Engineering Structures 77 (2014) 161–169

Contents lists available at ScienceDirect

Engineering Structures

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

Effects of near-fault ground motions and equivalent pulses on Large Crossing Transmission Tower-line System

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ARTICLE INFO

Article history:
Received 17 August 2012
Revised 5 August 2014
Accepted 7 August 2014
Available online 4 September 2014

Keywords:
Large crossing
Tower
Conductor
Near-fault
Seismic response

ABSTRACT

The focus of this paper is the seismic response of Large Crossing Transmission Tower-line System (LCTL) to near-fault ground motions, and whether simplified pulses are capable of representing the effects of the ground motion pulses present in near-fault ground motions on seismic response. The effects of forward-directivity pulses and fling-step pulses on the response of near-fault LCTL were assessed. Results showed that near-fault pulse-like ground motions impose a larger seismic response to LCTL compared to far-field ground motions. The response of LCTL to near-fault motions shows higher scatter than the response to far-field ground motions when correlated with simple intensity measures such as PGA. Moreover, the seismic responses increase with the pulse period of near-fault ground motions. The response of LCTL to the forward-directivity ground motions and fling-step ground motions were reproduced using two new equivalent pulse models. It is shown that the equivalent pulse models can capture the important response characteristics of the near-fault record. There are significant differences between the responses of LCTL subjected to forward-directivity ground motions and the responses subjected to fling-step ground motions. Finally, the tower-line coupling of LCTL subjected to near-fault pulse-like ground motion was investigated. Results show that the effect of tower-line coupling on seismic responses of LCTL to far-field ground motions is more obvious than the responses to near-fault ground motions.

1. Introduction

Transmission tower-line system is normally designed for dead weight, wind load, ice load and the loads resulting from a broken conductor. In the absence of seismic code provisions, it is not the practice to take earthquake load into account [1]. However, during the 1999 Chi-Chi earthquake, the vastest damage to transmission tower-line system occurred. The earthquake damage to transmission line in the earthquake is summarized in Table 1 [2–4]. The most extraordinary disaster has been associated with near-fault pulse-like ground motion of the Chi-Chi earthquake. This emphasizes the importance of the seismic analysis of transmission line subjected to near-fault pulse-like ground motion.

In spite of this, there are few investigations on the seismic response of transmission tower-line system [5–12]. The only study on the seismic response of transmission tower-line system subjected to near-fault pulse-like ground motion was conducted by Yue et al. [9]. In their study, the responses of tower-line system under the excitations of near-fault ground motions, artificial ground motions and El Centro ground motion were compared. The results indicate that the difference between the tower's response to near-fault ground motions and far-field ground motions is not obvious. However, the results are apparently different from earthquake damage in the Chi-Chi earthquake. The difference may be induced by the short-period transmission tower used in the study. The fundamental period of the tower established in their study is 0.39 s, which is far shorter than the pulse period of near-fault pulse-like ground motions. There may be large differences in the responses of transmission towers with different fundamental period to near-fault pulse-like ground motions. Specifically, the responses of towers in Large Crossing Transmission Tower-line System (LCTL) to near-fault pulse-like ground motions may be different from those of ordinary transmission towers.

LCTL is the most important part of transmission line. Generally, the span of LCTL is more than 1000 m, and the height of LCTL is more than 100 m [13]. Compared with ordinary transmission tower-line system, LCTL has a much longer span and much higher transmission towers. Therefore, it may be more sensitive to the ground motions with low frequency component. However, there has been no attempt to investigate the seismic responses of LCTL to near-fault pulse-like ground motions.

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http://dx.doi.org/10.1016/j.engstruct.2014.08.013
0141-0296/

Table 1
Summary of damage to transmission towers in Chi-Chi earthquake.

Voltage (KV)	Collapse	Leaning	Distort	Foundation sunk/crack	Displaced	Total
345	1	9	55	271	19	355
161	9	4	9	131	4	155
69	3	16	3	60	2	83

The objective of this study is to identify salient seismic response characteristics of LCTL subjected to near-fault ground motions, to represent near-fault pulse-like ground motions with equivalent pulse model, and to relate seismic response of LCTL to parameters of near-fault ground motions.

2. Ground motions and equivalent pulses used in this study

Ground motions near a fault rupture can exhibit the effects of fling-step or forward-directivity. The fling-step motion ordinarily generates permanent static displacement that occurs parallel to the fault. The forward-directivity effects are characterized by a large velocity pulse occurring at the beginning of the motions perpendicular to the fault.

Despite their varying characteristics, both ground motions influenced by fling-step effects and forward-directivity effects may be characterized by large velocity pulse, capable of causing severe structural damage [14–17]. Near-fault ground motions are different from far-field ground motions in that they often contain strong coherent dynamic long-period pulses.

Fig. 1 illustrates ground acceleration, velocity and displacement time history of TCU052 ground motion recorded in the Chi-Chi earthquake in 1999 and El Centro ground motion recorded in the Imperial Valley earthquake in 1940. Ground motion TCU052 is a typical near-fault ground motion. As indicated by the time history of velocity and displacement, the near-fault ground motion contains a large pulse within the time range from about 12 to 20 s. Acceleration spectra for the two ground motions are also presented in Fig. 1. It is shown in the acceleration spectra that the long-period responses caused by near-fault ground motions are larger than those caused by far-field ground motions. It is obvious that the near-fault pulse-like ground motions are much more severe for long-period structure than far-field ground motions.

2.1. Ground motions

In this study, a set of 10 near-fault ground motion records with forward directivity is used to evaluate the seismic responses of LCTL. These ground motions cover a pulse period range from 0.67 to 11.86 s and a rupture distance (closest distance from site to fault rupture plane) range from 0.24 to 8.0 km. Table 2 lists the basic properties of the ground motions.

To compare the near-fault seismic responses of the tower-line system with the responses caused by far-field ground motions, 10 widely used far-field ground motions are also used in this investigation. The basic properties of the recorded motions are presented in Table 3.

2.2. Equivalent pulses

As pointed out previously, ground shaking near a fault rupture is characterized by a large pulse in the time history. Although near-fault ground motions are very complex, studies [16] have shown that simple pulse representations are capable of capturing

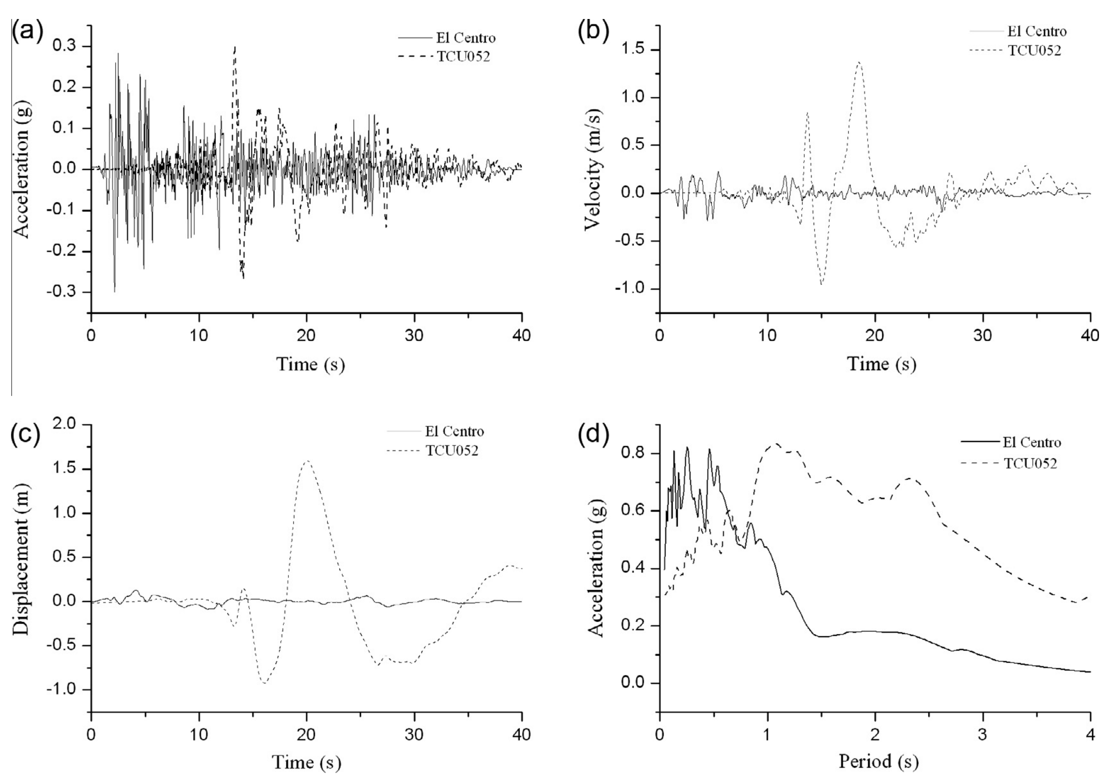

Fig. 1. Comparison of near-fault pulse-like ground motion and far-field ground motion: (a) acceleration; (b) velocity; (c) displacement; (d) acceleration spectra.