The Institution of Structural Engineers

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Project title: Seismic Rocking of TMD-Controlled Structures

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Aims of research:
Designing structures to resist seismic actions is not the same as designing for static forces, and indeed making the structure stiffer is not always the best option. Different strategies can be adopted to improve the seismic performance of slender structures, e.g installing a TMD (tuned mass damper) to subtract part of the energy that the ground motion imparts, or using special bearings to allow the rocking motion of the structure and therefore limit the forces transmitted by the foundation. The project will aim at assessing whether these two strategies can be successfully combined to better protect slender structures from earthquakes.

Description of method:
Linear structures equipped with different types of TMD (e.g. pendulum, liquid column, sloshing water) has been extensively studied in the technical literature, demonstrating the improved structural response under different dynamic actions, including ground shakings, wind gusts and moving loads. TMDs can also be effective in mitigating the seismic motion of rocking structures, but this solution has not been explored yet. Slender structures are indeed prone to enter the rocking motion when subjected to large seismic forces. Practical examples span from some expensive pieces of equipment, which may overturn during an earthquake, to tall stepping towers, which are designed to rock on their foundation in order to limit the seismic forces in elevation. The dynamics of these structural systems is highly nonlinear, and as such studying the effects of the added TMD would ideally require complementary analytical and experimental investigations. Since this is not feasible within the timeframe of an undergraduate final-year project, the proposed research will mainly consist of an experimental campaign conducted on different bench-scale models of slender 3D frames equipped with a TMD at the top level and with a rocking system at the foundation level. The tuned mass will be provided by the water sloshing in a rectangular plexiglass tank with variable geometry, so to adjust the equivalent values of natural frequency and damping ratio of the device. The rocking systems will be made with aluminum rollers designed to avoid the sliding and ease the initiation of the rocking. Different configurations will be tested with the bench-scale (50 by 50 cm) APS 400 Electro-Seis shaking table available in the Structural Dynamics lab of the School. Recorded and artificial (Eurocode-compliant) accelerograms will be used to assess the performance of the proposed TMD-rocking solution under both near-source and far-field scenarios.

Benefits to structural engineering:
The quest for slender and architecturally challenging structures often requires the adoption of combined systems to improve their performance under dynamic loads. As an example, structural engineers have managed to use TMDs in conjunction with seismic isolators in order to maximise the level of protection against earthquakes. The proposed experimental campaign will assess the feasibility of designing TMD-controlled stepping structures in seismic-prone areas. The test results will then be used to develop further analytical and computational research, allowing the exploitation of this innovative solution, which can be particularly effective for tall buildings and bridge towers..

Proposed finish date: May 13