Abstract

Mudflow is often associated with seismic activities. The present study applied a seismic based detection of the surface waves generated by the mudflow of Brumadinho dam collapse using records of Brazilian Seismographic Network. The signal envelope and time-frequency spectrograms of the mudflow signals were used in the analysis. As a result, the mudflow signals were successfully detected from the data recorded at a nearby seismic station. The findings of this study provide a good basis for future research to develop a flood early warning system based on cost-effective, remote and contentious seismic monitoring approaches.

Keywords: envelope; spectrogram; flood early warning system.
1. Introduction

The more frequent rainfall due to climate change is a worldwide problem as it may cause floods, debris and mudflow, which have disastrous impacts on the lives and property of downstream residents. In general, sediment transportation associated with floods is an important driving force in channel morphology and therefore has a wide range of applications in the field of landscape evolution, ecology, water quality, land use management, and civil and river engineering, such as dams and recreational reservoir silting (Stall et al., 1958). The remote seismic detection of these events may help in the development of early flood warning systems and possible quantification of the sediments.

Different attempts have been taken in the field of fluvial seismology for the detection and quantification of seismic signals generated by the fluvial processes (e.g., Burtin et al., 2011; Hsu et al., 2011; Schmandt et al., 2013; Barrière et al., 2015; Chao et al., 2015; Roth et al., 2016; Vázquez et al., 2016; Anthony et al., 2018; Goodling et al., 2018). These findings support the use of seismic emission for the high-resolution monitoring of river bedload and other flow attributes. In the previous studies, the attempts were also made for the seismic characterization of the signals generated by the massive mudflow, including frequency distribution modeling and Doppler effect estimation (Huang et al., 2019).

The present study applied analysis on the mudflow signals generated by the recent dam collapse of Brumadinho, based on the methodology adopted by Augurto-Detzel et al. (2016). On 25 January 2019, around 12:28:20 P.M. local time (UTC:14:28:20), a tailings dam in the Córrego do Feijão Mine, in Brumadinho, state of Minas Gerais, Brazil (Figure 1), collapsed releasing more than 13 million cubic meters of water and mine waste, which led to about 300 fatalities (Petley, 2019). The surface waves generated by the mudflow at a known time (video recording) and space were used as a priori information in checking the reliability of the detections of these events at the regional seismic network. The causes of the dam collapse are out of the scope of the present study.

2. Methodology

The mudflow envelope was generated in software Seismic Analysis Code (SAC) using the processing steps adopted by Augurto-Detzel et al. (2016). The calculated envelope indicated the average absolute amplitude of the vibrations. Spectrograms for the records during the event were calculated using the S-transform (Stockwell et al., 1996; Stockwell, 2007). The data were recorded with Trillium 120p seismometers and Taurus data logger of Nanometrics Inc (Bianchi et al., 2018). Details can be found at http://www.rsbr.gov.br.

3. Results and Discussions

The seismic signals generated by the mudflow are used for the analysis of the records at the nearby seismometers at the time of the collapse. These mudflow signals lasted for about 2 minutes, as evident from the envelope of the signal calculated at the nearest station BSCB (Figure 2). Different ascending and descending peaks can be seen, which may be related to different factors including effects of the topography of the region, the collapse of a railway bridge and other structural collapses. The signals finally diminish as the flooding speed decreases while flowing through the river. As the calculated seismic amplitude has a

Figure 1 - Location map: (a) shows location within South America, the State of Minas Gerais enclosed in red rectangle. (b) Map shows the locations of dam site and seismometers used in the analysis.
direct relationship with the discharge of the debris flow (Huang et al., 2008; Goodling et al., 2018, Anthony et al., 2018). There are other small unknown events which may be created by mining blasts or small magnitude regional earthquakes.

Figure 2 - Seismic envelope of the signal produced by the mudflow. The envelope of events (the events’ time indicated by red triangles). The red triangles on left indicate an unknown zoomed event around 14:12h.

The energy bursts can also be observed in amplitude power spectrograms of three-component records from a nearby station (BSCB) which show that the maximum mudflow amplitude content in the frequency domain is observed up to 2 Hz (Figures 3). These results are consistent with the findings of a previous case study on dam collapse in the area (Augurto-Detzel et al., 2016). In the spectrogram, the onset time, as well as frequency content, is quite clear. The signal energy is more prominent on the vertical and north components, while its amplitude is low at the east component. Because the recording was done at a distinct seismometer, the spectrogram shows a very narrow frequency range as frequencies are attenuated with distance from the source (Figure 3), and this was also found in a previous study by Burtin et al. (2009).

Figure 3 - From top to bottom: Z-component, N-component and E-component spectrograms of station BSCB generated during the mudflow event.

4. Conclusions and Recommendations

The possible seismic signals generated by the turbulent mudflow of the recent collapse of Brumadinho dam were analyzed by the seismic signal envelope and time-frequency spectrogram. By using this methodology, the onset and frequency contents of mudflow were detected from the remote seismometer data. The mudflow was well detected on the envelope and was found more prominent on the nearby station (BSCB) which installed almost ~120 km away from the dam.
The following findings and conclusions can be obtained from the study: (i) Spectrogram of the event recorded at the nearby station showed that its frequency was below 2 Hz. (ii) The results of the present study are consistent with the previous similar study on tailings dam failure in the area (Augurto-Detzel et al., 2016).

The regional seismic network (used in the present study) can detect events of strongest energies. However, for the monitoring of small energy events, dense temporarily seismic networks of short-period arrays can fill the gap of missed seismicity. The higher frequencies are attenuated because of the long distance between sources and receivers. Under these conditions, it is not possible to determine the frequency distribution model of the event, which explained the force applied by the mudflow generated signals. This analysis is recommended for future studies where sensors should be placed near the dam site.

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