Elastic wave transmission experiment to evaluate the accuracy of absolute AE locations in an acrylic cylindrical specimen

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Laboratory experiments using rock specimens have been performed to understand earthquakes (e.g., Mogi, 1962). The rock fracture experiments enable us to observe the fracture preparation process through elastic waves radiated from microfracture events called AE (acoustic emission) events. In order to understand the fracture preparation and propagation processes, it is very important to investigate how AE events occur on and around the rupture plane, based on the spatiotemporal evolution of the hypocentral distribution. Elastic waves from AE events can be observed using transducers, and their hypocenters can be estimated (e.g., Yanagidani et al., 1985), and Lockner et al. (1991) claimed that AE hypocenters were distributed along the fault plane to be produced. However, the accuracy of the hypocenters estimated from the arrival times of elastic waves has not been evaluated in detail.

Especially, it is necessary to evaluate the accuracy of absolute AE locations in order to investigate the relationship between the location of the fault plane and the spatial distribution of AE events, and it is useful to conduct elastic wave transmission experiments using specimens with an embedded wave source. Inanishi et al. (2022) conducted elastic waves transmission experiment with a wave source embedded in a mortar specimen using eight transducers as receivers. A jackknife test was applied to evaluate the accuracy of the absolute hypocenter location. The centroid of the hypocentral distribution was significantly off the embedded position. The hypocenters were widely distributed, which should be caused by the heterogeneity, anisotropy of the specimen, and/or the azimuth deviation of the transducers due to the small number. In this study, we tried to reduce these effects using acrylic specimens together with 16 transducers.

We prepared an acrylic cylinder and drilled a hole in it whose diameter was slightly longer than that of the iron nail. The iron nail was inserted and its tip was fixed to the bottom of the hole. The origin and the z-axis were set to be the center of the specimen and the cylindrical axis, respectively. The position of the tip was on the y-z plane. We attached 16 broad-band AE transducers to the cylindrical surface. The transducers were distributed at intervals of 22.5 degrees on the x-y plane. Elastic waves were radiated from a piezoelectric element attached to the nailhead, and signals were recorded at 20 Msps. The hypocenter was estimated from the P-wave arrival times. A jackknife test was applied using all combinations of more than 14 arrival times (Figure 1). The estimated hypocentral distribution was less scattered than that of Inanishi et al. (2022) but was positively shifted in the x-axis (Figure 2).

Then, we performed numerical experiments to investigate possible causes of the systematic shift. The picked arrival times are often delayed due to the presence of noise. Especially, the delays tend to be longer for waveforms recorded at distant transducers because the noise affected more. In the synthetic test, we assumed hypocenters in a simulated acrylic specimen and calculated travel times. The synthetic delays were calculated to be proportional to the hypocentral distances with some random perturbation and were added to the travel times. Changing the perturbation strength, we repeatedly estimated the hypocenters using the delayed travel times. The centroid of the estimated hypocenter distribution tended to be shifted more in the direction as the hypocenter was farther from the origin. The expected hypocenter shift for our laboratory measurement is in the y-z plane, which differs from the experimental result. We will examine the cause of the difference both numerically and experimentally in detail.

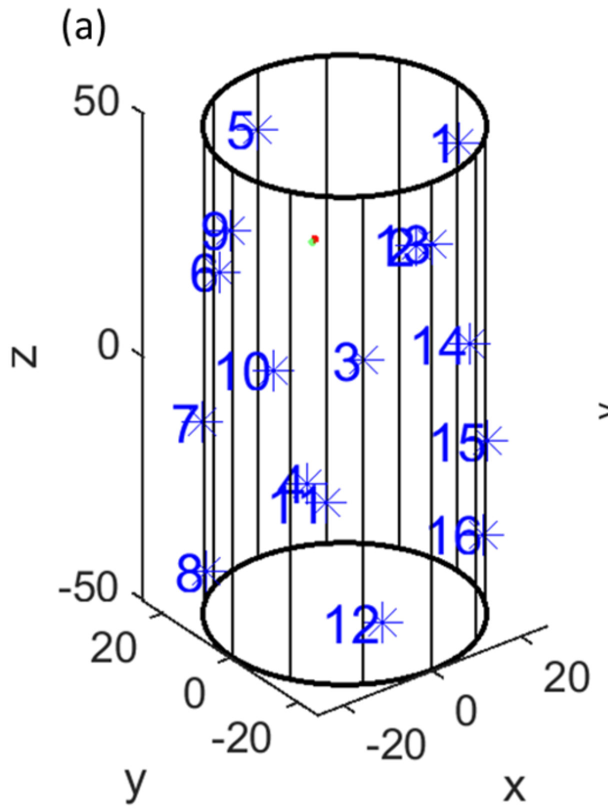

Figure (1) : Estimated hypocenters (red dots) together with the transducers (blue asterisks), and the embedded region of the iron nail (green sphere). (a) A 3-D image. (b) A 2-D image projected to the x-y plane.

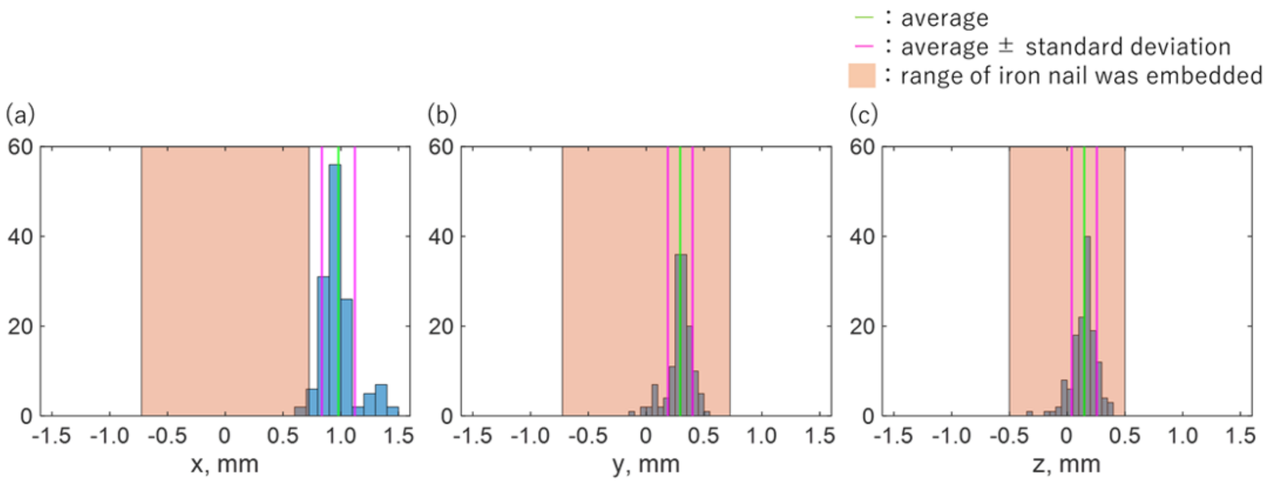

Figure (2) : Histograms of estimated hypocenters (blue) together with their averages (green), the averages ± standard deviations (pink), and the range of the embedded iron nail (orange) in the axes of (a) x, (b) y, and (c) z.

