D208

Numerical analysis on the failure of landslide dam resulting from seepage-induced stiffness degradation (A research progress)

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Landslide is a prominent disaster in hilly areas; it can harm the environment and people. The need to understand failure mechanisms of slope for countermeasure is urgently needed. In this research, a numerical method will be used to examine the failure mechanism of a landslide dam. both serial and parallel SPH-based codes were developed and their performances were examined. Subsequently, a Kleefsman's dam break test code was conducted numerically, and its experimental data sheets were used to validate the code. The result shows that the GPU parallel code increases performance by more than ten times faster than its serial CPU code. Moreover, in Kleefsman's dam break test, no obvious difference was found in both numerical and experimental results, although our code has a lag time of around 0.06 s.

Failures occurring on landslide dams or embankments are problematic disasters, especially in hilly areas. For example, in January - March 2021, several landslide dams were formed and then failed in Indonesia, resulting in 84 casualties and damage to 694 houses. To prevent and mitigate this kind of disaster, a better understanding of the initiation and movement mechanisms of these landslide dams or embankments will be of great importance. It has been well understood that the failures of landslide dams and embankments could be initiated due to internal erosion, surface-overtopping erosion, and slope instability. However, a comprehensive study of combining these three failure mechanisms is still rare. In this study, a numerical study of the combination of these failure mechanisms is conducted to obtain 1) the role of internal erosion and surface erosion on change of hydraulic gradient, stiffness degradation, and pore pressure leading to landslide dam failure and 2) the effect of soil erosion and deposition on surface evolution of the landslide dam leading to slope instability.

Method

The first step to numerically investigating the landslide dam failure mechanism is to develop a numerical code that incorporates soil-water interactions and multiphase flow. An SPH-based program is developed. Several test cases have been conducted to validate the developed code. A GPU offloading algorithm is opted for increasing performance besides its serial algorithm.

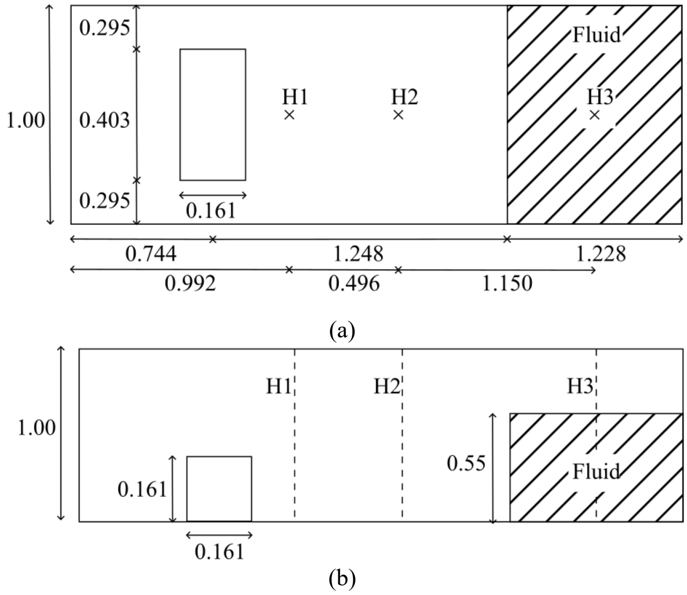


Fig. 1 Numerical validation set up based on Kleefsman et al., (2005): a) top, b) side view.

Results

1. Performance analysis

The result of the performance test between serial CPU and parallel GPU code is shown in Fig. 2. It shows that GPU offloading code can increase performance and accelerate the computational time by more than ten times than its serial code (Fig. 2)

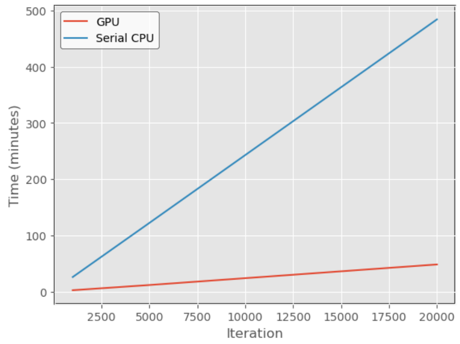
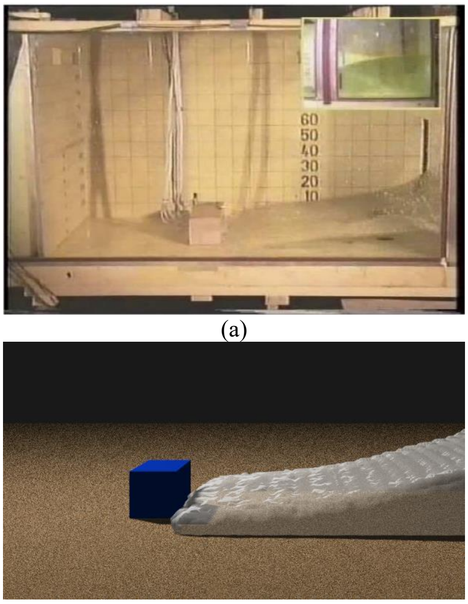


Fig. 2 Comparison of GPU offload code and CPU serial code.

2. Kleefsman's dam break

To this end, a weakly compressible SPH has been developed, and a Kleefsman dam break case has been conducted (Fig. 1). The results show that the developed numerical code can mimic the test case, although there is a small time-lag between the numerical and experimental results, i.e., 0.06 s (Fig. 3). The discrepancy can arise due to the chosen SPH parameter settings and particle resolution. However, the discrepancy can be reduced by calibrating the code.

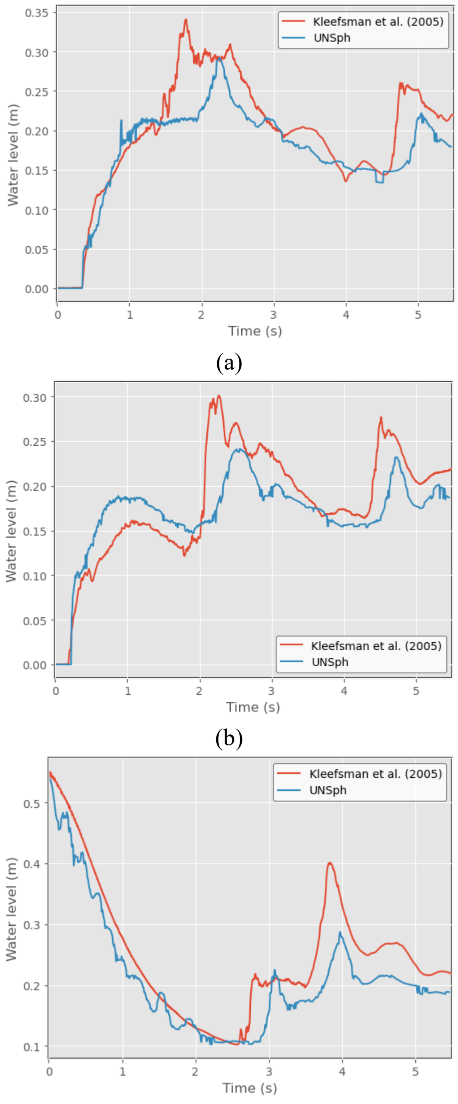


(a)

(b)

Fig. 3 Snapshot of 3D dam-break: a) Kleefsman et al., (2005) at 0.4 s, b) this study at 0.46 s.

The comparison of water levels between experimental *(Kleefsman et al., 2005)* and numerical results are shown in Fig. 4. In this figure, the numerical model can predict the dam break water profile evolution precisely, although tolerable small difference is observed. In Fig. 5, it's shown that the numerical and experimental results have a strong correlation, they have high pearson's coefficient of correlation, i.e., 0.917, 0.815, and 0.95 for H1, H2, and H3, respectively.



(a)

(b)

(c)

Fig. 4 Comparison of water level from experimental (Kleefsman et al., 2005) and numerical results after calibration: a) H1, b) H2, and c) H3.

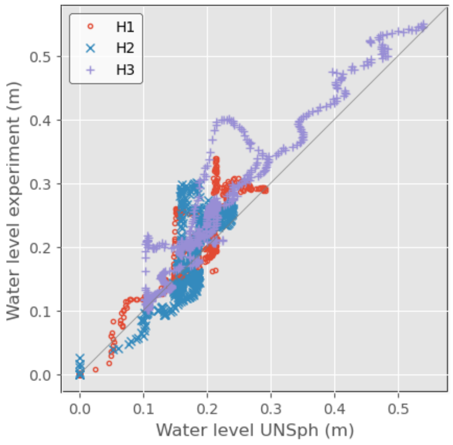


Fig. 5 Correlation of numerical (after calibration) and experimental results (Kleefsman et al., 2005).