The bridge

Millennium Bridge is situated in London and links St. Paul’s Cathedral on one bank of Thames River with the Tate Modern Gallery on the other. It wasdesigned by Norman Foster as a footbridge. 325 m long bridge was opened to the public on June 10th, 2000. During the first days of its use large number of people crossed the bridge. Significant sideway movements of the structure were the reason of the bridge being closed to the public only two days upon opening. This report discusses reasons of the unprecedented and unexpected lateral movement of the bridge and practical solution implemented to prevent the problem from occurring in the future. Millennium Bridge was designed to carry large load and a degree of structure’s movement was expected and taken into account. However, after about 80 000 people crossed it on the opening day, some vibration was detected. The bridge began to sway sideways noticeably, and the movement became so strong that people could not walk steady any more; many had to cling to the sides of the bridge to maintain balance. The phenomenon of bridge sideways movement is not unique to the Millennium Bridge only. There were other structures, completely different from the given bridge that, to a various degree, suffered the same effect. However, those cases have not been widely publicized, thus the phenomenon, known as Synchronous Lateral Excitation, was not anticipated and has not been given enough attention by bridge engineers. When people walk they have a natural sway motion. This very motion causes small regular vibrations, which, as the result of chance correlation, generated slight lateral movement of the bridge. When that happened, pedestrians instinctively adjusted and synchronized their motion with bridge’s movement to counteract the effect and to walk more comfortably. In addition, people locked their motions together, walking in

step in the same rhythm, thus creating even greater magnitude of force, which only reinforced the oscillation of the bridge. The central span of the bridge had the most movement, with deck vibration amplitude reaching as high as 70 mm. As an immediate solution, the number of people crossing the bridge simultaneously was limited, which helped the problem somewhat. However, to prevent any possible physical injuries of the pedestrians as well as case investigation purposes the Millennium Bridge was closed on June 12, 2000. Thorough research included laboratory investigations with following series of crowd tests on the site to confirm findings of the construction engineers. On site tests were needed to recreate exact walking conditions as well, and later tests were carried out to confirm viability of the solution found. The bridge was equipped with measuring instruments to document the intensity of movement. Exact timing of steps was measured by the sensors fitted in heels of the experimental crowd. Two possible solutions of limiting excitation were considered: either the structure has to be stiffened in order for the bridge and footsteps' frequency not to tally, or damping system has to be installed to absorb vibration created. The professionals came to the conclusion that the option of stiffening aluminum structure of the bridge would not be possible without dramatic changes in the sleek appearance of the bridge. So the option of dampers installation was further explored. Jones (2005) explains that an active damping system, which is comprised of the powered mechanisms, is commonly used in various engineering fields and also in buildings, especially in seismic active zones of the world. However, it is not sufficiently expanded for the complex systems such as bridges. Exploring possibility of active damping installation, engineers came to the conclusion that because of the production cost and timing as well as

maintenance requirements this system will not provide a viable solution to the problem. Instead, passive damping system, with Viscous damping mechanisms installed beneath the deck, around the piers and the south landing will provide needed control of the sideways motions. Passive damp system functions similarly to shock absorbers, which purpose is to limit structure’s response to the external force. In addition to viscous mechanisms, Tuned Mass dampers were attached to the discreet points under the structure and tuned to a specific frequency as the precaution of the possible vertical movement of the bridge. One major benefit of this system is that most of the damping mechanisms are installed under the structure or mounted into it, so they generally are hidden from the view and the appearance of the bridge is unchanged. The research and tests results provided engineers with valuable information, on the base of which a solution suggested successfully combined bridge’s appearance preservation and improved walking conditions. It also gave much new information for the practicing bridge engineers, which was previously not explored. References: Jones, H. (2005). Construction bridges. London: Macmillan , pg. 87 The Millennium Bridge. Arup. com [Online] Retrieved 25 March 2011from http//: www. arup. com/millenniumbridge/ London Landmarks. [Online] Retrieved 20 March 2011 from http://www. Urban75. org/London/millennium. html. Millennium Bridge. [Online] Retrieved 20 March 2011 from www. news. bbc. co. uk/2000/millennium_bridge/solution. st