

The digital twin use for modeling the multi-storey building response to seismic impacts

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Abstract

This work is dedicated to theoretical and experimental research on constructing a digital twin for a 24-story building located in a seismic zone with the possibility of seismic vibrations of up to eight on the Richter scale. A digital model of the building was developed considering the changes in its geometry (damage or absence of structural elements). This requires detailed field inspections of partially constructed buildings and consideration of the inspection results when constructing a digital model. The boundary conditions, in addition to the geometric characteristics of the building, include the physical and mechanical characteristics of all its structural elements obtained through nondestructive testing methods. Discrepancies between the structural elements' design and actual concrete classes were identified. The initial conditions included real accelerograms at the location of the building, which served as input data for the direct dynamic analysis. Thus, there is a need to develop a hybrid system for modeling the stress–strain state of a 24-story building that uses information technologies (Internet of Things) with sensors during research. Such an IoT system, combined with one information network using cloud technologies, allows us to obtain the necessary information in real-time, highlighting the features of the building (the second stage of constructing the digital twin). The bar and spatial models of buildings with distributed parameters of structural stiffness at bending and shear and the mass and mass moment of inertia were considered. The results of numerical studies of the first form of natural vibrations for the building rod (according to the expressions obtained by the authors) and spatial models (performed using the LIRA-CAD software package developed in Ukraine based on the finite element method) are presented. A comparison with the first experimental form of natural vibrations confirmed that considering the moment of inertia of the building mass makes it possible to determine the ordinates of the self-form of vibrations and seismic horizontal loads more accurately. The experimental first

frequency and form of natural vibrations of a 24-story residential building in Odesa were obtained from the results of vibration monitoring at the construction stage (16 floors were erected) and after all 24-floor erection. The direct dynamic method of building calculations for seismic effects specified by earthquake accelerograms was used along with the method proposed by the authors to consider damping during forced building vibration calculations and the actual physical and mechanical characteristics of concrete and reinforcement obtained by non-destructive testing methods. The calculated vibration amplitudes at the top of the building cantilever model were compared with the damping parameters obtained using the Voight model and the authors' method under the influence of an accelerogram recorded during the powerful 1977 Bucharest earthquake with an epicenter in the Vrancea area (Romanian Carpathians).