Increase of a high rise buildings damping behaviour by applying Large Scale Tuned Mass Dampers

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Born in 1975, Christian Meinhardt studied structural engineering at the Technical University Berlin and specialized in structural and soil dynamics. His first contact with Tuned Mass Dampers (TMDs) was during an undergraduate research internship at the KATRI and the Kobori Institute in Japan. After he received his degree in 2001 he worked in the fields of structural dynamics at the Federal Research Institute of Material Research and Testing. In 2006 he joined GERB Vibration Control Systems where he is also in charge of TMD projects.

Summary

The following paper introduces the application of large scale Tuned Mass Dampers (TMD) on high rise buildings to increase the buildings structural damping. Therefore the TMD effect and the practical handling of the optimum TMD specification are briefly described. Construction principles and the achievement and testing of the required specifications, as well as the experimental verification of the TMDs effectiveness - measuring the buildings ambient vibrations and using several methods to determine the structural damping – will be portrayed. Finally an example project for a successful and demanding application of a TMD will be introduced.

Keywords: Tuned Mass Dampers, High Rise Buildings, Structural Damping, In-Situ Assessment

1. Introduction

The distinctive trend in designing and constructing tall buildings is the use of lightweight materials and slender structures to achieve a maximum height with a relatively small dead load. The negative side effect of the improved capacity of materials and constructions is very low structural damping of these structures and the associated high susceptibility to horizontal and lateral wind induced vibrations. The resulting vibrations are most often due not to problems in bearing capacity but rather to a reduction in building comfort for certain heights.

2. Practical Application for Large Scale TMDs

2.1 Frequency Tuning

The most practicable, solution that allows a precise frequency tuning with a maintainable effort for a large scale TMD is a pendulum system. For such systems, the tuning frequency corresponds with the required pendulum length. Specifying the required pendulum length, the dynamic stiffness of the necessary damping system has to be considered. Therefore specific information about the damping device is required (see chapter 2.2). An important design criteria is the required space to apply an large scale TMD, which is defined by the pendulum length of the TMD. To reduce the seized space a folded pendulum system can be applied, which uses an additional frame to reduce the pendulum length by factor 2 (see Figure 1). Again, additional calculations have to be done to estimate the influence of the pendulum frame’s stiffness.

2.2 Verification of the optimum damping ratio

Due to the already mentioned interaction between structure and TMD, the dampers specifications can only be assessed by previous shop tests, where the time history of the by a hydro pulse cylinder applied force ***F*** and the resulting movements ***s*** of the dampers plunger are recorded.

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2.3 In-Situ Verification of the TMD- Effectiveness

The In-Situ Verification of the TMD Effectiveness can result from several methods. Since only ambient vibration measurements are available for high-rise buildings, a determination, analyzing the decaying behaviour solely in the relevant natural frequency is not possible. Additionally the input forces are unknown, which also excludes analyzing methods such as cross-correlation or cross-spectral methods. One possible method is to use an autocorrelation of the recorded time domain signal but can only be used for isolated vibration modes and is strongly dependent on the intensity of the input. Since the structural damping is nonlinear, the achieved results display a certain variation. A method that is also applicable for structures which not only display vibrations in one dominant natural frequency is the *Random Decrement Method*.

2.4 Project Example – Sport City Tower Doha

The Aspire Tower is a 318 meter (1,050 feet) structure located in the Sports City complex in Doha, Qatar. An assesment of the buildings dynamic performance indicated, that additional damping would be needed to reduce lateral accelerations at the top under wind loading to improve comfort levels. A feasibility study of various options for a total of 3% critical damping showed, that a TMD directly below the highest viewing levels was the most practical solution for the range of predicted frequencies. Therefore a TMD with an effective mass of 140 t, designed as a folded pendulum system was installed within the tower core (see Fig. 1) .

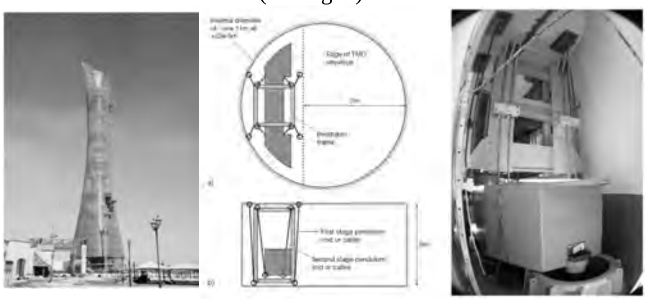

*Fig. 1: **Left** - Sport City Tower Doha after completion; **Centre:** Layout of the TMD within the structure; **Right:** completetd 140t TMD*

The previously calculated damping factor of the damper system which was required for the 140 t TMD had to be tested before the installation of the TMD on site. A hydro-pulse cylinder system was used to apply forces that were similar to the expect forces do to the TMD operation. Beside the confirmation of the required damping factor, the determination of the dampers dynamic stiffness was the objective of these tests. Knowing the dynamic stiffness and determining the relevant natural frequency on site, the fine tuning of the TMD could be carried out, varying the pendulum length.
The effectiveness of the installed TMD could be documented by comparing the determined structural damping ratio before and after the installation. To assess the structural damping ratio, all in chapter 3.3 introduced methods were exercised and showed a good conformity of the achieved results. Due to the TMD application the structural damping ratio could have been increased from 1.4 % critical damping to 3.4 %.

3. Conclusion

Beside the challenge to design dynamic devices such as a 140 ton TMD and ensure all of its specifications by preliminary tests, the challenge to document the effectiveness of a TMD application on a high-rise building can be achieved using practical identification methods. The determined results show that the application of a large scale TMD is an efficient solution to reduce occurring wind induced horizontal and lateral vibrations with a comparatively small effort and a comparatively small additional mass. The reduction leads to an increase of comfort and to possibilities for ever lighter and slender structures.