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Active control of vibrations in ultra-shallow floor beams

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Project objectives

The subject of this research is to investigate the dynamic behavior of ultra-shallow floor beams (USFB) and the possibility to actively control their vibration response under human induced loading (i.e. walking, running, dancing etc.). The combination of the advantages of the two innovative technologies (USFB and active control) will allow the construction of more slender and long-span floors without compromising the comfort of the occupants.

Different active structural control systems, control algorithms and strategies as well as challenges faced by the engineers for the implementation of such systems will be examined. Alternative methods for controlling the response of floor structures will be considered and solutions will be proposed.

Introduction

A perfect example of the advancements in steel and concrete design is the use of USFB as an alternative floor system. This particular floor system allows for slender floor systems (up to 150mm thickness) to be constructed while maintaining structural integrity. This novel technology, in addition to the tendency for open-plan (fewer internal partitions) and larger span floors, inevitably lowers the system's natural frequencies making it more susceptible to vibrations induced by human activities. Even though these floor systems are properly designed for strength and static live load deflection requirements, vibrations at a range perceivable by humans still occur. Floor motions with displacements as small as 1mm can still cause discomfort to the occupants (Hanagan et al., 2003; Hudson et al., 2011).

Traditional methods for improving the response of dynamic (floor) systems include structural stiffening of the framing members, addition of concrete thickness, incorporation of passive devices such as tuned mass dampers etc. The cost of implementation, obstructiveness and effectiveness vary widely between the different schemes (Hanagan & Murray, 1997). The drawbacks of these methods gave birth to the use of active control in civil engineering floor structures.

Active vibration, which is considered to be the natural evolution of passive vibration control (Nyawako & Reynolds, 2009), goes back to the 18th century. First attempts for active control were reported in Mallock (1905), where vibration control was applied on steam ships through synchronisation of the engines in opposite phase. Hort (1934) reported the reduction of roll motion using an actively driven Frahm tank where the water is pumped between tanks located on the two sides of the ship. Nowadays, active vibration control utilises sophisticated sensors and actuators for achieving the desired performance. Beyond the successful implementation of this method in other disciplines recently, active vibration control is considered an attractive technique for reducing vibrations in floor structures (Hanagan, 1994; Nyawako & Reynolds, 2009).

Methodology

It is expected that Finite Element Analysis (FEA) modelling will be an integral part of the research. FEA modelling will enable better understanding and assessment of the behaviour of such structures as well as serving as a means of validating laboratory experiments. The laboratory experiments to be performed will most likely include experimental modal analysis (EMA) for system identification and updating.

Potential for application of results

Typical results obtained from the analysis of the actively controlled and uncontrolled floor structures indicate a large reduction in floor vibrations (Hanagan & Murray, 1996). It is expected for similar behaviour to be obtained from the analysis of USFB floor systems. This will highlight the applicability of such systems for achieving more slender and long-span floors without compromising the comfort of the occupants. The slenderness of the floor will also reduce the dead weight on the structure thus potentially reducing the size of other structural components such as foundations etc.

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