

## **DYNAMIC TESTING OF THE LONDON MILLENNIUM FOOTBRIDGE**

Due to excessive lateral motion caused by large amounts of pedestrians crossing the bridge at the same time, the London Millennium Footbridge was closed to the public, for safety reasons and to allow further investigation, only two days after originally being opened. During the subsequent, successful, modifications Fugro Structural Monitoring played a major role in the testing. The work was undertaken in two phases.

### Prototype Test

The first phase was carried out in December 2000 when FSM were contracted by Arup to provide instrumentation and testing services during prototype trials of the innovative damping system which had been devised to alleviate strong motions observed when very large numbers of pedestrians used the bridge.

To quantify dynamic characteristics with different levels on damping on the bridge, FSM installed a grid of accelerometers orientated in both lateral and vertical directions.

In addition, load and displacement measurements were made on the prototype dampers, and environmental conditions were monitored. Data acquisition was performed using the FSM software package, SiMS-NT. SiMS-NT allows high-speed data acquisition simultaneously from a large number of sensors. It includes a range of analysis modules including frequency analysis, statistical analysis, fatigue cycle counting etc. Measurements were taken while varying numbers of pedestrians walked across each span of the bridge in turn.

A unique feature of the project was a shaker capable of inducing a 4kN lateral cyclic load into the bridge. The shaker, designed and built by FSM in 6 weeks, comprised a 1 tonne mass which was pushed and pulled along a 2m track by an hydraulic actuator (see picture). The shaker had an operating frequency range of 0.5Hz to more than 5 Hz. The shaker was used to quantify the modal properties of the bridge (natural frequencies, damping, mass and stiffness).

The results from the prototype test gave valuable insight into the behaviour of bridges when pedestrians “lock-in” to the natural frequency of a structure at the point at which crowd numbers exceed a critical value.

### Full Scale Pedestrian Tests

The second phase of testing took place in January 2002 during the recently publicised pedestrian tests. FSM installed arrays of highly sensitive accelerometers along both edges of the bridge and monitored the response of the bridge to the 2000 pedestrians. To ensure high quality data was collected during what was a one-off event, the instrumentation system was configured to be fully redundant with duplicate power supplies, data acquisition equipment, and data analysis computers.

Real time displays of critical parameters were made available to Arup so that the outcome of the tests was immediately available.

The results from the test demonstrated that the vibration levels experienced by the bridge were well within acceptable comfort levels, even when heavily crowded. The bridge was subsequently re-opened to the public two weeks after completion of the tests.