Vortex-Induced Vibration: the slower deceleration of the west bank leads to the shortening of the Humen Bridge in Guangdong, China

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Abstract:

The Earth self-rotates in the solar and lunar gravitational fields. According to Newton's Law of Inertia, large mass accelerates and decelerates more slowly than smaller masses, whereas small mass accelerates and decelerates more quickly than larger mass, which gives rise to stress when potential energy is present, damaging civil engineering projects. Humen Bridge of Guangdong, China and two century-old dams in Michigan which were affected recently can be explained by this theory.

Keywords:

vortex-induced vibration; Humen Bridge of Guangdong; water dam; potential energy; low density water; slower deceleration of larger mass

Recently, the shaking of Humen Bridge in south Guangdong, China had a huge impact on the traffic across Pearl River Delta. In the 21st century, modern bridges are constructed towards long spans and super long spans. As the length of bridge increases, the damping and the frequency of bridge decrease. The problem of wind vibration becomes more and more prominent. Vortex-induced vibration is one of them, especially for long-span suspension bridges such as Humen Bridge. Vortex-induced vibration occurs from time to time, which affects driving safety and comfort.

The earth self-rotates in the solar and lunar gravitational fields, and the self-rotation vector changes directions and speeds frequently¹. According to Newton's Law of Inertia, large mass accelerates and decelerates more slowly than smaller masses, whereas small mass accelerates and decelerates more quickly than larger mass. Due to the presence of potential energy on the Earth crust, slower decelerations of large mass or/and faster accelerations of smaller mass bring about earthquake, volcanoes, sand and dust storms, petroleum fields, hot springs, etc.¹⁻¹⁰ For instance, the deeper pacific ocean coastline in northern Chile gives rise to mega-earthquakes, whereas the shallow coastline in southern Chile creates volcanoes since mountain range is present in the east of Chile. The Chile landmass is north-south trending, in parallel with the direction of self-rotation. The northern pacific coast of Japan, the Indian Ocean where the magnitude 9 earthquakes occurred are also north-south trending, with a large area of flat slope from west to east along the self-rotation direction.

The two sides of Humen Bridge lie in an area with numerous low hills. There is the Weiyuan mountain of Humen on the east bank and the west bank is the South-North platform of Nansha. The center of the river has the Shanghengdang and Xiahengdang islands. The entire river is about 3.5km wide, and the waterway from Weiyuan Mountain on the east bank to Hengdang Island in the center of the river is called Humen waterway, with a maximum water depth of 21m. The waterway from Shanghengdang Island in the center of the river to the West Bank is called Puzhou waterway, with a maximum water depth of 19m. The latitude is low and the self-rotation linear velocity of this region is high. Humen Bridge lies in a low-latitude place which is subjected to solar and lunar pulls. The altitude of Nansha is 0 meter, which possesses potential energy to the river underneath Humen Bridge since water is low in density. Due to the larger inertia in the west, the slower decelerations of the west bank compresses the bridge. The slower deceleration of Nansha relative to the water makes Humen Bridge shorter as well as the distance between two bridge piers shorter. The above-mentioned scenario leads to vortex-induced vibration in Humen Bridge.

This problem is particularly noteworthy in the east-west trending bridges in low latitude regions with high linear velocity. Furthermore, there are similar problems associated with hydropower stations, dams and other water conservancy projects, which are also the focus of civil engineering. Two dams in Michigan failed recently, leading to a serious flood. About 10,000 people have been evacuated. The breakout occurred in Central Michigan, about 225 kilometers north of Detroit. Why the Edenville and Sanford Dams breached is that successive days of rainfall causing water levels to rise. A century-long slower deceleration of heavy water mass may have resulted in cracks in the water dam. Rail tracks and south-north trending bridges also need to consider the

slower decelerations of larger masses or faster acceleration of smaller masses, such as mountains on the two banks of a river.

Conflict of interest statement

The authors declare no conflict of interests.

Funding

This work was supported by grants from the Science and Technology Transformation Program of Sun Yat-sen University of China No. 33000-18843234 and Guangzhou Science and Technology Program No. 201804010328 to Q. Liu.

Acknowledgements

We thank Yan Shi for language editing.

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