Comparison of DEM and experimental results for evaluation of ground surface displacement due to fault movement below architectural structures

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Research Background

◆ Active fault and railway around Japan

http://www.hinet.bosai.go.jp/about_earthquake/sec6.2.html

https://roote.ekispert.net/ja/rmap/fullscreen
What is happening when fault movement occurs below architectural construction?

Evaluation method to reveal the effect of fault movement to the ground surface is needed.

- Distinct Element Method code PFC can simulate the discontinuity of displacement on a fault surface and a large deformation of the ground.
- Possible to estimate the influences of soil characteristics and properties around the ground surface when the fault displacement occurs and then propagates to the ground surface.
Conventional Research

Ground surface displacement in elastic region due to fault movement

(a) Analytical solution by Okada Model

(b) DEM by PFC

- Comparison of analytical solution and DEM
- Same tendency between them.
- Possible to be applied to static problem.

Demonstrating the first attempt in simulating ground deformation using the DEM due to fault movement that occurred below the structure, based on the preceding experiment to examine the effect of the structure on the ground.
Outline of the analyses

◆ Model

![Model Diagram]

- Fixed bottom wall
- Ascending bottom wall

◆ Input parameters\(^1\)\(^2\)

<table>
<thead>
<tr>
<th></th>
<th>Ball-Ball</th>
<th>Ball-Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density(^3)</td>
<td>2560 (kg/m(^3))</td>
<td>-</td>
</tr>
<tr>
<td>Stiffness (Nomal)</td>
<td>6.24×10(^7) (N/m)</td>
<td>6.24×10(^7) (N/m)</td>
</tr>
<tr>
<td>Stiffness (Shear)</td>
<td>2.08×10(^7) (N/m)</td>
<td>2.08×10(^7) (N/m)</td>
</tr>
<tr>
<td>Friction coefficient</td>
<td>0.67 (-)</td>
<td>0.00 (-)</td>
</tr>
<tr>
<td>Ball radius</td>
<td>0.004 (m)</td>
<td>-</td>
</tr>
</tbody>
</table>

1) Contact model: Linear contact model
2) Stiffness estimation\(^4\) : \( k_s = \frac{1}{4} \pi \rho V_s^2 \)
3) Friction coefficient : Estimated from friction angle

- Particle radius is homogenous in entire model.
- Bottom and side boundary is modeled by walls. Construction is by Convex rigid block.
- After packing is completed to stabilize the model, the bottom wall vertical velocity is set to 0.005 m/s in both analysis cases. The velocity is applied until the bottom wall vertical displacement reaches 120 mm.

◆ Analysis Case

Case 1 : Without construction on the ground
Case 2 : With construction

Case 1: Comparison with the experiment

◆ Analysis

Bottom displacement 50 mm
Bottom displacement 80 mm
Bottom displacement 120 mm

◆ Experiment

Bottom displacement 50 mm
Bottom displacement 80 mm
Bottom displacement 120 mm

- The ground is deformed and the ground surface is tilted as the bottom wall rises.
- Ground surface is gradually deformed in both the analysis and the experiment.

Case 1: Comparison with the experiment

- Bottom displacement 120 mm  Zoomed

- Slip lines are observed from the boundary of the ascending bottom wall and the fixed bottom wall.
- The slip lines also develop nearly vertically from the bottom, and then branch off near the ground surface which draws arcs from side-to-side near the ground surface; as is similar to the experimental results.
Case 2: Comparison with the experiment

- **Analysis**

  - Bottom displacement 50 mm
  - Bottom displacement 80 mm
  - Bottom displacement 120 mm

- **Experiment**

  - Bottom displacement 50 mm
  - Bottom displacement 80 mm
  - Bottom displacement 120 mm

  The tendency of the results are basically same as case 1.
Case 2: Comparison with the experiment

- Bottom displacement 120 mm  Zoomed

A drastic change in ground surface displacement is observed close to the left side of the structure; this is reproduced in the experiment as well.
Comparison between the cases

◆ **Ground Surface displacement**

- **Block location**

**Case 1**
- Vertical disp. 120 mm
- Vertical disp. 100 mm
- Vertical disp. 80 mm
- Vertical disp. 60 mm
- Vertical disp. 50 mm
- Vertical disp. 30 mm

**Case 2**
- Vertical disp. 120 mm
- Vertical disp. 100 mm
- Vertical disp. 80 mm
- Vertical disp. 60 mm
- Vertical disp. 50 mm
- Vertical disp. 30 mm

◆ **Rotation of the construction**

- Ground surface displacement is affected by the construction.
- Drastic change of ground surface displacement is observed around the construction in Case 2.
- Focusing on Case-2, the rotation of the structure is excessively estimated when compared to the experimental results.
  (1.7° in the experiment)
1. This paper demonstrates the first attempt in simulating ground deformation using the DEM due to fault movement that occurred below the structure, based on the preceding experiment to examine the effect of the structure on the ground.

2. Simulations are performed and replicated fault displacement by a simple model lab-experiment.

- The results of the analyses are in strong agreement with the experimental results and prove the applicability of using DEM to analyze these types of problems.
- The analyses can also simulate the effect of the structure on the ground surface displacement.

**Future works**

- There are some differences between the analyses results and the experimental results, such as rotation of the structure and slope of the ground surface.
  - Can be solved by a more detailed inspection of the input parameters, such as the friction coefficient.

- Applied to more complex target of the simulation (3D, real scale etc..).
- Consider the applicability to the prediction method of the ground deformation and design method.