Case Studies in Structural Engineering 2 (2014) 9–15

Contents lists available at ScienceDirect

Case Studies in Structural Engineering

journal homepage: www.elsevier.com/locate/csse

Damage analysis and seismic retrofitting of a continuous prestressed reinforced concrete bridge

Nicola Caterino *, Giuseppe Maddaloni, Antonio Occhiuzzi

Department of Engineering, University of Naples Parthenope, Centro Direzionale, Isola C4, 80143 Naples, Italy

ARTICLE INFO

Article history:
Available online 26 June 2014

Keywords:
Bridge
Bearing devices
Isolators
Dampers
Seismic retrofit

SUMMARY

The seismic analysis and retrofit of prestressed reinforced concrete bridge is discussed by considering a real case of a viaduct still in use. The unique features of this bridge make this type of bridge particularly interesting, either structurally or architecturally. The paper begins with the analysis of certain particular structural deficiencies that emerged during the viaduct operation. The results of the analysis indicate that the structural performance can be enhanced by only modifying the support devices. The primary structural components are not required to be involved in the retrofitting process. Using the modern seismic code, the upgrading of the viaduct performance is obtained by replacing the old bearing devices on the piers and existing viscous dampers connected abutments to the deck with new modernised ones.

Introduction

Due to the particular typology, lifetime loading and environmental condition of bridges and viaducts, enhancing the structural performance of existing bridges and viaducts involves special issues. In certain cases, the requirement of strengthening arises not only from deficiencies of the primary elements but also from the insufficiency of the structural details. Indeed, the viaduct presented in this paper faces these challenges. The design of the prestressed reinforced concrete deck of more than one kilometre in length was made to be structurally continuous above the supports given by piers and abutments, with the sequence of three different curvatures in the plan being required to address and solve special problems related to

(i) The global behaviour of the structure;
(ii) The thermal effects on such a long monolithic deck;
(iii) The seismic response of the viaduct due to the complex geometry.

In the following, after the reference structure is described in detail, the detected failures are introduced. Next, the possible causes are discussed on the basis of the design documents, as well as the structural analyses performed.

* Corresponding author. Tel.: +39 081 547 6728; fax: +39 081 19138483.
E-mail addresses: nicola.caterino@uniparthenope.it (N. Caterino), giuseppe.maddaloni@uniparthenope.it (G. Maddaloni), antonio.occhiuzzi@uniparthenope.it (A. Occhiuzzi).

http://dx.doi.org/10.1016/j.csse.2014.06.001
2214-3998/

Description of the bridge structure

The viaduct is made of 32 continuous spans. The total length of the prestressed reinforced concrete deck is 1127 m. According to the design specifications, the structure has been constructed in subsequent cantilever stages. The first and last spans are approximately 27 m long, while the intermediate ones have a length of approximately 36 m. The cross-section is variable along the length, gradually passing from a given mid-span shape to a higher one in correspondence to the supports (Fig. 1). Due to the scheme of the continuous beam, the deck is quite slim, with the height of its cross section varying from 106 cm (at the mid-length of each span) to 156 cm (at the supports).

In plan, the structure is substantially characterised by a curved shape. The first part has a moderate curvature with a radius of approximately 1632 m. Next, the radius of curvature decreases to approximately 743 m. The end part has an almost straight shape. From the altimetric perspective, the viaduct is built with a slope from the upstream abutment (SP1) to the downstream one (SP2), except for a small initial portion. A number of 31 piers in the central part (with a circular cross section having a diameter of 2.60 m and a height that varies between 4 m and 9 m) and two end abutments represent the supports for the deck. Two bearing devices are placed on each pier and each abutment, leaving free the relative longitudinal displacement of the connected parts.

Bearings

The viaduct kinematics associated with thermal effects is characterised by homothetic deformation with respect to the deck axis. Such displacements are allowed because of the presence of a two unidirectional sliding bearings for each pier, with each being characterised by a stroke of ±300 mm.

Regarding the response under seismic actions, for the design, the deck has been assumed to behave as a rigid body oscillating in the horizontal direction and not constrained on the piers but constrained only at the two abutments. The connection between the two ends of the deck and the abutments has been realised by means of four viscous dampers (two for each abutment). According to the original design, the seismic horizontal displacement of the deck is mainly represented by a rigid rotation around a vertical axis defined by the intersection of the planes containing the two end cross sections of the deck (Fig. 2). However, because of the particular geometry, the axes of the unidirectional sliding bearings do not coincide at a unique point. Therefore, the rigid deck rotation around the vertical axis is not allowable. To allow such rotation, the designer established that the unidirectional constraint devices were assembled on elastomeric reinforced pads. Moreover, due to the adoption of a metallic carpentry, only displacements transverse to the axis of the viaduct are allowed, thereby preventing the activation of those longitudinal displacements.

Dampers

Two viscoelastic dampers have been originally designed and placed at each end of the bridge. Each device is equivalent to a viscous damper and a spring connected in series. The purpose of these devices is to dissipate part of the input energy coming from seismic action and to link in a non-rigid manner the viaduct to both abutments. The innovativeness of such design is acknowledged considering the age of construction. Nevertheless, such link has no re-centring capability regarding the deck.

Fig. 1. A picture of the viaduct.