Physics of Near-Source Strong Ground Motions (2): Comparison of Kumamoto and Kobe

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We here reconsider the fling effect as a cause of near-source strong ground motion. It is written that "The other (cause) is due to the movement of the ground associated with the permanent offset of the ground" in Bolt and Abrahamson (2003). From this idea, some believe: static offsets are found in the displacements obtained by the integrations of strong motion records, and therefore the fling effect is a main cause of the near-source strong ground motions by the 2016 Kumamoto earthquake. However, this belief is not correct, because static offsets can also be found in the displacements obtained by the integrations of the 1995 Kobe near-source strong motion records, which are thought to be caused by the directivity effect. Though, records close to the nodal plane, such as at Kobe University (only 1 cm by GPS) do not include a significant static offset.

Then, what is the physical entity of the fling effect? Hisada and Bielak (2003) mentioned that the fling effects "correspond to mostly the static terms." In their formulation, the static terms are the omega-independent parts of the Fourier transforms of the Green's functions. Ground motion is a convolution of the Green's function and a slip time function. If the static terms are independent of omega, their Green's functions do not include time. From these, ground motions by the static terms are proportional to slip time function. Among ground motions radiated from an earthquake, those proportional to slip time function is called "intermediate-field terms" (e.g., Aki and Richards, 2002). Therefore, the static terms are the Green's function parts of the intermediate-field terms. Dreger et al. (2011) also wrote "Theoretically, the static offset is due to the intermediate-field term of the elastodynamic equations of motion (Aki and Richards, 2002), and as described, it is physically the sudden elastic rebound of the crust around the rupturing fault, which is called fling in the earthquake engineering community."

In addition, Dreger et al. (2011) concluded from the results of ground motion simulations for a hypothetical Mw 6.5 earthquake: The fling effect "is only sensitive to the slip on the immediate fault surface and is very sensitive to the depth of burial of the fault. Unfortunately, there are no observations in this very near-fault distance range (<100 m)." This means that there exist the fling effects within a range of 100 m from a large slip immediately below the ground for an Mw 6.5 earthquake. Kobe was not this case, because no large slip has been found in the shallow parts of the Kobe-side source fault, by source inversions and other analyses. For the 2016 Kumamoto earthquake, the source inversions (Asano and Iwata, 2016; Hikima, 2016; Kubo et al., 2016; Kobayashi et al., 2017) recovered considerable slips for the shallowest point sources. However, since their depths are 1 km or so, those do not show a large slip immediately below the ground. If this large slip exists, the fling effects by it and the directivity effects by the upward rupture propagation, which all the source inversions indicated, should produce extraordinarily large and concentrated ground motions. However, in reality, such a ground motion distribution has not yet been found.

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