Foreshock activity during stick-slip experiments of large rock samples

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For inland earthquakes such as the 2007 Noto Hanto earthquake (Doi and Kawakata, 2013) and the 2008 Iwate-Miyagi earthquake (Doi and Kawakata, 2012), foreshocks were reported to occur in the vicinity of main shock hypocenter. Moreover, for interplate earthquakes such as the 2011 off the Pacific coast of Tohoku earthquake (Kato, et al., 2012) and 2014 Iquique earthquake in Chile (Yagi et al., 2014), migration of foreshocks toward the main shock hypocenter was detected in one month before the main shock. In order to understand the generation mechanism of foreshocks, it is important to investigate under what environments foreshocks occur.
Since 2012, stick-slip experiments have been carried out using a large-scale biaxial friction apparatus at NIED (e.g., Fukuyama et al., 2014). Based on the experimental result that foreshocks were detected only in the later period of each run, Kawakata et al. (2014) suggested that the foreshocks occur only after the generation of gouge. In this study, we carried out a series of stick-slip experiments with and without pre-existing gouge along a fault plane to confirm if fault gouge affects the foreshock activity. When foreshocks are detected, we estimate the hypocenter locations of foreshocks.
We used two rectangular metagabbro blocks to make the simulated fault plane, whose dimension was 1500 mm long and 500 mm wide. The experiments were conducted under normal stress of 1.33 MPa and loading speed of 0.01 mm/s up to approximate slip amount of 8 mm. During each experiment, we continuously measured elastic waves to detect foreshocks. The sensor distribution is shown in the figure below. Gouge materials were prepared naturally during preceding experiments whose sliding speed was as high as 1 mm/s.
To roughly detect foreshock activity, we calculated cumulative amplitude of continuous waveform data every 0.01 seconds. During an experiment without pre-existing gouge materials (LB13-004), a few foreshocks were detected. On the other hand, during an experiment with pre-existing gouge materials (LB13-007), much more foreshocks were detected. Then we estimated hypocenters of foreshocks for a stick-slip event (event 44) in LB13-007. Although the initial phases of the main shock were contaminated due to the coda wave signals of preceding foreshocks, the hypocenter of the main shock was roughly estimated near the right end of the fault plane. Foreshocks began to occur in the left half of the fault plane, but most of later foreshocks occurred near the right end. Therefore, we confirmed that foreshock activity was high when gouge materials were present along a fault plane, and found a similar hypocenter migration of foreshocks toward the main shock hypocenter, which was reported for interplate earthquakes.
In the future, we shall examine the data obtained from other experiments to confirm if the aforementioned features are common.
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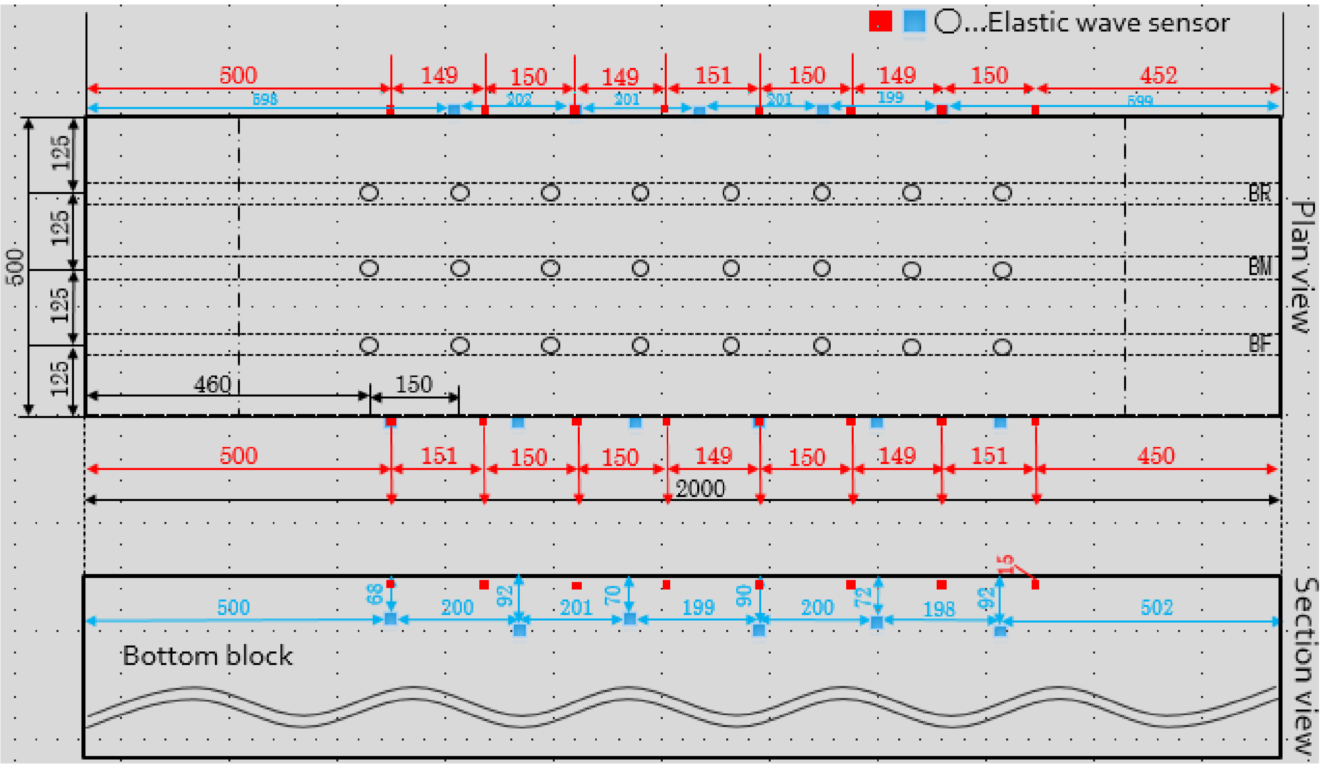
Keywords: large-scale biaxial experiments, foreshock activity, fault gouge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