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Seismic performance of a cable-stayed footbridge using a concrete damage plasticity model

Izabela J. Drygala[a,]*, Joanna M. Dulinska[a], Marek Wazowski[b]

[a]*Institute of Structural Mechanics, Cracow University of Technology, Warszawska 24, 31-155 Krakow, Poland*
[b]*Aspekt Laboratorium Sp. z o.o., Chopina 96, 43-600 Jaworzno*

Abstract

In this paper, a non-linear dynamic analysis of a cable-stayed footbridge to an earthquake is presented. The investigation was performed for an existing pedestrian bridge located in Czestochowa, Southern Poland. The total length of the structure is 46.90 m. The suspended structure consists of two spans (21.10 m and 25.80 m). The deck of the footbridge is made of a steel-concrete composite and is connected to the steel pylon by cables. The structure is equipped with elastomeric bearings as linking elements between the deck and the pillars. A three-dimensional FE model of the footbridge was created with the ABAQUS software program. For the verification of numerical model the modal assurance criterion (MAC) was applied. The acceleration time history of the registered shock was used as seismic excitation acting in three directions. The peak ground acceleration (PGA) of the shock was 0.4 g. To represent the inelastic behavior of the footbridges' deck under the earthquake, a concrete damage plasticity model was assumed as a constitutive model for the concrete. It turned out that the analyzed shock was strong enough to cause severe destruction in the reinforced concrete deck of the footbridge.

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Keywords: concrete damage plasticity model; footbridges; dynamic response; seismic performance; modal assurance criterion

* Corresponding author. Tel.: +48-12-628-21-21
E-mail address: imurzyn@pk.edu.pl

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1. Introduction

In last few decades dynamic performance of footbridges has become more prevalent as is evident by the increasing number of researches on footbridges reported in civil engineering literature. The studies were performed for a variety of reasons including the investigation of the dynamic response of the footbridges to human generated loading, aerodynamic response, correlation of numerical solutions with measured dynamic characteristics, and seismic and paraseismic assessment [1,2,3].

In this work, the cable stayed footbridge located in Czestochowa (Southern Poland) was selected as a case study. First, the dynamic properties of the footbridge, i.e. its natural frequencies, modes shapes and damping ratios, were estimated. The validation of the obtained results was then conducted. In the last stage of the study, the seismic performance of a cable-stayed footbridge using a concrete damage plasticity model was prepared.

Nomenclature

C_{10}, C_{01}	parameters of the Mooney-Rivlin material
E	equivalent elasticity modulus
MAC	modal assurance criterion
R_{xx}	autocorrelation for *x(t)* and *y(t)* signals
S_{xx}	spectral density for *x(t)* signal
Ψ_X	modal vector
f	frequency [Hz]
α, β	Rayleigh damping coefficients
ζ	damping ratio
δ	logarithmic decrement [-]

2. Outline of the footbridge structure and numerical model

The dynamic investigation was prepared for an existing 2-span footbridge located in Czestochowa, Poland. The primary purpose of the footbridge is to carry pedestrians and cyclists over the national expressway DK-1. The structure was designed according to technical requirements demanded for footbridges (PN-85/S-10030). The structural layout is shown in Fig. 1. In the Fig. 1 the location of accelerometers, used for the in situ experiment, is also presented.

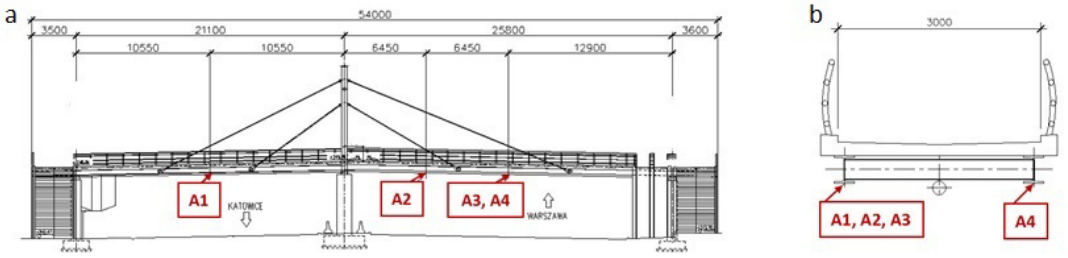

Fig. 1. Overall structural layout (a) and cross section (b) of the pedestrian and cyclist bridge in Czestochowa (Southern Poland)

The total length of the footbridge is 46.9 m (the length of spans are 21.1 and 25.8 m). The width of the structure is 3.5 m. The main girders are integrated with a concrete deck by steel bolts. The thickness of the deck varies from 0.17 to 0.20 m. The primary structural system of the footbridge consists of steel girders (I-section HEB 400) located at a distance of 2.8 m and connected by crossbars (I-section HEA 300). The superstructure has been suspended from a pylon 13.20 m high situated above the middle support (4 trusses on both sides of the deck). The trusses (type ASDO M42) are hinged to the pylon and to the deck. The pylon is constructed of the steel pipes of a diameter 457

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