The Supplementary Damping Advantage - Flexibility for a High-Rise Building

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Summary

In recent years in North America, there has been a growing trend towards using Supplementary Damping Systems (SDS) to improve the wind-induced dynamic behavior of mid-rise to high-rise buildings. During the design stages of a project, incorporating an SDS into the building is an efficient way to reduce expected tower motions and thereby enhances the comfort experience for the future occupants of the building. Likewise, the improvement in building dynamic performance can also be used to strategically optimize the structural system.

A design benefit analysis of an SDS is currently being applied to a proposed high-rise residential building in Toronto, Canada. For this project, Halcrow Yolles Structural Engineers and RWDI Motioneering Consulting Engineers have performed design assessments of the expected dynamic performance of the building. The original design of the tower's lateral system was performed using conventional methods, with motion criteria satisfied by way of a coupled shear wall core to provide sufficient stiffness properties. As an option to the project developer, a study was conducted to investigate implementing an SDS to the original lateral system design to simultaneously: (a) minimize the thicknesses of the concrete core shear walls (thereby saving construction materials, costs, and maximizing useable floor space for the developer) and, (b) maintain the tower motions within acceptable comfort guidelines for future occupants.

A cost/benefit analysis has been performed which indicates that significant savings in structural costs (between $400,000 and $500,000) are possible, which can offset the expense of designing and constructing an SDS. "Green benefits" of saving concrete and reinforcing steel can translate into reductions in greenhouse gas emissions (CO_2) of about 670 tons (the equivalent of removing about 143,000 cars from the road for one typical day in North America). These 'green benefits' can earn credits towards LEED certification or similar building credentials. As a second option for the developer, assessments indicate that by using an SDS five additional residential floors could be added without changes to the baseline structural core system, wall thicknesses, or unit layouts. This could result in approximately $30 million of additional sales revenue for the developer without significant modifications to the original design.

Keywords: supplemental damping systems, high-rise buildings, LEED, sustainable design, wind-induced responses.

What is a Supplementary Damping System?

One proven way to achieve a specific overall damping level is to incorporate a Supplemental Damping System (SDS) into the structure. An SDS is essentially a supplemental energy dissipation system that is optimally designed to absorb vibration energy from a structure, thereby reducing

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energy dissipation demand on the structure. There are many ways to add energy absorption to a structural system. Technologies in common use today can be broadly classed as distributed, impact, active mass, semi-active mass, mechanical passive tuned mass, and liquid-based passive tuned mass. Liquid tuned mass dampers typically have one of two forms, Tuned Liquid Column Dampers (TLCD) or Tuned Sloshing Dampers (TSD). The focus of this paper is on implementing Tuned Sloshing Dampers due to their attractive qualities of simplicity, low cost and dependability with little or no maintenance.

The Aura at College Park, Toronto, Ontario, Canada

Aura – The Residences at College Park Phase III, located in downtown Toronto, Ontario, Canada is a proposed 240 m tall tower being built by Canderel Stoneridge. The development consists of six basements beneath a five storey retail podium. The tower contains 71 floors of residential condominiums beginning at the fifth floor, with three primary typical tower floor plates providing step-backs over the elevation of the structure.

With the lateral system developed for the 75-storey tower, the client became interested in an option to increase the height of the structure, thereby adding more residential units to the tower. Given concerns about high torsional velocities, there was no reserve in the current lateral system to achieve additional tower height, due to increased wind responses associated with the increased mass and reduced stiffness of the structure.

As a result, Halcrow Yolles and RWDI Motioneering undertook two desktop analytical studies to estimate the wind induced tower responses, as follows: (1) A conventional study to determine additional height (to reach 80+ storeys) that could be achieved while maintaining the base lateral system, and (2) An assessment of achievable reductions in structural wall thicknesses for the 75-storey tower by adding supplemental damping, while maintaining the wind responses of the tower to acceptable levels of occupant comfort. Based on preliminary data from RWDI Motioneering, it was agreed that providing a total damping ratio of 3.0% (assumed inherent damping ratio of 2.0% plus 1.0% supplemental damping) of critical to the structure would produce a sizable reduction to structure while maintaining the cost of the damping system to a reasonable level.

Damping Solution for Aura

After the decision was made to include an SDS, a Supplementary Damping System Implementation Assessment was undertaken by RWDI Motioneering to determine the optimal size and location of the SDS damper(s) in Aura. Given the specific damping system design needs of the building, a TSD system was determined to be the best candidate as it would likely provide the most cost effective solution for supplementary damping within the defined space envelope. A range of possible TSD configurations was explored during this study, and an optimal configuration was selected. The damping system was optimized to the 50-year return period event, with a goal for the wave behavior to remain predictable during large amplitude motions. To provide a damping ratio of approximately 3.0% of critical for the three fundamental modes of vibration (X-sway, Y-sway and torsion), two dual-axis SDS tanks were deemed necessary in this case. The water in these tanks can also be utilized for the fire-suppression system, thus removing the necessity of installing a third tank for dedicated fire-suppression.

Conclusions

A cost/benefit analysis has been performed which indicates that significant savings in structural costs (between $400,000 and $500,000) can be expected. These costs can offset the expense of designing and constructing an SDS. Environmental benefits of saving concrete and reinforcing steel can translate into reductions in greenhouse gas emissions (CO_2) of about 670 tonnes (the equivalent of removing about 143,000 cars from the road for one typical day in North America). These ‘green benefits’ can potentially earn credits towards LEED certification.

[1] Additional design flexibility has also been achieved for the developer, whereby the performance enhancement of the SDS will allow them to add five additional residential floors without changes to the baseline structural core system, wall thicknesses, or unit layouts. This could result in approximately $30 million of additional sales revenue for the developer without significant modifications to the original design.