

Analysis of slip propagation in a simple shear field using super/sub-loading surface friction model considering temporal adhesion transition of the sliding surface

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We have proposed an elasto-plasticity-based super/sub-loading surface friction model¹⁾ that can describe velocity weakening of kinetic friction and stopping time dependency of static friction without the velocity and time as explicit variables. In this model, the transition of the adhesion is described by the evolution rule of “degree of adhesion” on a contact surface (decay of adhesion due to plastic sliding and healing of adhesion with time). The dynamic analysis with the proposed model exhibits the stick-slip phenomenon²⁾. In this abstract, we discuss the influence of the normal stress distribution at the contact surface on the global slip behavior under a simple shear condition with the dynamic infinitesimal deformation elastic finite element analysis³⁾.

The FE mesh and boundary conditions were set as shown in Fig. 1. As for the normal stress distributions on the bottom surface, uniform and triangular distributions shown in Fig. 2 were assumed in Cases 1 and 2, respectively. The parameters were set according to the previous study³⁾ considering both decay and healing of adhesion at the contact surface. The saturation of adhesion at the entire contact surface was assumed as an initial condition.

The time histories of the horizontal displacements at Nodes 1~6, the friction forces and the degree of adhesion $1/R^*$ at Segments A~F are shown in Figs. 3 and 4 for Cases 1 and 2, respectively. As for $1/R^*$, $1/R^* = 1$ ($1/R^* = 2$ in the case) represents the state where the adhesion is completely decayed (recovered) state. In Case 1, the adhesion on the entire contact surface repeated similar decay and healing (Fig. 3(c)), intermittent slip and friction force reduction occurred at the entire surface (Figs. 3(a) and (b)).

In contrast, the slip is non-uniform (Fig. 4(a)) in Case 2. That is, at the left end (Node 1), small slips occur 5 times in 1000 s from the beginning and the next slip occurs when the adhesion has not recovered enough ($1/R^* \sim 1.5$, Fig. 4(c)). On the other hand, at the right end (Node 6), large slip occurs once in 1000 s from the beginning, and the next slip occurs when the adhesion has recovered enough ($1/R^* \sim 1.9$, Fig. 4(c)). These results are consistent with the reduction tendency of the number of earthquakes with the increase of confining pressure⁴⁾. As for the slip propagation, the slip at the left side of the contact surface (Segments A and B) does not propagate toward the central region (time zone (1) in Fig. 4(b)) while slip on the right side of the contact surface (segments E and F) always accompanies the slip at the left side (time zone (2) in Fig. 4(b)). In Figs. 4(a) and (b), the tangential stress drop caused by the slip at the left side is balanced by the frictional resistance of the surrounding sliding surface (mainly Segment C) hindering the propagation to the entire contact surface. However, the large stress drop with the slipping of the right side exceeding the resistance of the surrounding area resulted in the slip propagation to the entire contact surface.

In future studies, we will investigate the effects of temperature and confining pressure on the evolution rule of the adhesion, and analyze the slip propagation on the fault, seismic wave generation, and stress rearrangement in the surrounding crust.

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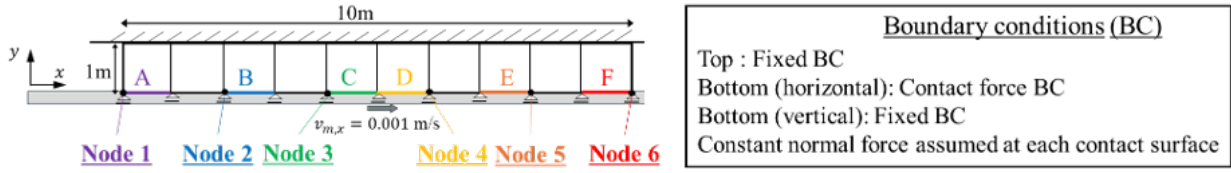


Fig. 1 Finite element mesh and boundary condition

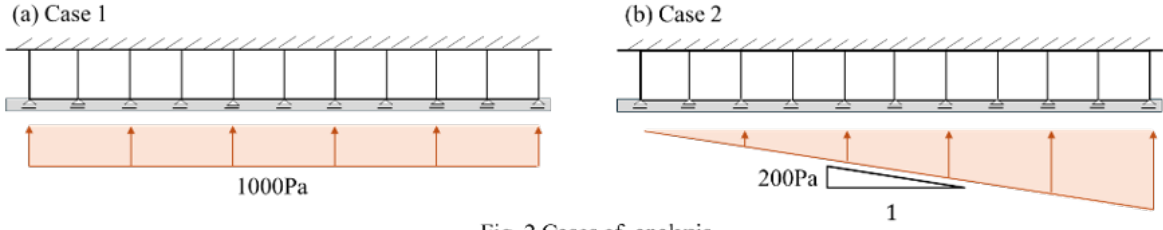


Fig. 2 Cases of analysis

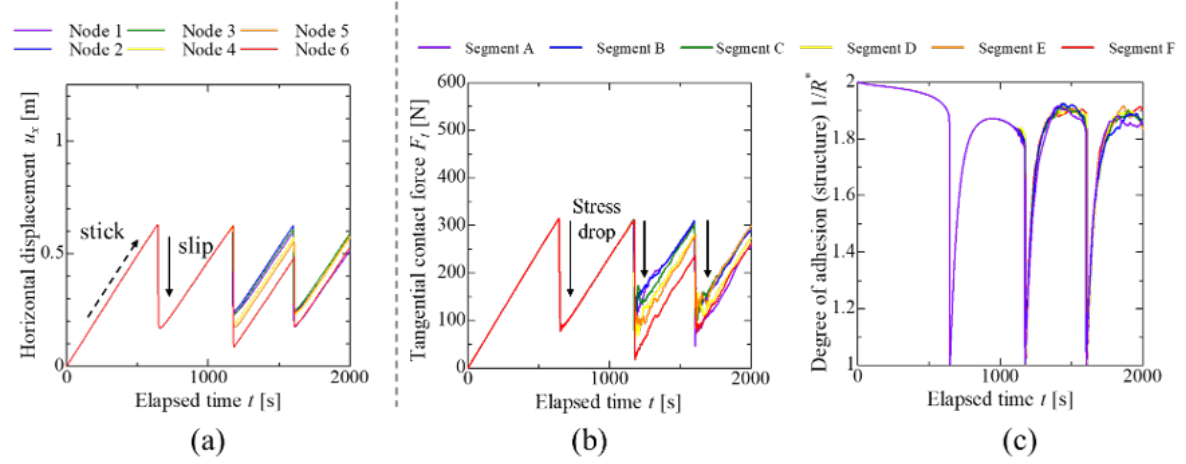


Fig. 3 Results of Case 1

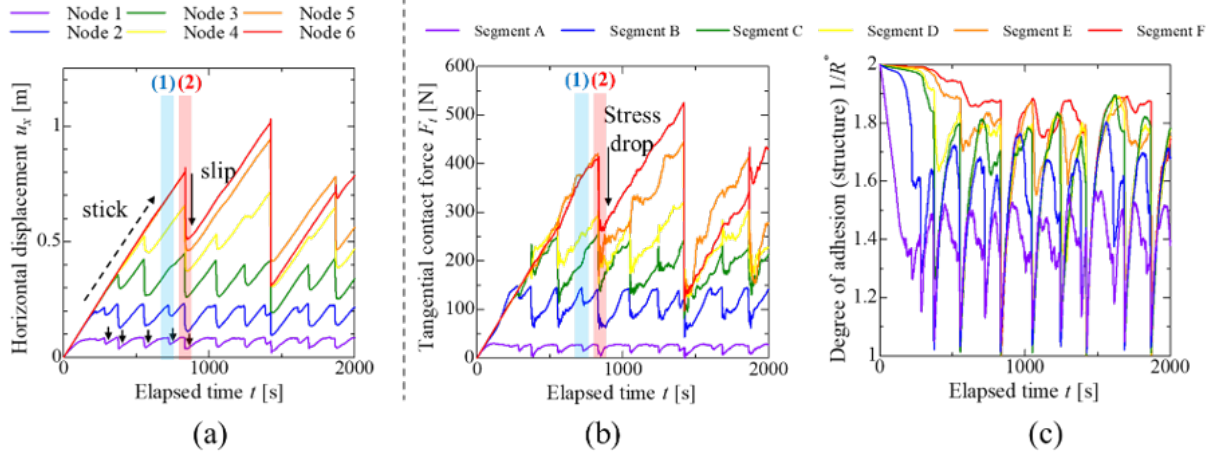


Fig. 4 Results of Case 2