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Measurement of Apparent Density of Powder

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Abstract

Apparent densities of spherical, crushed and rod-like glass powders were measured by a simple device. Effects of container size, property of container wall, sample weight and tapping strength on the apparent density measurement were observed. A new relation between the number of times of falling and the apparent density was proposed.

I. Introduction

The apparent density or apparent volume of powder is one of the most important properties of powder, for it always has intimate connections with the other properties of powder, and the other properties can not be expressed satisfactory without the help of it. Many measurements were reported in published articles, but these results were given under arbitrary conditions, and since they have no common standard, we can not compare or reproduce these results. In this paper, so as to find a common rule, we performed several attempts to find the effects of container size, sample weight, tapping strength or falling height and number of fallings on the apparent densities of glass powders.

II. Experimental

APPARATUS— In order to make constant conditions in tapping, we devised an apparatus, the general description of which is given in Fig. 1. The cylindrical glass container, holding the powder, is placed on the moving table A, the upper part of which is covered with hard rubber. As the cam B is rotated by the pulley E, which is driven by a motor, A is pushed upward at constant rate and when it comes to the highest position it falls suddenly. The falling of A is stopped by C, and as C can be moved up or down by the rotating screw system D, the falling height h of A is changeable.

MATERIAL— Three kinds of glass powder were used. The first one was ordinary glass powder prepared by crushing glass plates in a ball mill. The second one was spherical glass powder, produced from the first one by the method of

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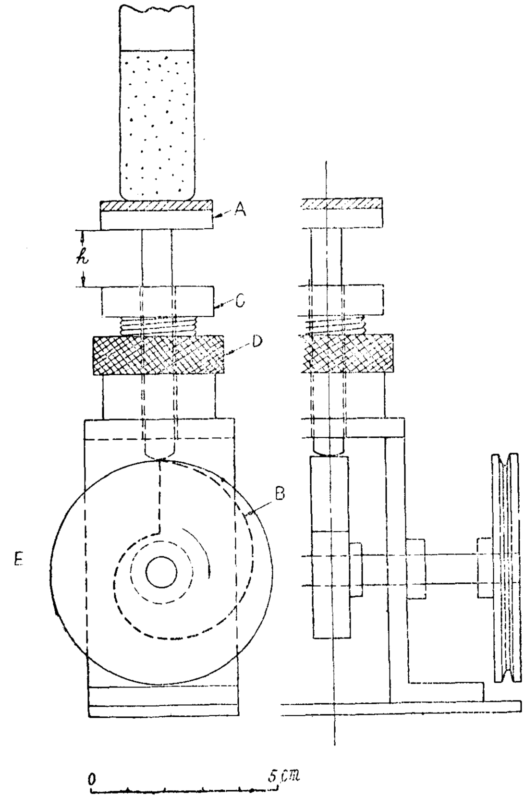

Fig. 1. Apparatus for apparent density measurement.

Bloomquist and Clark[1]. The third one, which had rod-like shape, was prepared by crushing glass wool of 8μ in diameter.

These powders were classified into several fractions of sizes by sieve and sedimentation procedures, and were washed in distilled water and in ethanol, dried at 120° C. for about 10 hours and kept in a dessicator. The microphotographs of the spherical, crushed and rod-like powders are given in Figs. 2, 3 and 4.

III. Procedure & Results

The sample, which was kept dry in dessicator, was weighed and put into the cylindrical glass container. This container was placed on the measuring apparatus, and the apparent volume of the powder in each falling was read on the graduation on the container. A typial change of the apparent density ρ_n against the number of times of falling n is illustrated in Fig. 5. The apparent density approaches to a final value ρ_f in that condition as the number of times of falling is increased.

1) C. R. Bloomquist and A. Clark; Ind. Eng. Chem. Anal. Ed., **12**, 61 (1940)

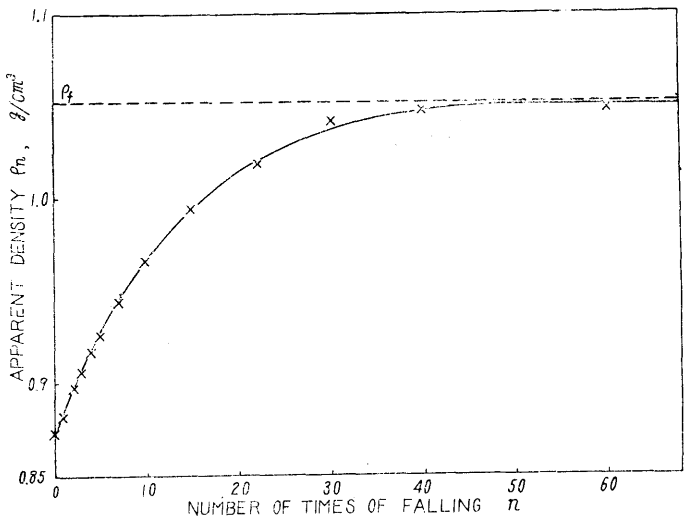

Fig. 5. Variation of apparent density with number of times of falling for crushed glass powder of mean dia. 78μ: falling height 5mm.; container diameter 13.5mm.

The final apparent densities of the materials measured under various sample weights and falling heights are given in Table 1.

The effect of the container size was measured on three materials of about the same size but different shapes held in the containers of different diameters.

Table 1. **Apparent Density of Glass Powder.**

ρ_f **in g./cm³. ; Diameter of Container 13.5mm.**

Sample Weight	Falling Height	Spherical Glass mean dia. μ.				Crushed Glass mean dia. μ.					**Rod-like Glass mean length μ.***			
g.	mm.	71	56	29	20	187	113	78	56	36	152	112	80	47
10	5	1.42	1.41	1.38	1.38	1.13	1.06	1.07	1.05	0.96	0.78	0.87	0.89	1.03
	10	1.44	1.43	1.41	1.42	1.15	1.12	1.12	1.11	1.01	0.83	0.92	0.92	1.08
	18	1.45	1.44	1.42	1.45	1.16	1.14	1.14	1.13	1.05	0.86	0.96	0.98	1.10
15	5	1.42	1.42	1.35	1.38	1.14	1.07	1.06	1.06	0.96	0.74	0.88	0.89	1.05
	10	1.44	1.43	1.40	1.42	1.16	1.11	1.12	1.10	1.01	0.82	0.92	0.94	1.09
	18	1.45	1.44	1.42	1.45	1.18	1.16	1.15	1.12	1.05	0.84	0.96	0.95	1.12
20	5	1.43	1.42	1.36	1.32	1.13	1.07	1.07	1.05	0.96		0.89		1.03
	10	1.44	1.42	1.38	1.41	1.15	1.13	1.12	1.11	1.01		0.93		1.08
	18	1.46	1.44	1.41	1.43	1.18	1.16	1.16	1.13	1.06		0.95		1.10
25	5	1.44	1.41	1.35	1.29	1.13								1.04
	10	1.44	1.43	1.39	1.39	1.15								1.07
	18	1.46	1.44	1.42	1.43	1.18								1.10

* 8μ. in diameter.

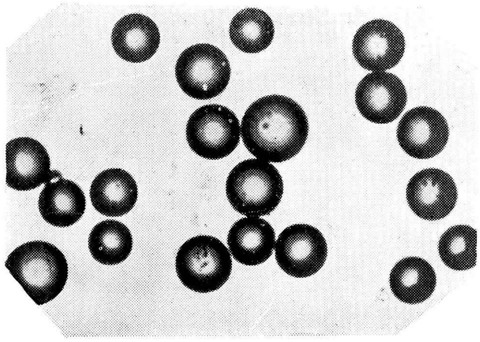

Fig. 2. Spherical glass powder. (×120)
mean dia. 56μ.

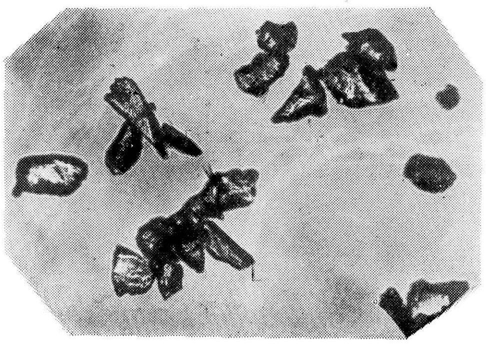

Fig. 3. Crushed glass powder. (×120)
mean dia. 56μ.

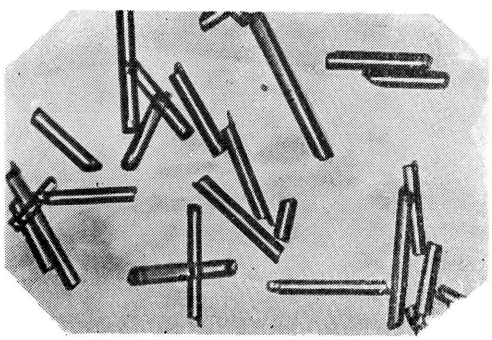

Fig. 4. Rod-like glass powder. (×120)
mean length 47μ. diameter 8μ.

The property of the container wall was changed by coating inside of a container with thin celluloid film, and the efect of the wall was tested by comparing the measurements of this coated container and those of the ordinary glass container on three materials described above. The results given in Table 2 and 3 illusttrate the effects of container size and wall property respectively.

Table 2. Effect of Container Diameter on Apparent Density of Powder.
ρ_f in g./cm³.

mean dia. μ.		Spherical Glass 56			Crushed Glass 56			Rod-like Glass 47*		
Diameter of Container mm.		13.5	5.0	2.9	13.5	5.0	2.9	13.5	5.0	2.9
Sample Weight g.		10.0	11.8	5.1	10.0	7.7	3.2	10.0	7.0	3.6
Falling	5	1.41	1.41	1.43	1.05	1.01	0.99	1.03	0.97	0.95
Height	10	1.43	1.42	1.45	1.11	1.08	1.03	1.08	1.06	1.04
mm.	18	1.44	1.44	1.47	1.13	1.13	1.13	1.10	1.11	1.12

* mean length, 8μ in dia.

Table 3. Effect of Container Wall Property on Apparent Density of Powder.
ρ_f in g./cn³.; Diameter of Container 13.5mm.; Sample Weight 20g.

mean dia. μ.	Spherical Glass 56		Crushed Glass 56		Rod-like Glass 47*	
Celluloid coating	not coated	coated	not coated	coated	not coated	coated
Falling 5	1.42	1.44	1.05	1.03	1.03	0.99
Height 10	1.42	1.45	1.11	1.10	1.08	1,03
mm. 18	1.44	1.46	1.13	1.15	1.10	1.11

*mean length, 8μ. in dia.

IV. Discussion

According to a paper of the soil physics, the logarithms of the tapping number n and the apparent density ρ_n of the sand have a linear relation, but in our experiments, as given in Fig. 6, the plots of log $(\rho_f-\rho_n)$ vs. n show a straight line.

This relation will be expressed in a equation

$$\rho_f-\rho_n=A\cdot e^{kn} \tag{1}$$

where, A and k are parameters which depend on the properties of powder particles and the conditions of the measurements, i. e., falling height, weight of sample and properties of containers.

This relation was also found in other measurements of the apparent densities of magnesium oxide powders. Although our relation contradicts to that reported in the paper of the soil physics, we believe ours is reasonable, since it has no fault that ρ_n approaches to infinity as n is increased infinitely.

We can calculate ρ_f from Eq. (1) using several data of n and ρ_n, and need not continue the measurement to get the final apparent density. The relation between the properties of the powder and the parameters A and k in Eq. (1) is not still clear, but these parameters will play important roles in describing the powder properties.

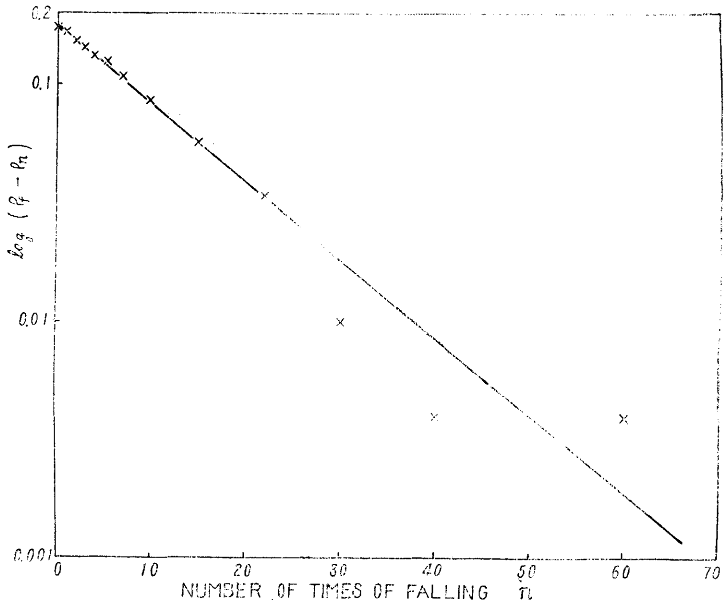

Fig. 6. Relation between apparent density and number of times of falling for the same material and under the same condition as Fig. 5

The apparent densities of the spherical and crushed glass powders decrease as the particle sizes become smaller as seen in the case of ususal powders. In the case of rod-like glass powder, however, the apparent density of the small particles is greater than that of the big ones. This tendency of rod-like particles is due to the change of the shapes of particles, that is, since the diameter of all rod-like particles are constant, the shape of particles becomes more shperical, therefore the apparent density becomes greater, with the decrease of particle length.

The results in Table 1, which show the greatest apparent density for spherical glass powders and the smallest for rod-like glass powders, can also be explained by the sphericities of the powder particles.

The effect of the sample weight was not appreciable in the course of this experiment.

The apparent densities measured by the container of small diameter were smaller than that measured by the container of large diameter in the case of crushed and rod-like glass powders. The effect of the wall property of the container was also appreciable on both powders. But these effects were not clear in the case of the spherical glass powder.

In any case the apparent density always became denser as the falling height was increased. The effects of the container were covered by the effect of the falling height, and when the falling height was heigh no difference of the apparent density caused by using different containers was observed.