

Determination of contact areas in a cylindrical geo-sensing prototype using DEM simulations

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1. INTRODUCTION

In order to measure the soil pressure comprehensively, Shiraishi et al. (2019) proposed a cylindrical geo-sensing prototype based on electrical contact theory. The prototype is composed of plenty of stainless balls that deform elastically in response to pressure and offer high electrical conductivity. Once the pressure applied onto the stainless balls, the changes of contact area induces the changes in the electrical resistance between them. As shown in Fig.1, the stainless balls are glued with silicone resin by which the contacts among them are retained, and separated by acrylic plates into 3 sectors to measure the pressure change in 3 directions. The prototype was tested under uniaxial compressive load applied along the radial direction, and the resistance change of the 3 sectors was recorded. However, the 3 sectors are not exactly the same, so the slopes of the resistance-load curve obtained from 3 partitions are utilized to compute the loading direction. Later, Pipatpongsa et al. (2020) employed the Flamant solution to obtain the mean stress distribution in the cylinder under the line load as shown in Fig. 2 to justify the test results. The previous study successfully related the change in equivalent resistance of the 3 sectors to the area integral of the mean stress through the proportional slopes of resistance-load curve of the tests as shown in Fig. 3. However, the assumption of calculation that the prototype is semi-infinite elastic continuous body is not persuasive since the stainless balls are not continuous. This study utilizes the distinct element method (DEM) to confirm the relationships between contact area variation and the mean stress distribution. Therefore, the results based on both continuum and discrete mechanics can be compared and strengthen the principle used in the geo-sensing prototype.

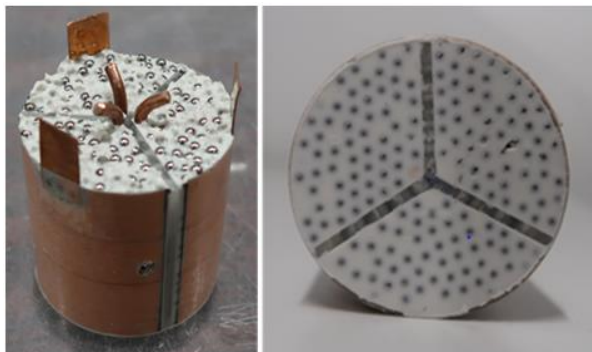


Fig. 1 Geo-sensing prototype

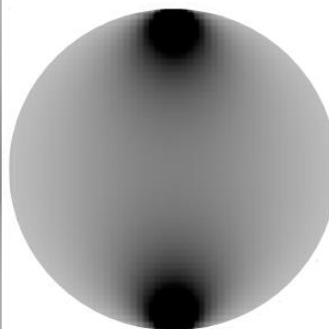
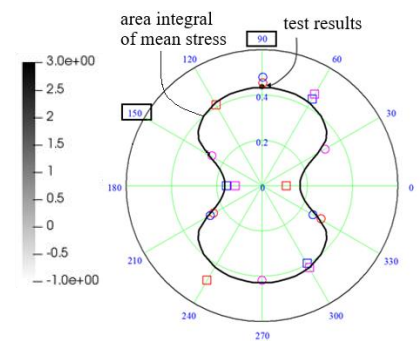


Fig. 2 Mean stress distribution



The servo plane moved downward at the beginning until the contact forces against the balls reaches 320N, then it moved upward as the unloading stage. Fig. 5 shows the variation in contact force between top/bottom plates and the balls. The contact forces among the balls were recorded when the load reached 20, 40, 80, 160 and 320N.

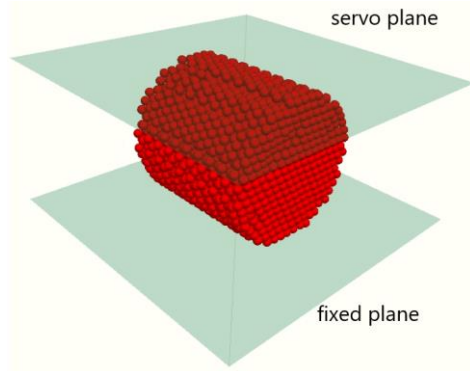


Fig.4 DEM model

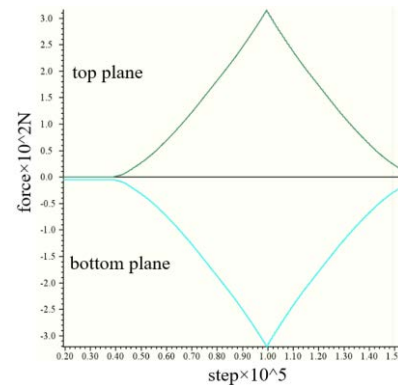


Fig.5 Contact forces between wall and balls

3. DATA ANALYSIS

Based on the Hertz contact theory concluded by O'Sullivan (2011), the contact radius, a , between the balls is calculated by Eq. (1), where F_n is the normal contact force between two particles, R^* is the effective particle radius, and E^* is the effective Young's modulus.

$$a = (3F_n R^* / 4E^*)^{1/3} \quad (1)$$

As shown in Fig. 2, both tension and compression exist in the model, but the model will not break apart due to the bonds. So, only the normal contact forces in compression are counted, while the tension contacts are neglected. The contact areas between balls in the same sector for three sectors in the cylinder are summed up. No matter how contact areas in different sectors varies, the proportional slopes of total contact areas are used to investigate the relationship by plotting in Fig. 6. Although the upper part is not entirely symmetric with lower part due to the setting pressure, the scatter plot of the proportional contact area is acceptably similar to the area integral of mean stress shown in Fig. 3. Fig. 7 shows the variation of the contact points in the whole model changes with respect to the loads. By changing the effective modulus from 0.1 to 1GPa, the proportional slopes of contact area-load curve are related to the mean stress distribution and slightly influenced by the material parameters.

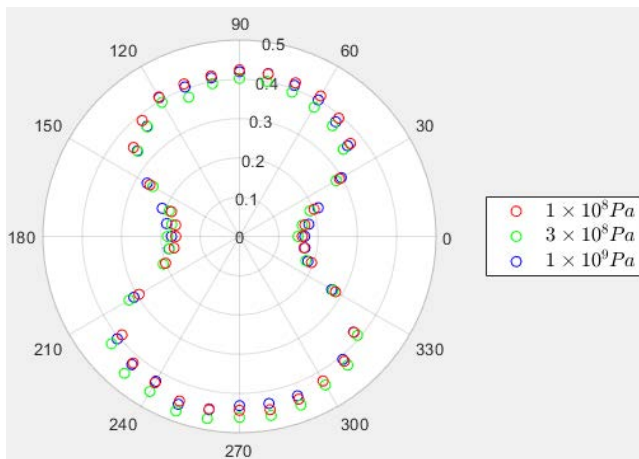


Fig. 6 Proportional contact areas

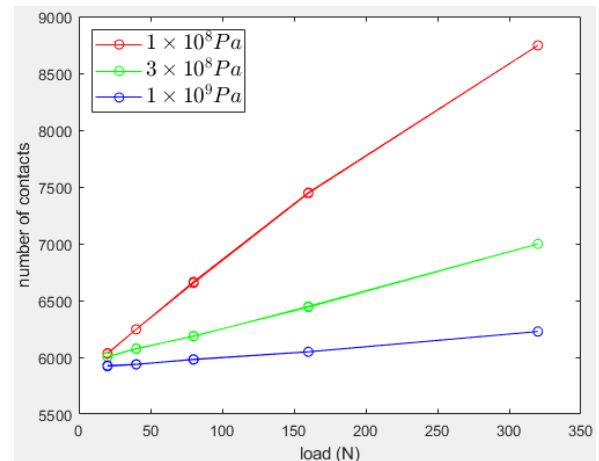


Fig.7 Variation of contact points with respect to the loads

4. CONCLUSIONS

As DEM simulation can associate the mean stress distribution with contact area change, the principle of the cylindrical geo-sensing prototype is proved to be valid.

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