EFFECTS OF THE RATIO OF PRESSURE GAUGE SIZE TO GRAIN SIZE ON THE RELIABILITY OF EARTH PRESSURE MEASUREMENTS

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1. INTRODUCTION

It is well known that the reliability of earth pressure measurements of soils such as sands or gravels are dependent on the size ratio of the pressure gauge diameter to the grain size diameter. To date there has been no criterion or theory that is capable of determining proper size ratio for the reliable measurement, however, there are some experiment results for this purpose[1]. In this study, we investigated the effects of the size ratio on the reliability of earth pressure measurements by a new approach.

2. FORCE AMPLITUDE DISTRIBUTIONS

Some experiments[2), 3)] and simulations[4), 5)] by the Discrete Element Method have revealed that the contact forces acting on a plate have a wide range of amplitudes. Mueth et al.[3)] proposed a probability density function for the normalized contact force amplitude f on a plate based on a series of uniaxial compression tests using glass bead packs. The normalized contact force is defined by dividing each contact force by the average contact force on the plate. The function $P(f)$ is represented as follows:

$$P(f) = a \cdot (1 - b \cdot e^{-f^2}) \cdot e^{-bf}, \qquad (1)$$

where the three parameters in the function $P(f)$ are given as a=3, b=0.75 and b=1.5 respectively. **Figure 1** shows this probability density function. Note, that the amplitude of the contact forces has a wide variation. Most of the contacts generate relatively small contact forces while a few contacts generate significantly larger contact forces. It is also interesting to note that there is an exponential decay at large f in the function given in equation (1).

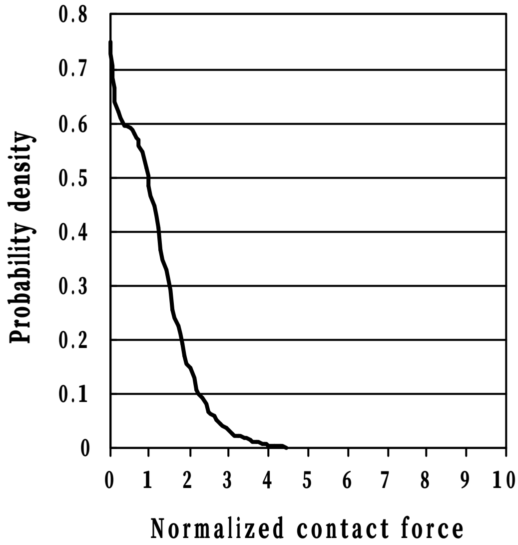

Figure 1 Probability density distribution of normalized contact force[3)]

Other numerical simulation results and experimental results also have shown the same exponential decay. Therefore, this exponential decay seems to be one of the characteristics of the force distribution within an assembly of particulate media. From the point of view regarding the measurement reliability of an earth pressure gauge, this exponential decay has an important role because the larger contact forces will dominate the fluctuation of the measured earth pressure sensed by an earth pressure gauge.

3. RELIABILITY OF EARTH PRESSURE MEASUREMENT

Based on the above probability function defined in equation (1) with the Monte Carlo simulation method, we investigated the relationship between the reliability of the earth pressure measurement and the number of particles, which are in contact with the pressure gauge. **Figure 2** shows a flow chart of this procedure. First, a population data set of normalized contact forces is generated based on the function defined by equation (1). A sample of Ns (sample size) contact forces is constructed from the normalized contact forces within the population and is taken as one of the trials for the Monte Carlo simulation and the average contact force is calculated from the Ns contact forces. After a certain number of trials, we are able to obtain sampling distributions of the average contact force. Note, that the sample size Ns corresponds to the number of contact points between a pressure gauge and grains, and the average contact force corresponds to the earth pressure measured by the Ns contact forces. After these procedures are performed, we are able to obtain sampling fluctuation of different sample size Ns. In this simulation, 1,000,000

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contact forces were created according to the function described in equation (1) as population data and 50,000 trials were conducted within a Monte Carlo simulation for each sample size *Ns*.

Based on the simulation results, we obtained a relationship between sample size *Ns* and "*confidence coefficient*" regarding with each different "*confidence interval*". In this study, ±5%, ±10%, ±15% *confidence intervals*, which correspond to the error ratio (%) from the average contact force (f=1) , were chosen. **Figure 3** shows the relationship between the *confidence coefficient* and the number of contact points (sample size), which are in contact with a pressure gauge. For example, if you would want to measure the earth pressure within a ±10% error (*confidence interval*) from the true earth pressure at 95% of *confidence coefficient*, then approximately 250 of contact points on the pressure gauge will be required. It is clear that the measurement reliability becomes more accurate as the number of grains is increased. On the other hand, this result also indicates that it is very difficult to measure the earth pressure accurately with a small number of grains. For example, suppose the grains are located in an ordered lattice as shown in **Figure 4**, and the size ratio of pressure gauge diameter *d* and grain diameter *D* is related to the sample size *Ns* as shown below.

$$\left(\frac{d}{D}\right)=2\times\sqrt{\frac{N_s}{p}} \qquad (2)$$

Note, that the 250 contact points, which was described above, corresponds to a size ratio (d/D) of approximately 17. Though more studies are needed to clarify the effects of the ratio of pressure gauge diameter to grain size diameter on the reliability of earth pressure measurement, we were able to propose a new method for this purpose.

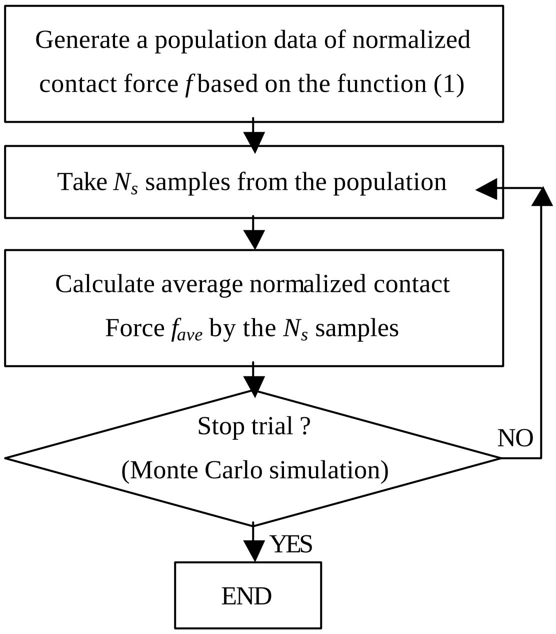

Figure 2 Monte Carlo simulation procedures

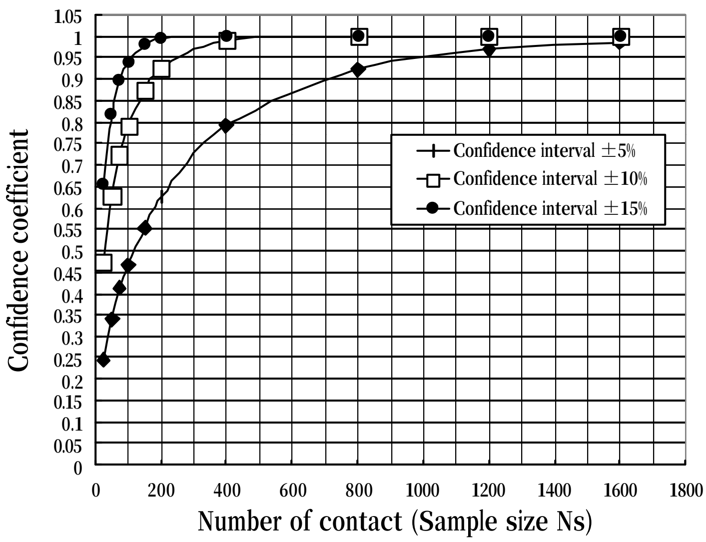

Figure 3 Relationship between confidence coefficient of earth pressure measurement and the number of contact points

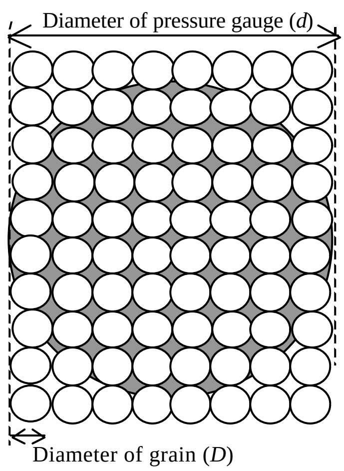

Figure 4 Schematic view of pressure gauge and grains

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