towers in the development used multiple flag wall damped outriggers with VCDs spanning between the external columns and the concrete flag wall cantilevered off the RC core. Over 500 VE damping panels were supplied by Nippon Steel Engineering for the project. The dampers were particularly used for minimizing wind and seismic drifts under frequent loads, with supplemental damping provided between 3% and 8% in the fundamental modes of vibration depending on the tower. Advertising enhanced comfort for wind and seismic vibrations from VCDs was utilized by the developer which was unique for the Philippines construction market.



7. REFERENCE

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