Lego-Structured Tilting Table Method for Angle of Repose Measurement

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Abstract. Flowability of solid material is important especially in food and pharmaceutical industry where solid material is the main material used. When designing equipment, understanding flowability of solid material becoming crucial point to maintain effectiveness of the equipment. Angle of repose is one of the oldest method to determine flowability of solid material. From several different method to measure angle of repose, tilting table method was chosen as the basis for this equipment design. Lego structure basis was chosen to modernized method for angle of repose measurement. For the experiment, 2 different materials were chosen: coriander seeds and cement powder. These 2 materials were chosen due to their different flowability properties to ensure the effectiveness of the designed equipment. From the measurement result, average angle of repost for coriander seed was 19.3^0 and 32.6º for cement powder. Based on these results, the percentage of error for angle of repost measurement using lego tilted structure equipment is between 6 until 20% which is in an acceptable level. This showed that the design of the equipment was a success and can be used to determine angle of repose of solid material.

Keywords: Angle of repose, Flowability, Solid material, Lego, Solid properties

1. INTRODUCTION

Solid particle is a common material used in a variety of industry due to its stability, compatibility, ease of transportation and longer shelf-life. Understanding physical properties of solid particles give an insight on how to handle, transport, and design an equipment used for these types of material. One of the physical characteristics of particulate solid is flowability. Powder flowability is the ability of powder to flow under a specific condition or circumstances (Xu, Lu, Menghui, & Cai, 2017). There are several ways to determine flowability of powder material (Macho, et al., 2020) but the most common method used is by angle of repose measurement (Sklubalova & Zatloukal, 2008).

The angle of repose, also known as the critical angle of repose for granular materials, refers to the steepest angle at which these materials can naturally rest on a slope, ranging from 0 to 90 degrees. In simpler terms, it's the maximum slope at which powders or granules can be piled up without sliding or falling down (Mehta & Barker, 1994). Angle of repose measurement is widely used across different industries, from chemical, agricultural, mining, geology to civil engineering usage (Al-Hashemi & Al-Amoudi, 2018).

2. LITERATURE REVIEW

To determine the angle of repose for different materials, it must be measured through practical experimentation. Generally, angle of repose measurement was divided into two different types: static and dynamic (Geldart, Abdullah, Hassanpour, Nwoke, & Wouters, 2006). Static measurement methods can be employed for this purpose, with the most common one being the funnel method. In this approach, a specific amount of material is poured from a funnel, and the angle of the resulting heap is measured. Another method which is dynamic measurement involves a revolving cylinder, where the material is rotated within a cylinder, and its natural angle of repose is observed (Hurychova, Ondrejcek, Sklubalova, Vranikova, & Sverak, 2018). However, the method employed in this research is the static measurement or the tilting table method.

The tilting table method, resembling industrial practices, is a reliable means of determining the angle of repose for granular materials. It entails setting up a tilting platform and gradually increasing its incline until the material on its surface begins to flow. The angle at which this flow initiates is recorded as the angle of repose. This method is particularly suited for fine-grained, non-cohesive materials with individual particle sizes less than 10 mm. But flow characteristics of particulate solids combined complex physio-chemical and mechanical properties (Trpělková,, et al., 2019). In addition, interaction forces such as Van der Waals, capillary, and electrostatic force will affect powder flowability (Guo, et al., 214).

Tilting table method is favored for its simplicity, reproducibility, and adaptability to a wide range of materials, making it an excellent choice for researchers and industries seeking to assess the behavior of bulk materials in industrial slope applications.

3. METHODOLOGY

3.1 Equipment

- Lego components (Structure)
- Specific Lego Components:
- Gears
- Linear Actuator
- Motor
- Battery and Power Supply
- Acrylic Sheets (1.5 mm thickness)
- Ruler
- Acrylic Cutter
- Tape
- Stainless Steel Chopstick
- Protractor
- Hair Dryer
- Glue
- Wool String

3.2 Material

- 25 g of coriander seeds
- 25 g of cement powder

3.3 Equipment construction

(Assembly of the Base Structure)

1) Assemble the base of the device by integrating specific Lego components into the Lego structure to create a tilting platform.

(Construction of the Tilting Plane)

2) Use the acrylic cutter to trim an acrylic sheet to dimensions of 11.3 cm x 21 cm.
3) Gently bend the acrylic sheet to a suitable angle using a hair dryer and secure it to the tilting structure base with tape.
4) Attach a wool string beneath the tilting plane, perpendicular to the rotation axis.

(Formation of the Tilting Plane's Border)

5) Cut two acrylic sheets measuring 13 cm x 5.2 cm.
6) Securely connect these acrylic sheets to the tilting plane's structure base by heating a stainless steel chopstick and creating holes in the acrylic, reinforcing them with additional tape to prevent leaks.

(Incorporation of the Measuring Component)

7) Fix a protractor onto the acrylic part measuring 5.4 cm x 7 cm for measurement.
8) Ensure the protractor remains fixed on its axis.
9) Attach and secure it to the Lego structure by heating stainless steel chopsticks and embedding them into the acrylic.

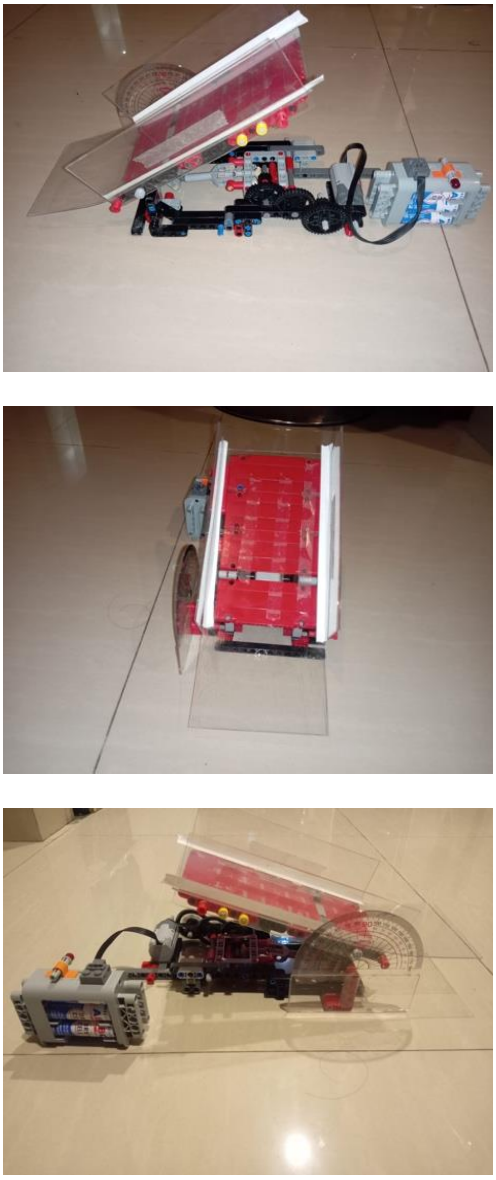

Figure 1. Lego structured equipment to measure angle of repose

4. **PROCEDURE**

   To operate the equipment, a specific procedure was used to measure the angle of repose of material.

1) Prepare the base and the tilting plane.
2) Ensure the protractor's thread is aligned with the 0° mark.
3) Measure 25 g of coriander seeds using a scale. (Repeated for cement powder)
4) Place the solids onto the tilting device.
5) Activate the "UP" switch.
6) Stop when all solids are in motion.
7) Record the angle displayed on the protractor.
8) Maximize the tilting device.
9) Clean the tilting device by wiping it with the acrylic sheet and towel, using water if necessary, and dispose of the solids in the disposal rig.

5. RESULT AND DISCUSSION

The experiments were conducted using two different materials: coriander seed and cement powder. This material was chosen due to their different properties to showed the effectivity of this device through different flowability materials.

Table 1. Angle of Repose Result. For Different Granular Materials

Material	1st Trial	2nd Trial	3rd Trial	Average Angle
Coriander Seed	20	20	18	19,3
Cement Powder	35	31	32	32,6

The data reveals noticeable differences in the angle of repose between the materials tested. Coriander seed exhibited the low angle of repose at 19.3°, with higher angle of repose of cement powder followed by sand at 32.6°. This result can be attributed to difference in particle size and shape. Cement powder, consisting of irregularly shaped particles, tend to form a steeper pile before flowing compared to the more spherical coriander seed.

To ensure the reliability of the results, each material was tested three times. The measurements were in a consistent range, with maximal variation observed between trials is ±2°.

Based on literature, the coriander seed have an angle of repose of 24.91° and cement have an angle of approximately 35°. So the margin of error for coriander seed is 21.31% but for the cement is 6.85%.

The difference in measurement between the experiment and the literature can be caused by several factors like moisture content, the method used, and the material variation itself

There are also several factors that can influence the measurement of the angle of repose itself, including particle size, shape, and cohesion. In this experiment, particle size and shape emerged as a differentiating factor as mentioned above.

The angle at which each material began to flow on the tilting table was measured in degrees. The results are presented in below:

6. CONCLUSION

In conclusion, the tilting table method proved easy to do in determining the angle of repose for different materials. The results demonstrated that particle size significantly influences the angle of repose. This information can be applied in various industries to enhance material handling and storage processes.

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