An experimental investigation into the effect of moisture content in salt on its flow properties

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The flow-ability of granular is important parameter to be considered in many solids handling processes and operations such as transportation and storage. Flow property of granular solids depends on many factors of the physical properties such as the particle size distribution, the roughness of its surface, the content of moisture in solids and the relative humidity and temperature in its surroundings.

It is known that effect of moisture content of granular on its flow properties varies very much from one solid to another. Some solids may increase their moisture content without major change in flow properties, whereas for other solids, even a small increase in moisture content may significantly affect the flow properties, a case encountered during the measurement of flow properties for an industrial salt with the Jenike shear tester in a silo design project.

The Jenike shear cell (Institute of Chemical Engineers, 1989) was used in the measurement. The cell consisted of an upper ring and a base cell, with an internal diameter 75 mm and a height of 50 mm as illustrated in Figure 1. The cell was loaded with sample salt. The sample of salt provided had a size below 1 mm, with moisture content around 3%; but the authors were informed that the moistures could be as high as 5-6 % in the producing line -- samples with different moistures were therefore prepared in the present measurement. They were all tested in different measurements for the worst-case scenario.

Following the procedure recommended by the Standard Shear Test Technique (SSTT), a known applied normal load was imposed on the top of the lid above the cell (see Figure 1). To start with, the loading pin moved forward at a constant speed of 0.04 mm/s. As a result the sample in the cell was sheared, and would yield along a plane between the upper ring and base cell. The shear force to balance the force of loading pin was recorded with a data logger Scout 55 (HBM, Norway) in real time. The development of shear stress with the displacement was monitored during tests, and a slip-stick in internal movement was observed in some measurements. Measurement results showed:

- The development of shear stress increased with the movement of loading pin, and appeared to be stable after reaching a maximum value when the moisture content was low 0.2% (shown in Figure 2-a). But when the moisture of sample was high (2%), the shear stress jumped to greater value, and a slip-stick occurred (see Figure 2-b). The minimum shear stress could be as low as about half of the maximum one. Further increases of moisture in sample did not

contribute the increase of shear stress considerably, but the stick-slip movement remained (Figure 2-c). Further investigations are required to identify the critical value of moisture where the jump of shear stress and the slip-stick starts to occur.

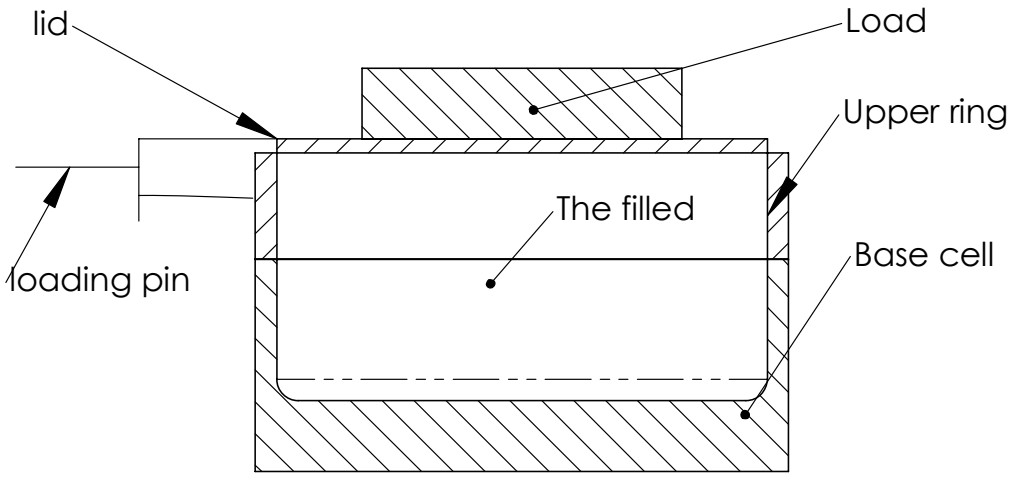
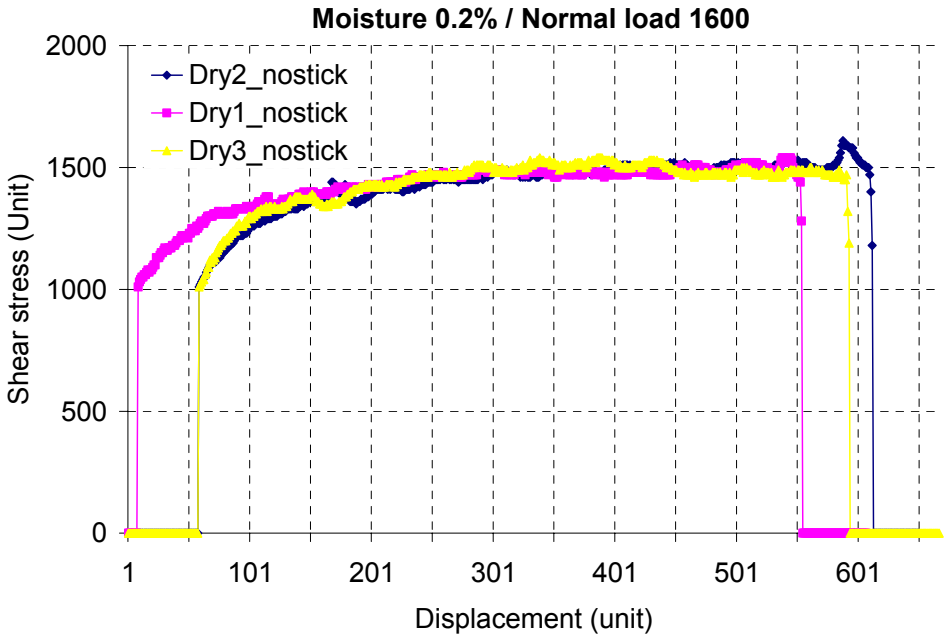
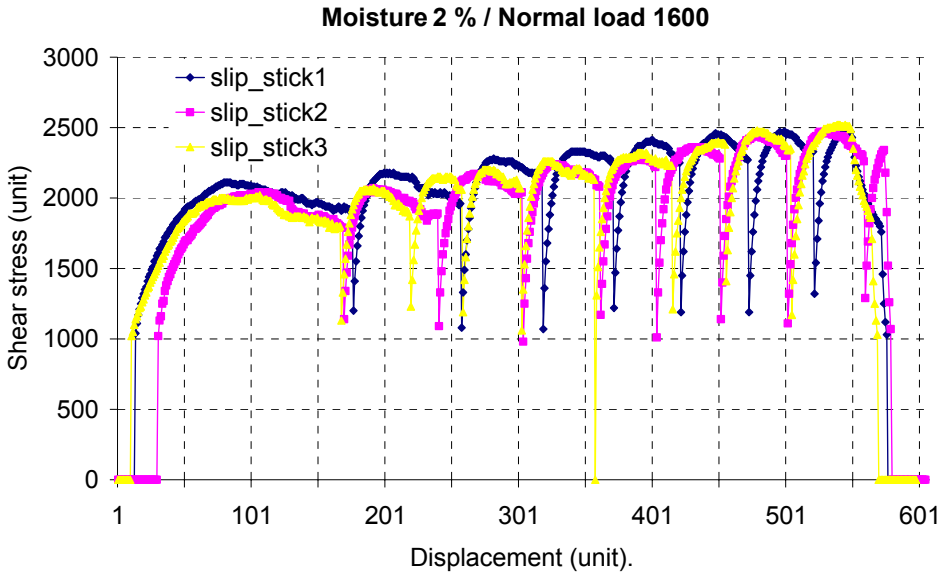


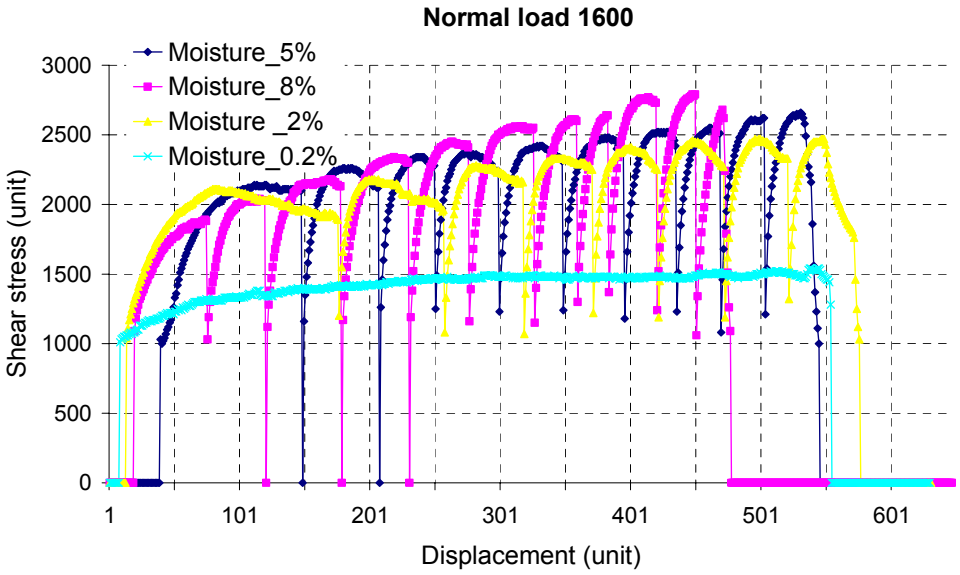
Figure 1. Flow property measurement with Jenike shear cell



-a. shear stress for sample with lower moisture in three parallel tests



-b. shear stress for sample with higher moisture in three parallel tests



-c. Shear stress for samples with different moistures

Figure 2 Development of shear stress in samples with different moistures under the same normal loads

- The level of normal stress applied during the measurements had little effects on the slip-stick, that is, no slip stick occurred when the moisture in sample was low, but appeared when the moisture in sample was high. However, the shear stress increased rapidly with the increase of normal loads when the moisture of sample was getting high (Figure 3).

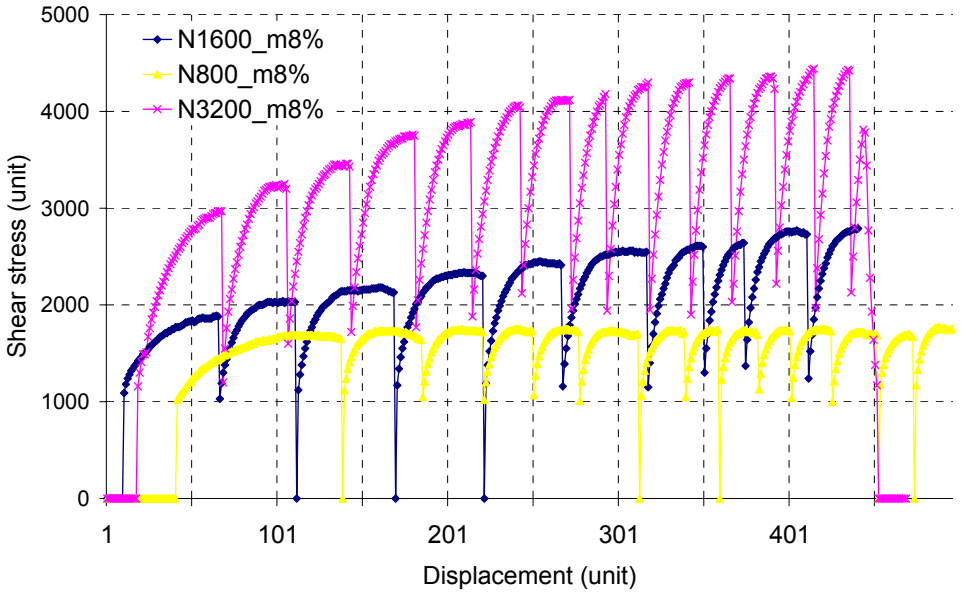


Figure 3 Development of shear stress under the same normal loads for the same sample (moistures was 8%)

- Extra measurement of wall friction with normal stainless steel observed no slip-stick movement, no matter whether the moisture in sample was great or low.

Referring to slip stick along the interaction between wall and solids, it has been used to explain the mechanism of some phenomenon like silo dynamics. It has been also recommended that the maximum value should be taken for obtaining a wall friction angle, which is used in silo design for mass flow to occur. The fact that slip-stick of the internal shearing is related to the moisture content of solids might have implications to understand the mechanism of solid flow patterns in some industrial operating processes, whereas the greatest value of slip-stick shearing in the worst-case was adopted in the determination of critical parameters for silo geometry design in this specific project.