Dynamic test of a pedestrian bridge as part of safety assessment

Dynamic Test of a Pedestrian Bridge as Part of Safety Assessment

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Summary

The results of the dynamic tests carried out on the approach pedestrian bridge to Civita di Bagnoregio, Italy, are shown. The structural elements were in bad conditions due to the carbonation of concrete. The results of the experimental campaign allowed to state that the structural behaviour of the bridge was quite similar to that we could expect. Under ambient vibrations the structure behaved as a whole, formed by the piers linked at their tops by means of the beams.

Keywords: bridges, experimental dynamic analysis, system identification.

1. Description of the bridge

The approach pedestrian bridge to Civita di Bagnoregio is composed by 14 spans, which are simply supported on the piers. These are spaced by about 19.00 *m*. Starting from Civita we first find a 20% steep slope, which interests five spans. The heights of the piers from pier 1 to pier 5 vary from 11 to 15 *m*, pier 4 being the highest. The viaduct between pier 5 and pier 9 is almost horizontal while in the last part, from pier 9 to pier 13, it shows a 6% slope. Piers from 6 to 13 are much shorter than the others. The girder is composed by three pre-stressed concrete beams and a concrete slab. The total height of the cross-section is 80 *cm*. The horizontal distance between the beam axes is 90 *cm*, the total width of the bridge is 2.50 *m*, included the two longitudinal parapets. Each span has a length of about 16.70 *m*, but the first one is 16 *m*. The beams are supported by the upper plate of the piers by means of leaden pads. All the piers are composed by 4 circular pillars, whose diameter is 50 *cm*, and by an upper plate of 65 *cm* height. The pillars start from a rectangular foundation plate, supported by concrete piles with a maximum length of 25 *m*. The structural elements were in bad conditions due to the carbonation of concrete. All the external beams were damaged, the phenomenon being favoured by the combined action of rain and wind. Several cracks could be seen in the pillars, where the concrete cover was split and the reinforcement bars was uncovered. The upper plates of the piers were damaged too.

2. Experimental dynamic analysis

Recently, the bridge showed vibrations of high amplitude during a funeral, when it was very crowded. The SGM Engineering S.r.l. of Perugia (Italy) carried out, on behalf of Bagnoregio Town, a series of experimental campaigns on the structure, in order to analyse the static conditions and the dynamic characteristics of the bridge and to find out any structural damages. The dynamic tests of the structure revealed a strange behaviour of the piers. The authors, involved in the interpretation of the results of the tests, decided to carried out another experimental campaign, in order to better

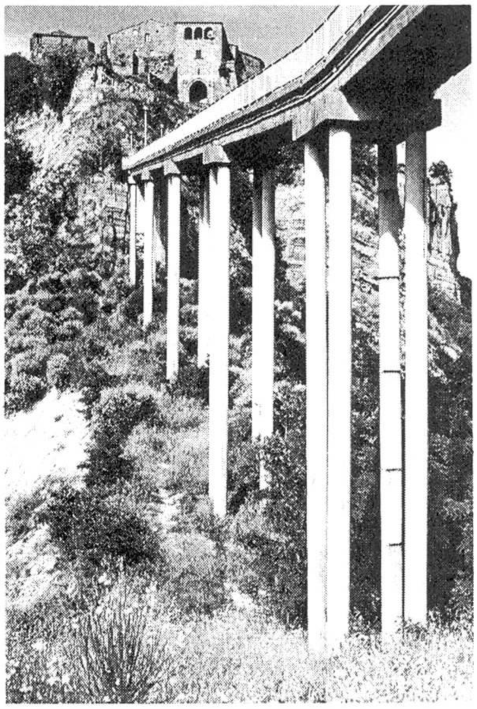

Fig. 1 Piers 1 to 5

characterise the dynamic behaviour of the piers. The experimental set-up was composed by eight seismometers Kinemetrix SS1, an HP3566A signal conditioner and a HP laptop. Measurements were carried out on June 1997. Sensors were deployed in several configurations. Both ambient and forced vibrations were considered, the latest being caused by the passing of pedestrians or vehicles of small size. The recorded data were analysed both in the time domain and in the frequency domain.
The recorded data allowed to analyse the behaviour of the viaduct, with particular attention to its part between pier 1 and pier 5. The following frequencies are particularly apparent in the spectra: 0.95, 1.38, 2.07, 2.83 *Hz*. This occurrence suggested that the viaduct behaved as a whole, the records at the piers presenting the same features. Records at the basement of each pier were always in phase with those at the top, at all the found resonance frequencies. Peaks at the same frequencies are apparent in all the cross spectra between the sensors at the tops of the piers, with significant values of the phase factor and the coherence function.
The analysis of the phase factors allowed to find out the modal shapes associated to these resonance frequencies. We concluded that the girder behaved as a beam supported by horizontal elastic restraints at the piers. In the longitudinal direction vibration amplitudes were much lower.
Piers 2 and 3 were particularly analysed. The already observed resonance frequencies were found. We could also state that no torsional modes were associated to these frequencies. The experimental results were compared with those obtained from the analysis of a finite element model. The girder was modelled by means of a spatial beam, having the same geometrical and mechanical properties of the bridge and elastically supported by the piers in the transversal horizontal direction. Vertical displacements and torsional rotations were not allowed in correspondence of the piers. The stiffness of the elastic restraints were equal to the stiffness of the piers. The first four modal shapes of such a model are very similar to the experimental ones. Instead, the resonance frequencies are higher. This occurrence demonstrated that the actual stiffness of the piers are lower than the original ones, relative to the undamaged structure, but the stiffness decrease was almost uniformly distributed along the bridge and not concentrated in a particular element.

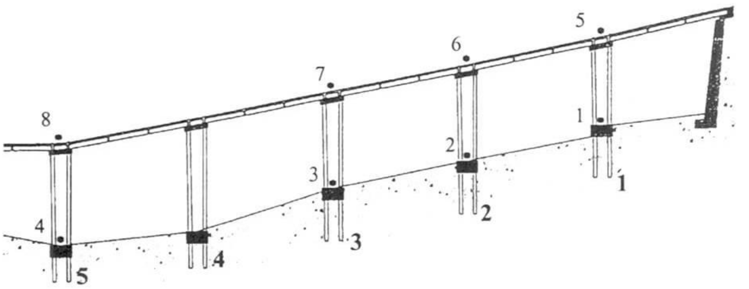

Fig. 2 Sensor locations in configuration A

3. Conclusions

The structure showed a very high deformability, more evident in the part where are the highest piers. This characteristic, due to the slenderness of the vertical elements was emphasised by the structural damages, which resulted in a reduction of the effective cross-sections of the pillars. Therefore the viaduct was very vulnerable to wind actions, which are particularly insidious in the area. Besides, when the bridge is very crowded the natural wind flow is obstructed, the vertical structures very stressed and the vibrations could be amplified very much.
We suggested that all the piers should be repaired, in order to be suitable to support the vertical and horizontal loads that can act on the structure. No works were needed on the foundation structures. These may be damaged in the future because of the landslides and the continuous erosion of the soil surface. Therefore they should be monitored or frequently tested.