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Objekttyp: **Article**

Zeitschrift: **IABSE reports = Rapports AIPC = IVBH Berichte**

Band (Jahr): **83 (1999)**

PDF erstellt am: **28.06.2024**

Persistenter Link: https://doi.org/10.5169/seals-62874

Monitoring of the New Tagus Bridge in Lisbon

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Summary

The Vasco de Gama Bridge in Lisbon, was opened to traffic in March 1998. The structure is 12.3 kilometres long, including 9 kilometres over the Tagus estuary. The monitoring of such a large bridge requires a design phase necessary to adapt the procedures and instruments to the goals of this monitoring. Analysis carried out by the Contractor and the Designers has led to a system based on networks and standard data acquisition systems and protocols linked to the supervisory control system of the bridge, design which is well known in the industry, but quite new in civil engineering.

Keywords: monitoring, bridges, viaducts, instruments, data acquisition, networks, standardisation.

1. The Vasco de Gama Bridge

The new Tagus crossing, called the "Vasco de Gama Bridge", has been built to cope with increasing traffic bringing the 30 years old « Ponte 25 de Abril » to saturation. It allows to deviate the regional and national traffic around Lisbon linking the North highway A1 to Porto with the Coina Ring and highway A2 to Algarve and Spain. The design of earthquake has been specified to 0.45g horizontal acceleration, representing 4.5 times the assumed acceleration that occurred during the historical earthquake of November 1^{st}, 1755. This specification led to a considerable increase of the capacity of foundations, piers, bearings and expansion joints ; and thus, various seismic devices (buffers, limiters, lateral restraints) have been incorporated in the design.

The 12 300 m continuous bridge is divided into five structures:

- The North viaduct which is 488 m long, 11 spans of 45 m average, is a multiple 3.40 m high T beam deck, with a width varying from 60 to 37 m;
- The Expo viaduct which is 672 m long, 11 spans increasing from 45 m to 62 m, is a segmental double box girder, same height as the North viaduct;
- The Main Bridge, cable stayed, is 820 m long with a 420 m central span over the main shipping channel. It is a totally suspended twin deck (2.60 m high) with longitudinal concrete beams and light steel cross beams every 4.40 m.;
- The Central viaduct is 6531 m long including 9 viaducts of 9 spans of 80 m average length;
- The South viaduct is 3825 m long and has a similar cross-section to the one of the North viaduct.

2. Design of the monitoring

2.1 Objectives and priorities

Objectives of the monitoring of the Vasco de Gama Bridge are multiple : the safety of the users of the bridge, the verification of the consistency between the state indicated by computations and the measured state, the verification of the state of the work after a major event, that is to say an earthquake, a shock of boat or a storm and finally, the confirmation of the period of which it will be necessary to restress the stays of the main bridge, determined by the computation.

Two techniques of measurement are used to answer these targets: high precision topography and sensors (electric sensors or manually read instruments).
The seven types of measurements carried on the bridges and viaducts, consist in meteorological measures, topographic readings, accelerations during earthquakes, concrete strains, temperatures, rotations, and opening of expansion joints between viaducts.

2.2 Topographic survey

The topographic measurements use high precision levelling and triangulateration (angles and distances) and DGPS.

2.3 Sensors

Vibrating wire extensometers for the measure of concrete strain (169), biaxial inclinometers (16), sensors of temperature (54), are linked to networks of data acquisition and can be read with the help of a microcomputer. Sensors of opening of expansion joints (6) are read automatically by computers of the central station that uses a fibre optic network. A specific data processing (removal of temperature effects) is applied to the readings of the opening of the expansion joints.

2.4 Earthquakes monitoring

The earthquakes monitoring includes triaxial strong motion accelerometers (27) that continuously supervise movements of the bridges and viaducts. This data acquisition unit assures the monitoring of accelerations and their recording in case of the threshold of a programmed acceleration.

2.5 Data Acquisition System

Industrial standard procedures and well documented protocols have been adopted. They simplify the design, the installation and the data processing. On the other hand, modules for the specific vibrating wire instruments have been especially developed. Data acquisition and recording use the software ItelTage, a specific module of the modular suite ADAMAS Itelos97, a suite designed for advanced telemonitoring of buildings, bridges, dams, natural slopes, power plants, environmental parameters, research tests and industrial facilities.

The table summarises the types of instruments, data acquisition units, networks used in the Monitoring System.

	Data acquisition unit	Recording and data processing	Link
Meteorological instruments	Industrial modules	Central PC	Fibre optic
Temperatures	Industrial modules	PC NoteBook*	Local network (wires)
Rotations	Industrial modules	PC NoteBook*	Local network (wires)
Concrete strains	Industrial modules	PC NoteBook*	Local network (wires)
Expansion joints	Industrial modules	Central PC	Fibre optic
Temperature joints	Industrial modules	Central PC	Fibre optic
Earthquakes monitoring	Specific data acquisition unit	internal PC NoteBook*	no

Legend: PC Note Book* used to transfer and record data.

The results of the measurements during operation are recorded in a data base used for easy data management and interpretation. The load tests and the first survey readings confirm the advantages of the structure adopted here, which can be easily upgraded or modified at every moment.