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Effect of a soft surface layer on static and dynamic displacements and their frequency dependency

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We studied the effect of a soft surface layer on static and dynamic displacements for strike-slip faults with the discrete wavenumber method. If a soft surface layer exists above a fault, static displacement at the surface is amplified everywhere near the fault (Honda and Yomogida, C17, SSJ fall meeting 2001). This is due to the impedance contrast across the layer boundary, similar to the case of dynamic motions. We shall compare the amplification pattern of static displacements due to a surface layer with that of dynamic waves, including their frequency dependency. Using a vertical strike-slip fault, we compare the increasing rate for the dynamic displacements of two frequency ranges (0.1-0.5 and 1.0-1.5Hz) with those for static displacement.

In the case of a fault located just beneath the surface layer, static displacements of both horizontal components are amplified as the surface-layer thickness increases. The vertical component is not amplified significantly except for around the area of the maximum amplitude. The increasing rate clearly declines if the fault top crosses the layer boundary. Since we fix the amount of slips on the fault, the total moment release of the fault becomes smaller in the point of the fault buried in the surface layer. The largest amplification for static displacement, which appears in the fault parallel component, reaches nearly 45 %. Although the increasing rate decreases as the distance between the boundary and the fault top becomes large, surface displacements are amplified even in the case of a thin surface layer and a deep fault (i.e., for 2 km layer and the fault top is 7 km deep, the increasing rate is nearly 20 %).

Dynamic waves, mainly consisted of S-waves, are amplified by the directivity effect, and the existence of a surface soft layer further enhances this effect. Since dynamic motions have large amplitude and a pulse-like shape at the rupture stopping point, they are amplified stronger than those at the rupture initiation point are. As a result, the amplification pattern of dynamic waves varies in space complexly. We define the increasing rate of dynamic motions, in order to compare the static ones, as the difference of the maximum displacement between the half space model and a layered model. The higher the frequency is, the more amplified dynamic displacements are. The dynamic displacements of the fault-normal component are the most amplified of all the three components, while the fault parallel component, which corresponds to the slip vector, is the most amplified for the static. Unlike static displacements, dynamic motions are amplified monotonically as the thickness of the surface layer increases. Dynamic waves such as P- and S-waves are amplified by the existence of a low rigidity layer just above the fault, while the small moment release in the surface layer constrains the amplification of static displacements if a fault is very shallow. The increasing rates in a low frequency range are smaller in the 2 km layer case than those in the 5 km layer case, because the effect of the surface layer appears only if the wavelength is comparable or smaller than the layer thickness.

In summary, a thin layer can amplify static displacements at the surface, which corresponds to infinite wavelength, even if the distance between the fault top and the layer boundary is large. The amplification pattern of dynamic motions is quite different from the static ones. We must consider the effect of a thin surface layer on static and dynamic displacements individually, when we estimate the slip distribution on a fault or the fault depth with both geodetic and seismic data.