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Ground motion processing and observations for the near-field accelerograms from the 2015 Gorkha, Nepal earthquake

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ABSTRACT

Processed accelerograms define the ground motion input for a variety of engineering and scientific analyses. The M_w 7.8 Gorkha, Nepal earthquake of 25 April 2015 currently has data from six near-field seismograph stations, recorded from within Nepal, available in the public domain. However, only the USGS sensor from the Kantipath (KATNP) station in Kathmandu has a processed data set available. The remaining acceleration time series are only provided in raw form, which require additional signal processing to be properly utilized for analysis. This paper discusses three different processing schemes for the accelerograms that may be used based on the intended application. Based on these processed records, some observations of the ground motions are then discussed. Fourier and response spectra results are presented to illustrate the effects of the processing procedure and the frequency contents. The processed ground motions are compared to applicable ground motion prediction equations (GMPEs) for peak ground acceleration (PGA) and velocity (PGV). It is shown that existing GMPEs generally overestimate the PGA and PGV. Due to the presence of long period pulse-like behavior in the time series, two pulse extraction models are used to estimate the pulse parameters, including the pulse period (T_P). By comparing the pulse period to an M_W–T_P relationship from the literature, it is shown that the recording from the rock site is an excellent match, while the other five soil sites have shorter periods than predicted. The M_W-T_P relationship shows longer pulse periods in rock sites than soil sites for magnitudes greater than M_W 7.8, which is also observed from the results of this study. The observed long period peaks in the response spectra are attributed mainly to directivity effects.

1. Introduction

The 25 April 2015 Gorkha, Nepal earthquake occurred due to thrust faulting on the subduction boundary between the Eurasian and Indian plates [1], which converges at a rate of approximately 20 mm/year [2]. The rupture occurred on the Main Himalayan Thrust (MHT), which reaches the surface near Nepal's border with India. Fig. 1 shows a map of Nepal, the location of the ruptured MHT fault, the fault projection and proximity to the sensors in Kathmandu. The event epicenter has been located at 28.231°N 84.731°E with a focal depth of 8.2 km [1]. Due to a shallow dip of ~7°, nearly all the strong-motion sites have a rupture distance ~ 14 km as shown in Table 1. The Kathmandu Valley is composed of sedimentary deposits with thickness up to 549 m, with shear wave velocities in the range of 167–297 m/s [3]. The existing literature has identified that the strong motion recordings are influenced by non-linear soil response [4,5], forward rupture directivity [2,6], and resonance within the basin [2]. The non-linear soil response reduced the high frequency content which lowered the magnitudes of high frequency quantities such as PGA [4,5,27]. Forward rupture directivity results in pulse-like behavior at the beginning of the record, while resonance may be responsible for subsequent long period oscillations at the soil sites. Hence the literature has shown that source (directivity) and site effects (soil non-linearity and resonance) are responsible for reducing magnitudes of the recorded accelerations and producing long period resonance and pulse-like behavior. This combination of effects at the strong motion stations is rare and not well represented within the existing strong motion databases [27].

As identified by [7], the limited availability of strong-motion data has restricted research into the 2015 Gorkha earthquake. This paper discusses processing methods to utilize the available data for engineering analysis. Seismic signal processing is necessary to remove both low and high frequency noise from the raw recording [8]. The processing can also correct for instrument response, make baseline adjustments, and eliminate spurious acceleration data. Processed records are generally provided by organizations such as the United States Geological Survey (USGS), Italian Accelerometric Archive (ITACA), and Pacific Earthquake Engineering Research Center (PEER). Typically, both raw and processed data are provided in electronic format. In some

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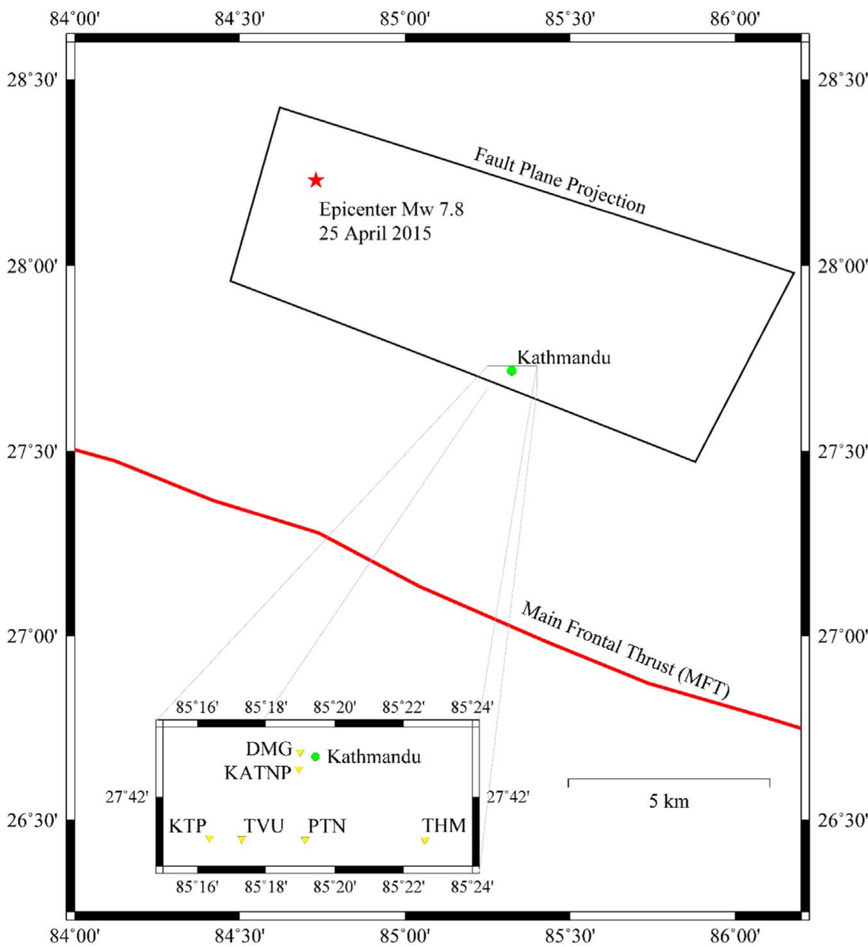

Fig. 1. Map of Nepal showing the epicenter (red star), ruptured fault (red line), fault plane projection (black polygon), and Kathmandu city center (green circle). The inset shows the location of the six stations (yellow triangles).

Table 1
Sensor and Processing Summary.

Station	Sensor	sps	f_c (Hz)	t_w (sec)	t_p (sec)	t_d (sec)	R_{epi} (km)	R_{rup} (km)[a]
KATNP	Geosig-GMS (NetQuake)	200	0.02	129	29	100	81	14.1
DMG	Geosig-AC23	200	0.05	100	9.5	100	81	14.4
KTP	Mitsutoyo JEP-6A3–2	100	0.02	99.99	12	99.99	81	13.7
PTN	Mitsutoyo JEP-6A3–2	100	0.02	99.99	12	99.99	84	13.1
THM	Mitsutoyo JEP-6A3–2	100	0.02	99.99	12	99.99	88	13.5
TVU	Mitsutoyo JEP-6A3–2	100	0.02	99.99	12	99.99	82	13.6

[a] : From [7].

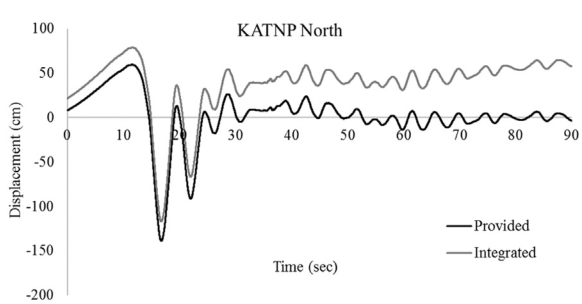

Fig. 2. Incompatible time series.

cases, only the raw data is available, including five of six near-field stations from the 2015 Gorkha earthquake. There is no global standard on electronic file format distribution or even processing methods which can vary widely between different agencies and regions [9]. For example, some ground motion databases distribute padded acceleration time series while others provide pad-stripped versions. The processing procedures discussed here will result in "compatible" waveforms: all adjustments are made to the acceleration waveform, and velocity and displacement are found by linear time domain integration. Incompatible records are those where the processed velocity and displacement cannot be obtained by single and double integration of the acceleration time series, respectively. An example of an incompatible time series can be seen in Fig. 2, using the USGS processed data from the North component of the Kantipath (KATNP) station record of the 2015 Gorkha earthquake. In Fig. 2, the "Provided" time series is obtained directly from reading the electronic displacement time series, while the "Integrated" waveform is obtained by double numerical integration of the acceleration time series, assuming zero initial conditions for velocity and displacement. It is evident that additional processing may be necessary to match the two displacement waveforms. In this case, the "Provided" time series may only be obtained by assigning the correct initial velocity and displacement conditions. These values are not identified in the header lines of the acceleration file, but may be