

A Sliding Block Analysis

1 Introduction

This example simulates the sliding of a block on a rigid surface. The primary purpose of this example is to check the behavior of the slip (interface) elements in SIGMA/W.

2 Configuration and setup

Figure 1 shows the problem setup. The block is represented by the upper two rows of elements. The rigid sliding base is represented by the lower two rows of elements. The slip surface is represented by the interface (thin) elements between the other elements.

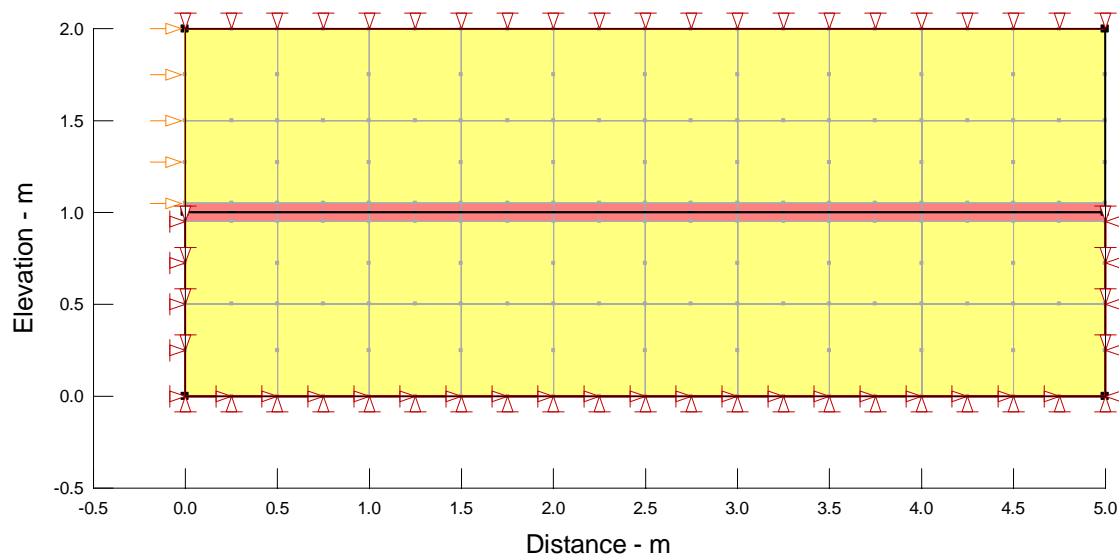


Figure 1 Sliding block configuration and setup

The lower block is fixed by specifying zero displacements on the ends and at the bottom.

The sliding is induced by specifying a strain rate on the left, on the upper block. The rate for this case is 1 mm (0.001m) per second. Time has no effect on the results, but time is used to apply a series of load steps and to discuss the progress of the applied and resisting forces.

The node at the middle of the interface on the left requires special consideration (the square symbol in Figure 2). The displacement strain rate on the block is applied to the top region left edge, and the zero-displacement on the base is applied on the lower region left edge. One of these two boundary conditions will be assigned to the Point at the interface mid-height. Neither of these boundary conditions are what is required at this Point. Since a boundary condition at a point has a higher priority or status, we can apply a boundary condition to the Point and override the conditions inherited from the region edges.

We cannot remove the edge-specified boundary condition from the Point, but we can create a special null-type boundary condition. This can be done by creating a Force or Displacement boundary condition with the type or action set to “none”. The end effect is that the Point has a null-type boundary condition.

Unfortunately, the null-type boundary condition is not graphically evident. The View Objects Information command must be used to check that the null-type boundary condition has been applied.

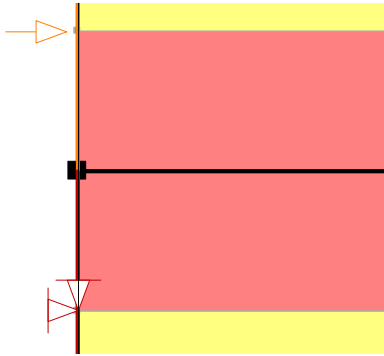


Figure 2 Special boundary condition on Point at mid-height of interface

3 Analysis: Cohesion Only

The first analysis looks at the case where the interface is represented by a constant undrained strength. This is simulated by giving the interface (slip surface) a cohesion of 100 kPa and $\phi = 0$.

The top of the block for this analysis is fixed in the y-direction. This is analogous to modeling rollers along the top. The rollers are required to prevent the block from lifting up when it is pushed to the right.

A total of 30 time steps (displacement increments) are applied. The total lateral movement will then be 30 mm (0.30m).

The slip material is assigned a shear Modulus of 10,000 kPa.

Figure 3 shows the ultimate slip force and how the slip force develops with displacement.

The slip surface is 5 m long and $C = 100$ kPa. Therefore, the maximum shear resistance is 500 Kn, which is correctly displayed in Figure 3.

The displacement at the point of slip should be,

$$\Delta d = \frac{2 F}{L G}$$

F is the maximum shear force available, L is the total length of the slip surface, and G is the specified shear modulus. The factor of 2 is required because of the double thickness of the interface element.

So for this case, the displacement at the point of slip should be $2 \times 500 / 5 \times 10000 = 0.02\text{m}$ (20 mm), which is consistent with the slip point in Figure 3 when F is 500 kPa.

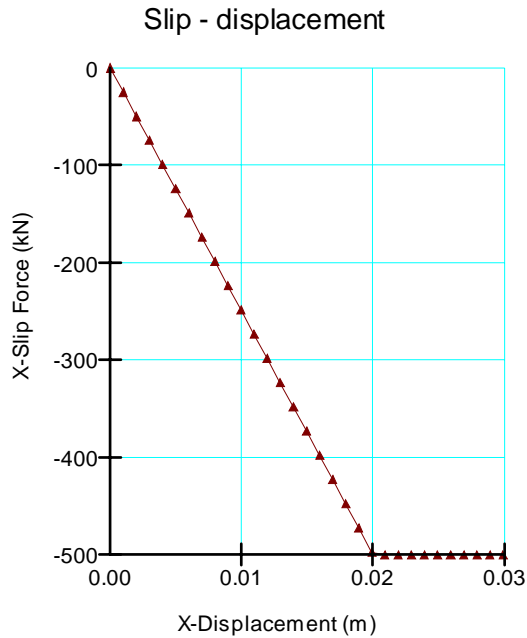


Figure 3 Slip force versus displacement

The slip forces at the top and bottom of the interface elements are, and must be, equal, but in opposite directions. This is confirmed in Figure 4.

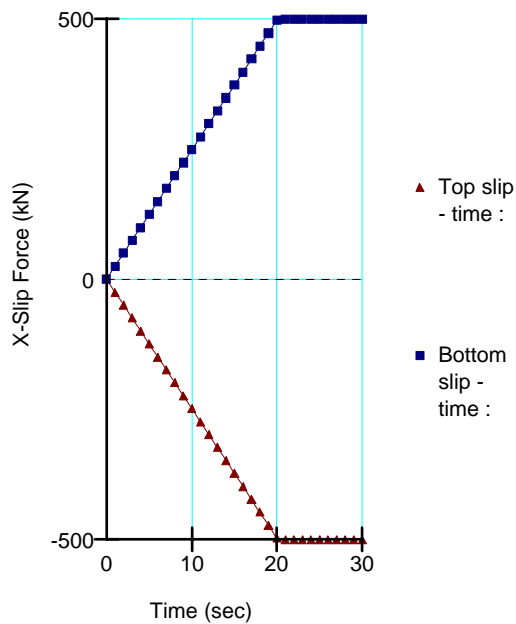


Figure 4 Top and bottom slip forces

4 Analysis: Friction only

This analysis looks at the case where the friction is a function of the normal stress on the slip surface. To achieve this, the top surface “rollers” are replaced with a normal pressure, and the material properties are changed to $C = \text{zero}$ and $\phi = 30$ degrees.

The maximum shear force should now be: $5 \times 100 \times \tan 30 = 288.68 \text{ kN}$.

Figure 5 shows the SIGMA/W computed slip forces versus displacement. The maximum total slip surface matches the hand-calculated value (288.675 or 268.68) exactly.

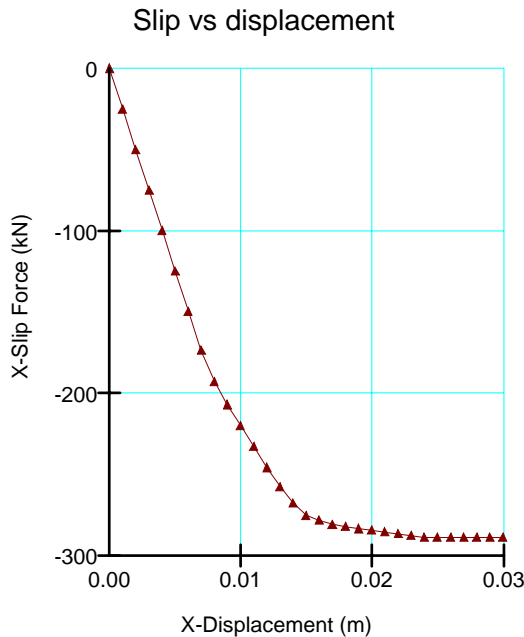


Figure 5 Slip versus displacement for frictional case

The point at which the slip starts is now not as sharp and distinct as for the previous undrained strength case. The point at which the slip starts now varies along the slip surface. This is because of the top normal pressure boundary, which allows the top block to lift slightly while it is being pushed along. The tendency for lifting alters the point at which the slip starts. The ultimate maximum slip total slip force however matches the expected value.

Again, the top and bottom edges of the interface elements give mirrored results, as shown in Figure 6.

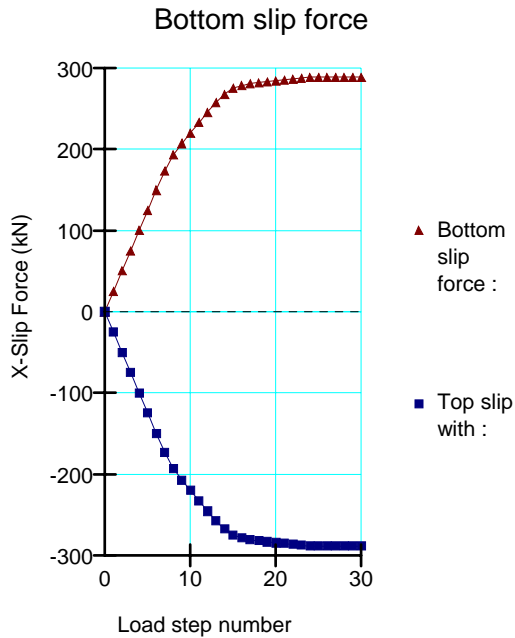


Figure 6 Top and bottom slip forces for frictional case

5 Analysis: Under water

In the frictional case, it is the effective stress on the slip surface that governs the sliding resistance. This analysis tests this case by putting the block under water; that is, a water table is specified at Elevation 3 m. The slip surface is at Elevation 1 m. Therefore, the pressure head on the slip surface is 2 m. If the unit weight of water is specified as 10 kN/m^3 , then the pore-pressure at the interface level is 20 kPa. The effective stress is then 80 kPa ($100 - 20$) and the maximum shear resistance should be $5 \times 80 \times \tan 30 = 230.94 \text{ kN}$. The results exactly match this value as illustrated in Figure 7. The final data point is 230.94.

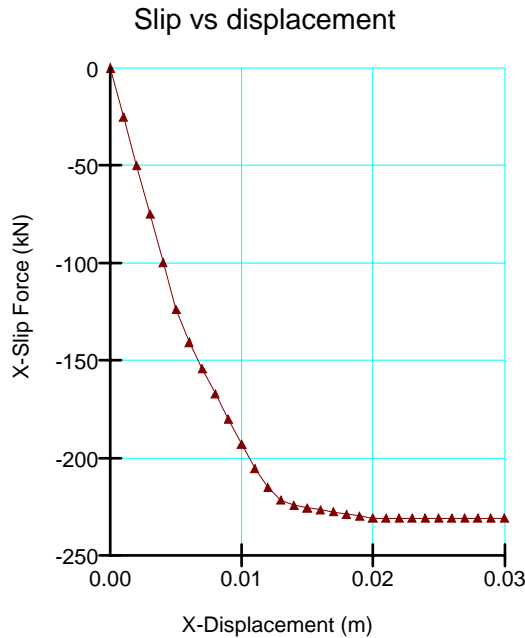


Figure 7 Slip versus displacement for submerged case

6 Slip surface thickness

Earlier, it was noted that the displacement at the point of slip (at least for the undrained case) can be estimated from,

$$\Delta d = \frac{2 F}{L G}$$

Note that this formula does not include the interface element thickness. The interface element characteristic formulation is based on a “spring-based” concept, which does not include the element thickness.

From a practical modeling perspective, this means that there is no value in simulating the elements as being very thin. Making them too thin makes it difficult to apply material properties and select the interface surfaces for plotting purposes. It is beneficial, for practical reasons, to make them thick enough that they are visible at a zoom factor of 100%.

7 Conclusion

This analysis confirms that the interface elements in SIGMA/W are functioning as intended.