Bauhaus-Universität Weimar

Liquid Dampers for Wind-Sensitive Structures

TUNED LIQUID DAMPERS - AN ENGINEERING SOLUTION FOR MITIGATING THE EXCESSIVE STRUCTURAL VIBRATIONS CAUSED BY WIND LOADING

1. CLIMATE CHANGE & NATURAL HAZARDS

According to IPCC (Intergovernmental Panel on Climate Change), the anthropogenic emissions of green-house gases are highest in history among the observed changes (Fig.1). The climate models show two distinct scenarios of global surface temperature (Fig.2). Continued greenhouse gas emissions will cause further warming, increasing the likelihood of climate-related hazards such as cyclones, local extreme wind speeds, or tornadoes, occurring more frequently.

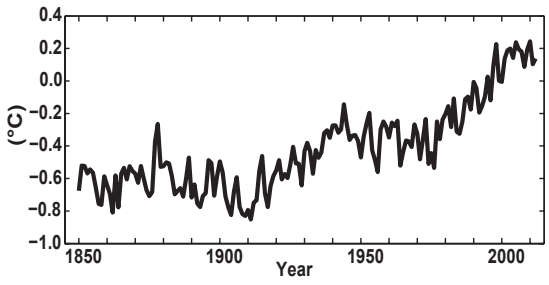

Figure 1: Globally averaged combined land and ocean surface temperature [1].

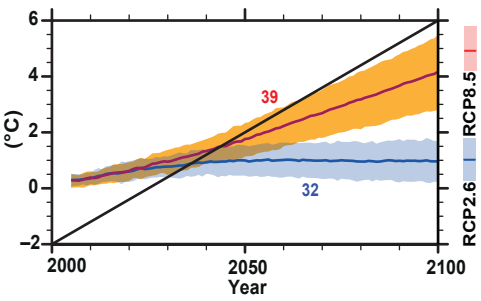

Figure 2: Global average surface temperature change (relative to 1986–2005 - IPCC AR5). Mean over 2081–2100 [1].

2. WIND & MEASUREMENT SYSTEM

Wind engineering is a particular field of civil engineering that evaluates the resistance of structures caused by wind loads. The main design parameters are the wind–induced accelerations, comfort criteria and local pressures for cladding or bridge decks. As a consequence, these effects should be considered for wind sensitive structures.

Along the history, meteorological stations were installed to monitor wind speed measurements, to establish wind zonation maps. Nowadays, with the advancement in technology and computers, it is possible to build monitoring systems at affordable costs.

As part of the research group (TAB FGR0096) involving several chairs at Bauhaus-University Weimar, the project on climate change enabled a series of studies, including measurement systems for weather stations (Fig.3, Fig.4). In this way, monitoring setup can be deployed at remote places to analyze the local effects, through long-term measurements.

Figure 3: Weather station deployed on the top of a roof (industrial building). Long-term measurements for climate observations (wind speed, temperature, precipitation, humidity).

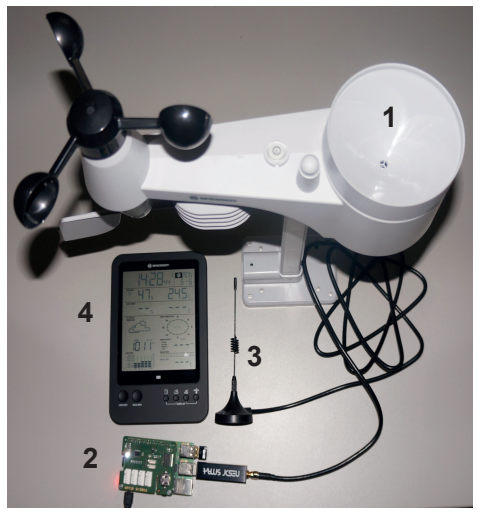

Figure 4: Measurement system for weather station
1 - Weather station (Bresser 6in1), 2 - Raspberry Pi with Raspyre framework [2], 3 - Antenna USB connection, 4 - Weather display.

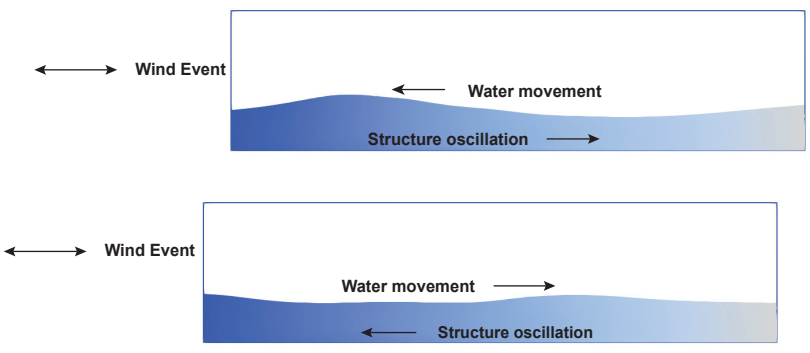

Figure 5: Simulation of water behavior inside a tank, subjected to an horizontal motion.

3. WHY DAMPERS?

Structures are designed and constructed to ensure their resistance and serviceability criteria during their lifetime. The engineers are using the data wind measurements to determine the frequency of the extreme events. Depending on the climate hazards and exposure of the construction location, the structural material for ensuring the resistance and safety-in-use criteria can be very costly.

For many of these structures, the provision of additional damping is the only robust and practical method to control the external dynamic actions. The costs can be avoided from 5 % to 10 % of the total construction cost.

4. TUNED LIQUID DAMPERS

The principle consists in adding a secondary system (i.e. damper) that can work in counter–phase with the motion of the primary system (i.e. high-rise building), to reduce the structural vibrations and keep the comfort for the inhabitants during an extreme wind event (Fig. 5).

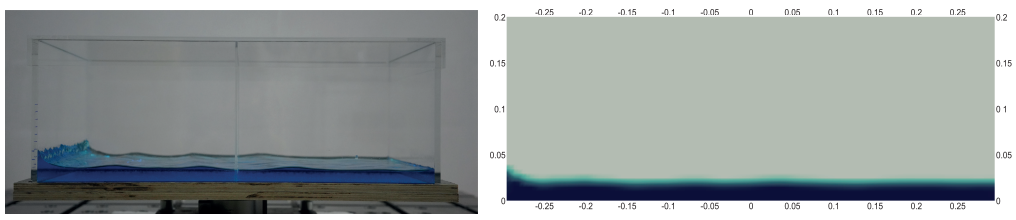

Figure 6: (left) Sloshing experiment at shaking table at Geotechnical Department of BUW / (right) Numerical sloshing under similar excitation conditions and geometry [3].

5. STATE OF THE ART & RESULTS

Advancement in computational fluid dynamics and scientific studies permit us doing research on structural design assessment for accurate predictions. Once the structural dynamic properties are known, the designer can use numerical models to study the impact of liquid dampers in the response of wind-structure interaction (Fig. 7 a,b,c).

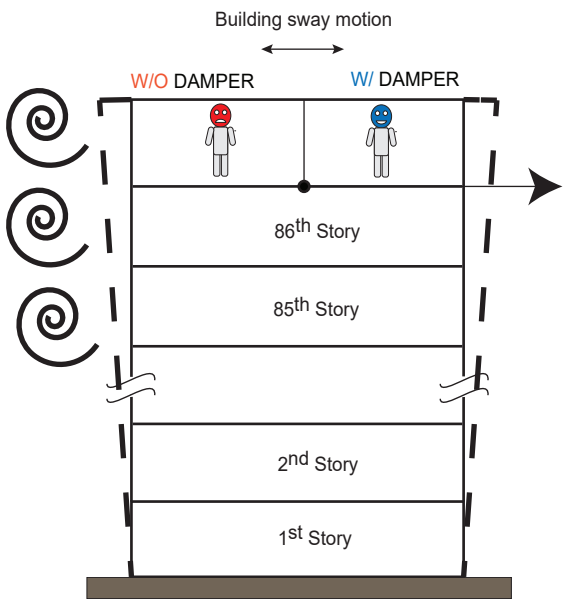

Figure 7a: Schematic representation of a building subjected to sway motions caused by high wind speeds. Left side: Case without damper Right side: Case with damper.

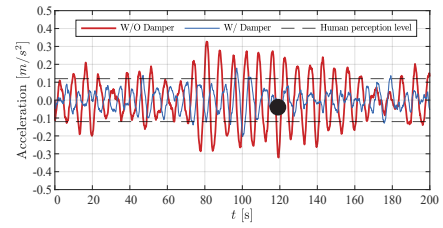

Figure 7b: Story accelerations in case of high wind speeds. Comparison between case without damper (W/O) and with damper (W/). Dashed line represents the level at which most sensitive persons perceive vibrations (0.12 m/s²).

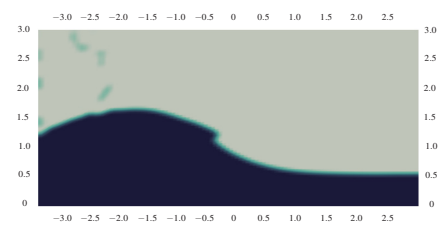

Figure 7c : Simulation snapshot of the liquid damper at the time instant of 120 s (see Fig. 7b).

References:
[1] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.
[2] Morgenthal, G., Eick, J. F., Rau, S, Taraben, J.:Wireless Sensor Networks Composed of Standard Microcomputers and Smartphones for Applications in SHM, Sensors, Special Issue Selected Papers from 7th Asia-Pacific Workshop on Structural Health Monitoring 2018 19(9) (2019)
[3] Weller, H.G., Tabor, G., Jasak, H., Fureby, C., 1998. A tensorial approach to computational continuum mechanics using object-oriented techniques. Computers in Physics 12, 620.

Victor Vîlceanu, PhD candidate

Faculty of Civil Engineering
Chair of Modelling and Simulation of Structures
99423 Weimar, Marienstraße 7
E-mail: victor.vilceanu@uni–weimar.de