

Strong Ground Motion near Surface Faulting -What is the Fling Step?-

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The fling step is the displacement wave with the permanent offset in the vicinity of surface faults, which occurs across a ruptured fault (ex., Stewart et al., PEER Report 2001/09). Its velocity waveform shows the unidirectional long-period pulse amplitude, and thus, it is called the fling pulse and/or the long-period pulse. The fling step is prominently observed near the large-scale surface faulting, such as the 1999 Chi-Chi earthquake and the 2016 Kumamoto earthquake, which has been important for the aseismic design of life-line facilities and buildings across the surface fault.

However, as compared with the directivity pulse, the fling step doesn't seem recognized well in seismological community yet. This is probably that the strong motion records have been rare near large-scale ruptured fault, and it has been occasionally misinterpreted. For example, Dreger et al. (BSSA 2011) mentioned "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." . On the other hand, Koketsu et al. (Nature/Scientific Report 2016) define the near-field terms as the fling step. These interpretations are clearly wrong as the following reasons.

1. The static offset are not the individual contribution of the intermediate- nor near-field terms, but both contributions (see equation (4.34) in Aki and Richards).
2. Since the fling step appears very near the faulting plane, it cannot be expressed by the point source; it should be evaluated by the extended source in the representation theorem. In the latter case, the fling step converges to that of the fault slip (Hisada and Bielak, BSSA 2003).

One the other hand, Hisada and Bielak (BSSA 2003) define the fling step as the contribution of the static Green function in the representation theorem, because the dynamic Green function converges to the static one, when the observation point is close to the fault plane. This definition is valid to any media including the layered half-space, and provides accurate results of the fling step.

We demonstrate the fling step using a simple circular fault model as shown on Fig.1 (R is the radius, D is the uniform fault slip, z is the distance from the center of the fault, and U is the displacement at z ; Hisada, Proc. AIJ 2014). Fig.2 is the normalized static displacement ($U/D/2$) in a homogeneous full-space using the point and extended sources. When the normalized distance (z/R) is larger than 1, the two results by the point and extended sources agree well, but when z/R is less than 1, the normalized amplitude of extended source converges to 1, whereas that of the point source goes to infinite. Fig.3 shows the velocities and displacements using the static and dynamic Green functions, where we use the triangle slip velocity of the 1 s duration and 1 m slip. When the observation point is close to the fault ($z/R=0.1$), the waves by the static Green function agree well with those of the dynamic Green function. When the observation point is far from the fault ($z/R>1$), the contribution of the static Green function becomes negligible, and that of the far-field term of the dynamic Green function becomes prominent. We will present the detail results including more realistic fault in layered media at the meeting.

Keywords: Strong Ground Motion near Surface Faulting, Fling Step, Representation Theorem, Contribution of Near-, Intermediate-, and Far-field terms

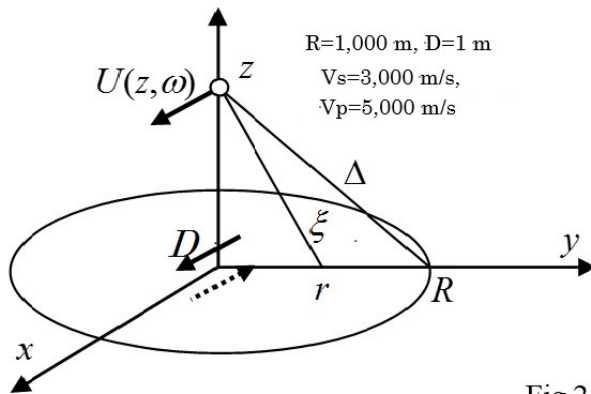


Fig 1. Circular fault model

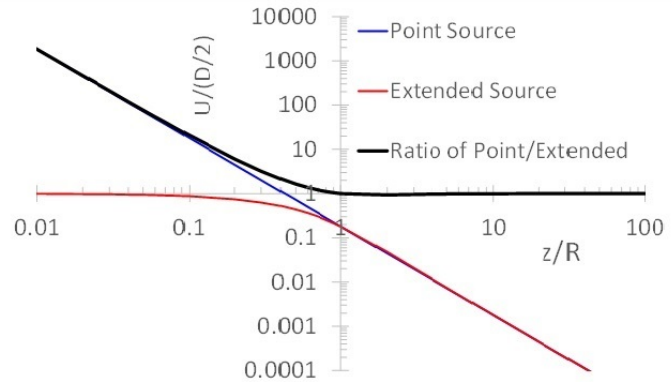


Fig 2. Normalized displacement amplitude using point/extended circular fault models and the static Green function

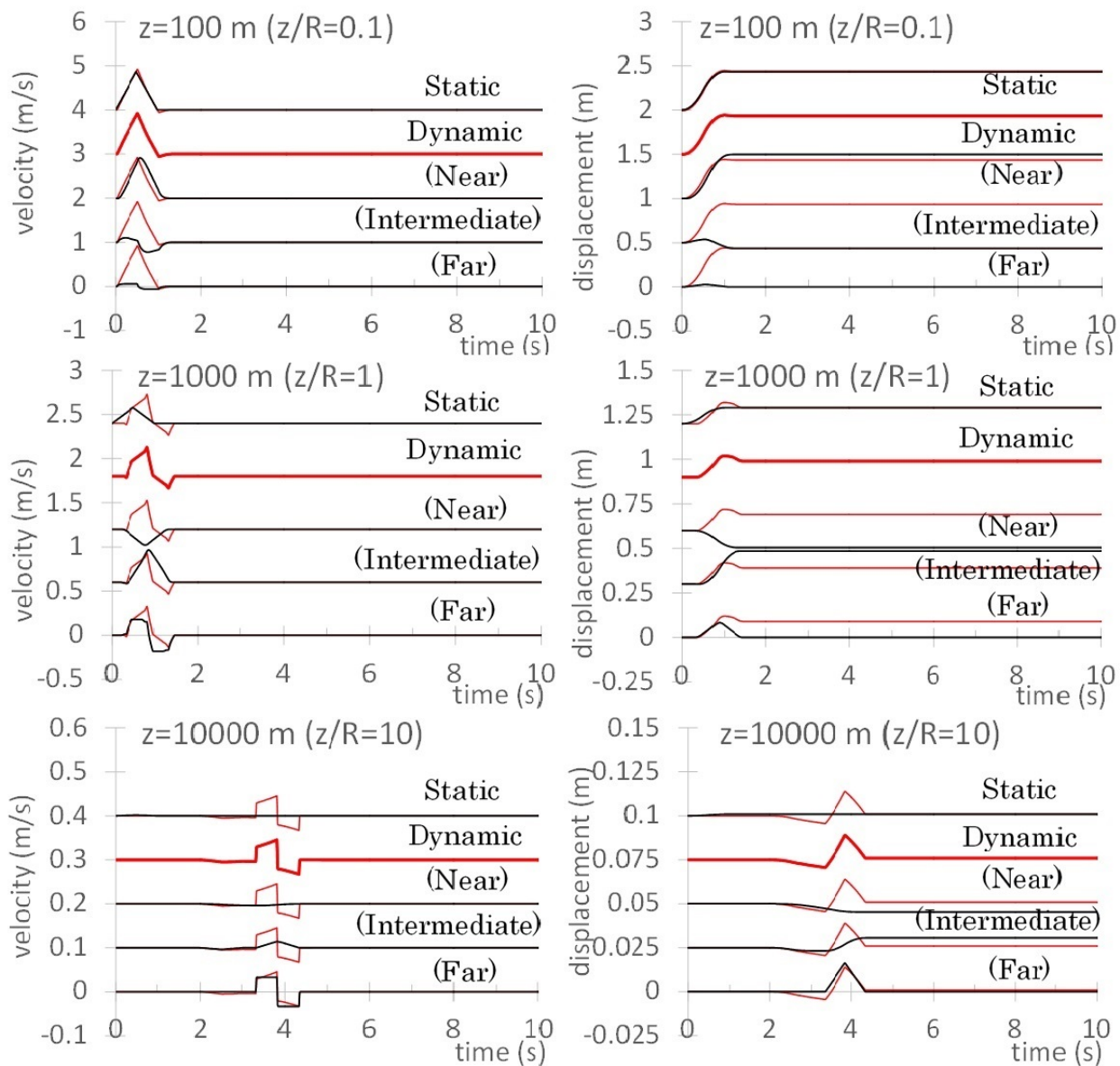


Fig 3. Velocities (left) and displacements (right) using the circular fault model and the static and dynamic Green functions. The contributions of the near-, intermediate-, and far-field terms are also shown.