

Millinium Bridge

The Millennium Bridge, officially known as the London Millennium Footbridge, is a steel suspension bridge for pedestrians crossing the River Thames in London, linking Bankside with the City of London. It is owned and maintained by Bridge House Estates, a charitable trust overseen by the City of London Corporation. The structure links the U.S. city of San Francisco, California—the northern tip of the San Francisco Peninsula—to Marin County, carrying both U.S. Route 101 and California State Route 1 across the strait. It also carries pedestrian and bicycle traffic, and is designated as part of U.S. Bicycle Route 95. Being declared one of the Wonders of the Modern World by the American Society of Civil Engineers, the



bridge is one of the most internationally recognized symbols of San Francisco and California. It was initially designed by engineer Joseph Strauss in 1917. The Frommer's travel guide describes the Golden Gate Bridge as "possibly the most beautiful, certainly the most photographed, bridge in the world." At the time of its opening in 1937, it was both the longest and the tallest suspension bridge in the world, with a main span of 4,200 feet (1,280 m) and a total height of 746 feet (227 m).

HISTORY

The bridge opened on 10 June 2000, two months late. Unexpected lateral vibration due to resonant structural response caused the bridge to be closed on 12 June for modifications. Attempts had been made to limit the number of people crossing the bridge, which led to long queues but were ineffective to dampen the vibrations. Closure of the bridge only two days after opening attracted public criticism as another high-profile British Millennium

project that suffered an embarrassing setback, akin to how many saw the Millennium Dome.

Vibration was attributed to an under-researched phenomenon whereby pedestrians crossing a bridge that has a lateral sway have an unconscious tendency to match their footsteps to the sway, exacerbating it. The tendency of a suspension bridge to sway vertically when troops march over it in step was well known, which is why troops are required to break step when crossing such a bridge. An example is London's Albert Bridge, which has a sign dating from 1873 warning marching ranks of soldiers to break step while crossing.

The bridge's movements were caused by a positive feedback phenomenon, known as synchronous lateral excitation. The natural sway motion of people walking caused small sideways oscillations in the bridge, which in turn caused people on the bridge to sway in step, increasing the amplitude of the bridge oscillations and continually reinforcing the effect; the maximum sway was around 70mm. On the day of opening, the bridge was crossed by 90,000 people, with up to 2,000 on the bridge at a time.

CONSTRUCTION

rdinarily, bridges across the River Thames require an Act of Parliament. For this bridge, that was avoided by the Port of London Authority granting a licence for the structure, and the City of London and London Borough of Southwark granting planning permission. Construction began in late 1998 and the main works were started on 28 April 1999 by Monberg & Thorsen and Sir Robert McAlpine. The eventual cost was £18.2 million (£2.2m over budget), primarily paid for by the Millennium Commission and the London Bridge Trust.

Resonant vibrational modes due to vertical loads (such as trains, traffic or pedestrians) and wind loads are well understood in bridge design. In the case of the Millennium Bridge, because the lateral motion caused pedestrians to directly participate with the bridge, the vibrational modes had not been anticipated by the designers. When the bridge lurches to one side, the pedestrians must adjust to keep from falling over, and they all do this at the

same time. The effect is similar to soldiers marching in lockstep, but horizontal instead of vertical. They concluded that making the bridge stiffer, to move its resonant frequency out of the excitation range, was not feasible as it would greatly change its appearance. Instead, the resonance was controlled by retrofitting 37 viscous fluid dampers to dissipate energy. These include 17 chevron dampers – long V-shaped braces under the deck panels – to control lateral movement, 4 vertical to ground dampers to control lateral and vertical movements, and 16 pier dampers to control lateral and torsional movements.



Additionally, 52 tuned mass dampers add inertia to control vertical movement. The work took from May 2001 to January 2002 and cost £5M. After a period of testing, the bridge was reopened on 22 February 2002 and has not been subject to significant vibration since. In spite of the successful cure, the affectionate "wobbly bridge" (sometimes "wibbly-wobbly") epithet remains in common usage among Londoners. In May 1924, Colonel Herbert Deakyne held the second hearing on the Bridge on behalf of the Secretary of War in a request to use federal land for construction. Deakyne, on behalf of the Secretary of War, approved the transfer of land needed for the bridge structure and leading roads to the "Bridging the Golden Gate Association" and both San Francisco County and Marin County, pending further bridge plans by Strauss. Another ally was the fledgling automobile industry, which supported the development of roads and bridges to increase demand for automobiles.

DESIGN:

The bridge opened on 10 June 2000, two months late. Unexpected lateral vibration due to resonant structural response caused the bridge to be closed on 12 June for modifications. Attempts had been made to limit the number of people crossing the bridge, which led to long queues but were ineffective to dampen the vibrations. Closure of the bridge only two days after opening attracted public criticism as another high-profile British Millennium project that suffered an embarrassing setback, akin to how many saw the Millennium Dome.

Vibration was attributed to an under-researched phenomenon whereby pedestrians