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ScienceDirect

Procedia Engineering 199 (2017) 194–199

Procedia Engineering

www.elsevier.com/locate/procedia

X International Conference on Structural Dynamics, EURODYN 2017

Study on changes in dynamic characteristics of high-rise steel-framed buildings based on strong motion data

Toshihide Kashima*

Building Research Institute, 1 Tachihara, Tsukuba 305-0802, Japan

Abstract

The Building Research Institute (BRI) of Japan operates a strong motion network that covers buildings in major cities across Japan. A great number of strong motion data has been accumulated in the observing stations integrated in the strong motion network over many years.
This paper selects four high-rise steel-framed buildings from the BRI strong motion network. These buildings suffered severe shakings in the 2011 Tohoku Earthquake.
To discuss the dynamic characteristics of the buildings, the fundamental natural periods and damping ratios of the target buildings are identified using strong motion data. First, changes in natural periods and damping ratios with time are discussed. In general, the natural periods gradually increase with time. Caused by the severe motions in the Tohoku Earthquake, significantly changes in natural periods are observed in all the buildings. Second, the amplitude dependence of natural periods and damping ratios are discussed minutely. The obvious amplitude dependence of natural periods can be recognized in all cases. The types of the relations established between the response amplitudes and damping ratios are dependent on the buildings. Finally, the relations between the response amplitudes and natural periods were formulated based on the regression analysis. The result makes it easy to quantify the changes in the natural periods.

Peer-review under responsibility of the organizing committee of EURODYN 2017.

Keywords: Steel high-rise building; system identification; strong motion data; 2011 Tohoku Earthquake, Japan

* Corresponding author. Tel.: +81-29-864-6762; fax: +81-29-864-6777.
E-mail address: kashima@kenken.go.jp

1877-7058
Peer-review under responsibility of the organizing committee of EURODYN 2017.
10.1016/j.proeng.2017.09.269

1. Introduction

The Building Research Institute (BRI) of Japan is a national institute engaged in research and development in the fields of architecture, building engineering and urban planning. As one of its research activities, the BRI operates a strong motion network that covers buildings in major cities across Japan. A great number of strong motion data has been accumulated in the observing stations integrated in the strong motion network over many years.

On 11 March, 2011, an enormous earthquake with a moment magnitude (Mw) of 9.0 occurred off the Pacific Coast of northeast Japan. The earthquake, known as the Great East Japan Earthquake (hereafter, simply referred to as the Tohoku Earthquake), caused a monstrous tsunami and massive damage to eastern Japan. Seventy-nine stations in the BRI strong motion network were running at occurrence of the earthquake. Among them, 61 stations were triggered [1]. Many buildings in the BRI strong motion network were affected by the strong motions in the Tohoku Earthquake [2].

In this study, four high-rise steel-framed buildings were selected from the BRI strong motion network to investigate their dynamic characteristics before and after the Tohoku Earthquake. Then, changes in dynamic characteristics of the buildings with time were examined. Moreover, the amplitude dependence of the dynamic characteristics of the buildings was minutely investigated.

2. Target buildings

The target buildings of the analysis are listed in Table 1, and schematic cross sections and plans of those buildings are illustrated in Fig. 1. The building A, located in Sendai City, about 300 km north of Tokyo, was constructed more than 40 years ago. The buildings B and C are situated in the heart of Tokyo. The building B consists of two towers having common lower floors as shown in Fig.1(b) and the south tower (Tower C in Fig. 1(b)) is treated in this paper. In all the buildings, the moment resisting frame is used as the lateral load resisting system, and the buildings B and D partially have braced frames. The building C has the seismic control system composed of low-yielding steel walls and viscos damping walls. The building D is situated in Yokohama City, nearly 30 km south of Tokyo.

The strong motion instrument installed in each building has two or more acceleration sensors. In this paper, the strong motion data recorded in the lowermost and uppermost sensors are used as the input motion and building response, respectively. Red asterisks in Fig. 1 indicate locations of the sensors used in this paper.

On the right-hand side of Table 1, peak accelerations recorded during the Tohoku Earthquake are listed with an epicentral distance of each station. The building A suffered the severest shaking among the target buildings because of its closest location to the epicentre.

Table 1. Target buildings and peak accelerations of strong motion data acquired during the Tohoku Earthquake of 11 March, 2011

Building	Location	Number of floors/ Structure system*	Year completed	Strong motion records during the Tohoku Earthquake				
				Epicentral distance (km)	Sensor location	Peak accelerations (m/s^2)		
						L**	T**	V**
A	Sendai City, Miyagi	15F+B2F/ MRF	1973	175	B2F	2.59	1.63	1.47
					15F	3.46	3.61	5.43
B	Chiyoda Ward, Tokyo	20F+B3F/ MRF+B	1994	386	01F	0. 91	0.85	0.45
					19F	1.77	1.35	1.30
C	Chiyoda Ward, Tokyo	21F+B4F/ MRF+D	2000	386	B4F	0.75	0.71	0.49
					21F	1.21	1.31	1.04
D	Yokohama City, Kanagawa	23F+B3F/ MRF+B	1995	412	B2F	0.60	-*	0.30
					23F	1.62	-*	0.72

* MRB: moment resisting frame, +B: braced partially, +D: damping walls

** L(longitudinal), T(transverse) and V(vertical) directions. * Missing data caused by a failure in the instrument.