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Response Analysis of a Steel Reinforced Concrete High-Rise Building during the 2011 Tohoku Earthquake

Authors : Naohiro Nakamura, Takuya Kinoshita, Hiroshi Fukuyama

Abstract : The 2011 off The Pacific Coast of Tohoku Earthquake caused considerable damage to wide areas of eastern Japan. A large number of earthquake observation records were obtained at various places. To design more earthquake-resistant buildings and improve earthquake disaster prevention, it is necessary to utilize these data to analyze and evaluate the behavior of a building during an earthquake. This paper presents an earthquake response simulation analysis (hereafter a seismic response analysis) that was conducted using data recorded during the main earthquake (hereafter the main shock) as well as the earthquakes before and after it. The data were obtained at a high-rise steel-reinforced concrete (SRC) building in the bay area of Tokyo. We first give an overview of the building, along with the characteristics of the earthquake motion and the building during the main shock. The data indicate that there was a change in the natural period before and after the earthquake. Next, we present the results of our seismic response analysis. First, the analysis model and conditions are shown, and then, the analysis result is compared with the observational records. Using the analysis result, we then study the effect of soil-structure interaction on the response of the building. By identifying the characteristics of the building during the earthquake (i.e., the 1st natural period and the 1st damping ratio) by the Auto-Regressive eXogenous (ARX) model, we compare the analysis result with the observational records so as to evaluate the accuracy of the response analysis. In this study, a lumped-mass system SR model was used to conduct a seismic response analysis using observational data as input waves. The main results of this study are as follows: 1) The observational records of the 3/11 main shock put it between a level 1 and level 2 earthquake. The result of the ground response analysis showed that the maximum shear strain in the ground was about 0.1% and that the possibility of liquefaction occurring was low. 2) During the 3/11 main shock, the observed wave showed that the eigenperiod of the building became longer; this behavior could be generally reproduced in the response analysis. This prolonged eigenperiod was due to the nonlinearity of the superstructure, and the effect of the nonlinearity of the ground seems to have been small. 3) As for the 4/11 aftershock, a continuous analysis in which the subject seismic wave was input after the 3/11 main shock was input was conducted. The analyzed values generally corresponded well with the observed values. This means that the effect of the nonlinearity of the main shock was retained by the building. It is important to consider this when conducting the response evaluation. 4) The first period and the damping ratio during a vibration were evaluated by an ARX model. Our results show that the response analysis model in this study is generally good at estimating a change in the response of the building during a vibration.

Keywords : ARX model, response analysis, SRC building, the 2011 off the Pacific Coast of Tohoku Earthquake
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