FLOW PATTERNS OF SOLIDS PARTICLES IN A BLOW TANK

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SYNOPSIS

Flows of solids particles in a blow tank are observed by using a transparent model tank of semi-circular cross section. For granular particles such as glass beads of relatively large particle size the flow is smooth and is similar in pattern to mass flow in a hopper under the gravity. For fine particles the flow is intermittent and the particles flow in a conveying pipe after being fluidized.

1. Introduction

A blow tank is one of solids transporters. Air flow blown in the tank entrains solid particles into the air stream and transports them through a conveying pipe to a destination. It will be highly interesting how solids particles enter the conveying pipe in the blow tank. In order to observe the particles flow a model blow tank of semi-circular cross section is made which frontal plane is transparent. Through the plane the flow is examined.

2. Experimental apparatus and procedure

Figure 1 shows the experimental setup. The blow tank consists of a half-cylindrical part and a half-conical part and the transparent frontal plane crosses their axes. The tank volume is about $28\times10^{-3}\,m^3$. The conveying pipe rising vertically from the tank is 16 mm I. D. transparent pipe. The position of the pipe inlet is adjustable within 300 mm from the porous plate. The air flow rate is measured by the quadrant flow nozzle and/or the float meter. The solids weight flow rate is measured by the load cell attached to the weighing tank. The injection feeder is used for returning the solids to the blow tank.

In order to visualize the flow of solids in the tank laminae of coloured paricles are placed horizontally between non-coloured particles. Colouring is made by using black ink. The thickness of the coloured particles is 0.5 cm and that of non-coloured is 5 cm. In each run the air flow rate is kept constant. The observation of the flow is carried out by taking photographs.

Physical parameters of test materials are shown in Table 1.

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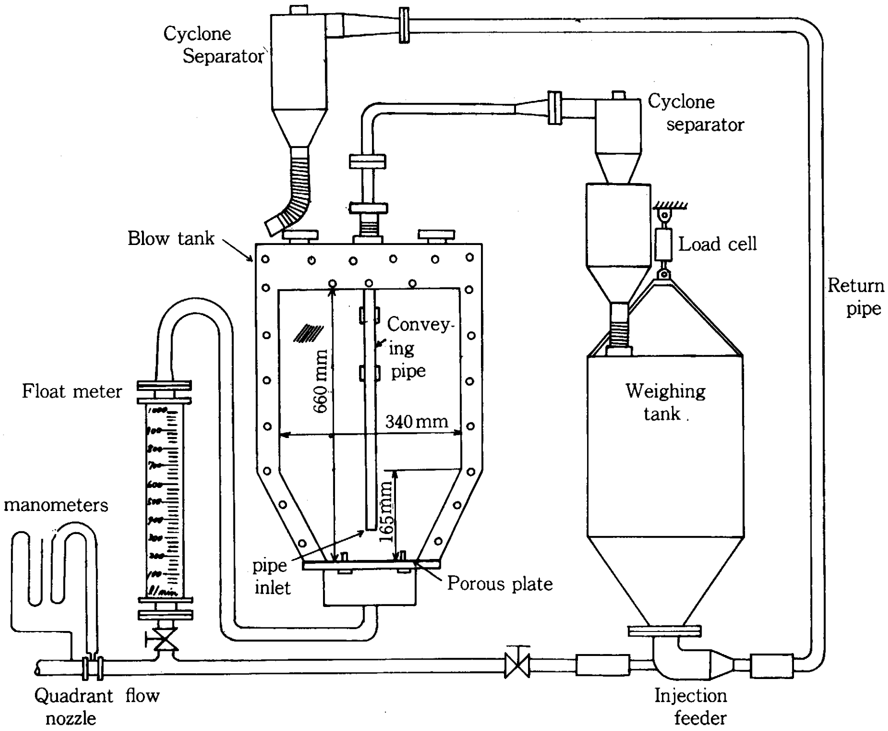

Fig. 1 Schematic diagram of experimental apparatus

Table 1. Physical parameters of test materials

Material	Particle size (μm)	Material specific weight (kg/m^3)	Bulk specific weight (kg/m^3)	Free falling velocity (m/s)
Glass beads	250	2480	1470	2.84
Cement raw materials	30	2560	1000	0.07

3. Experimental results and discussion

Figure 2 shows successive photographs for glass beads when the nozzle height from the porous plate is 50 mm and the air flow rate is 200 1/min. Figure 2 (a) shows the state before air being blown in. The state shown by Figs. from 2 (b) to 2 (h) is steady and the solids weight flow rate is kept constant. The solids in a narrow vertical region at the center is held between the plate surface of the tank and the conveying pipe and is halted there to the last. The flow patterns in the steady state are almost similar to those of granular materials in a hopper when the materials issue from a bottom orifice under the gravity. It is seen that the particles situated upper layer firstly flow out from the tank; the particles exposed at an inclined particles surface slide down the slope toward the tank axis, fall down in the central region of the tank and flow in the pipe. It is noted that during this period the particles situated between the pipe inlet and the porous plate are not disturbed by the air flow. When the particles surface is lower than the pipe inlet, the air flow rate increases and the remaining particles are fluidized as shown in Fig. 2 (i). When the particles layer is enough high, three different flow patterns are discerned, that is, radial flow toward the tank axis near the particles surface layer, vertical downward flow in the central region and suction flow near the pipe inlet. The pattern which is seen when the particles surface is low such as shown in Figs. from 2 (d) to 2 (g) is due to combination of these three flow patterns.

Figure 3 shows successive photographs for glass beads when the nozzle height is 200 mm and the air flow rate is 200 1/min. General view is almost the same as that for 50 mm nozzle height. It is noted, however, that the slope of the particles surface is smaller in this case. Also, the solids weight flow rate is smaller in this case. It is seen from Fig. 3(e) that by a large bubble rising up from the porous plate the particles between the pipe inlet and the porous plate are about to be disturbed. When the particles are fluidized, particles convection occurs as shown by Figs. 3(h) and 3(i).

The solids weight flow rate in the steady state, G_s, is given by

$$G_s = cA\gamma_s(u_a - u_g) \tag{1}$$

where A is the cross sectional area of the pipe, γ_s is the material specific weight, u_a is the superficial air velocity in the pipe inlet and u_g is the free falling velocity of the particle. The coefficient c is dependent on the tank geometry and the material transported.

Figure 4 shows successive photographs for cement raw materials when the nozzle height is 50 mm and the air flow rate is 200 1/min. In this case colouring of the particles is not made. It is easily seen that the general view of flow is quite different from that of the glass beads. In case of the cement raw materials the particles are fluidized before flowing in the pipe. Similar flow pattern is also seen in case of the glass beads when they are fluidized as showh in Figs. 2(i), 3(g), 3(h) and 3(i). It is seen that there is always a air chamber near the pipe inlet. This chamber will be necessiated to fluidize the particles. The particles surrounding the chamber fall in the fluidized region intermittently and then flow in the pipe. Then the particles situated upper layer flow out from the tank at last. The solids weight flow rate is also given by the same type equation as Eq.(1). But air velocity when the weight flow rate becomes zero is much larger than the free falling velocity of the particle of cement raw materials. Further the weight flow rate has fluctuation about the average value, which is caused by the intermittent collapse of the materials into the fluidized region.

4. Conclusion

The flow patterns of solids in the blow tank are visualized. When the transported materials are granular solids such as glass beads of relatively large particle size, the solids flow in the pipe smoothly. On the other hand when the materials consist of fine particles, the solids flow in the pipe after being fluidized.

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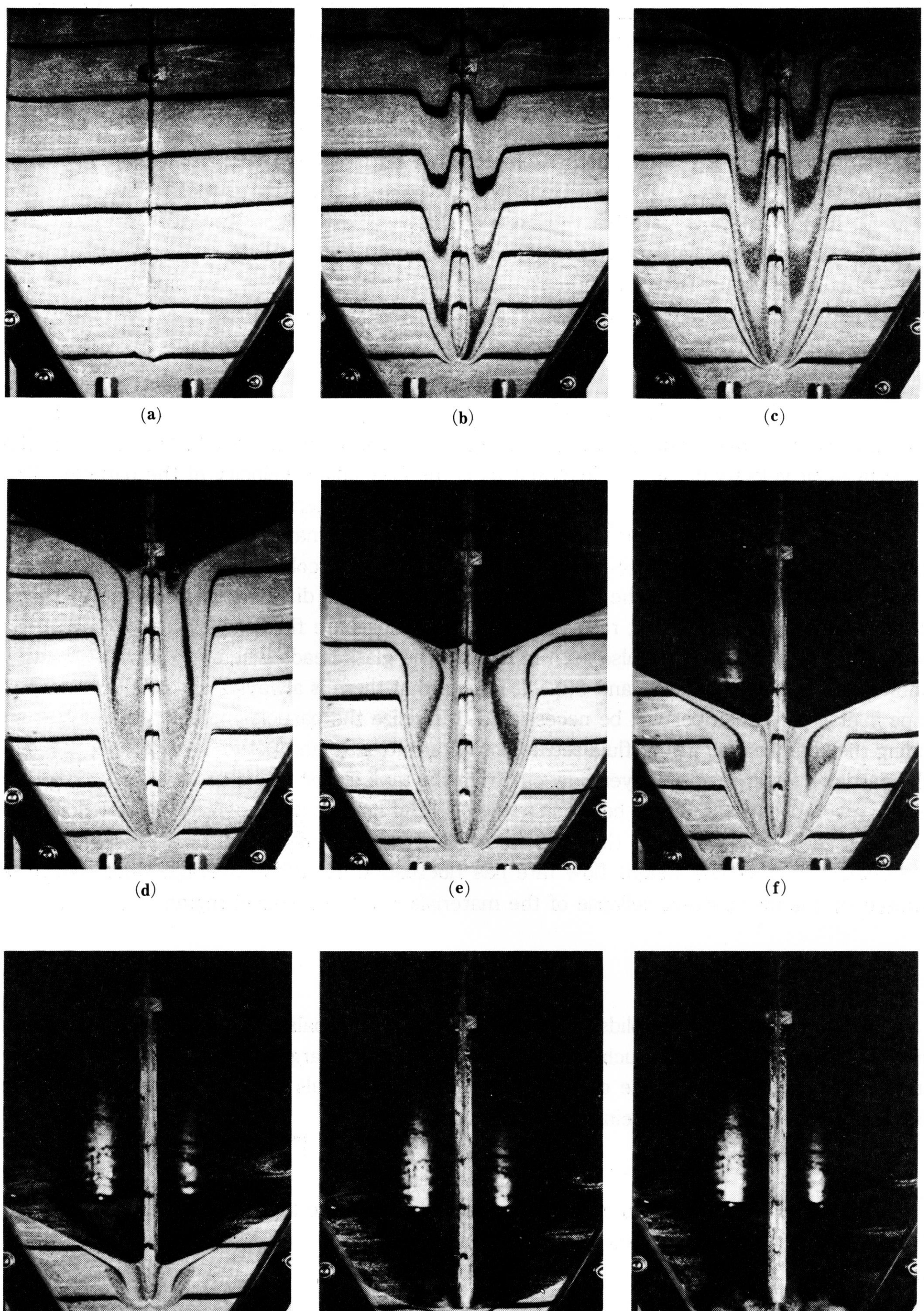


(a) (b) (c) (d) (e) (f) (g) (h) (i)

Fig. 2 Successive photographs showing how the glass beads flow in the conveying pipe. Nozzle height 50 mm; air flow rate blowing in the tank 200 1/min.

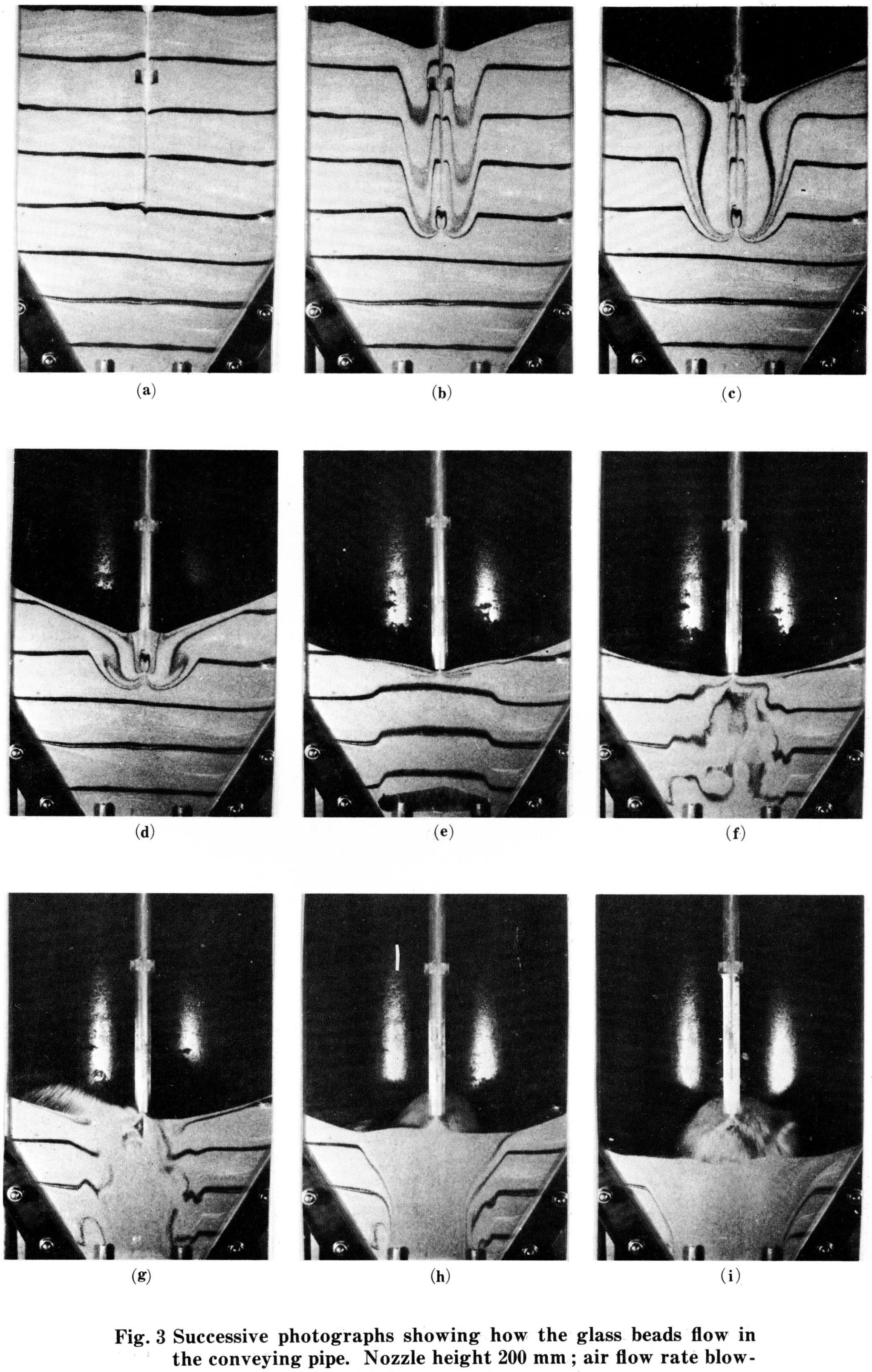
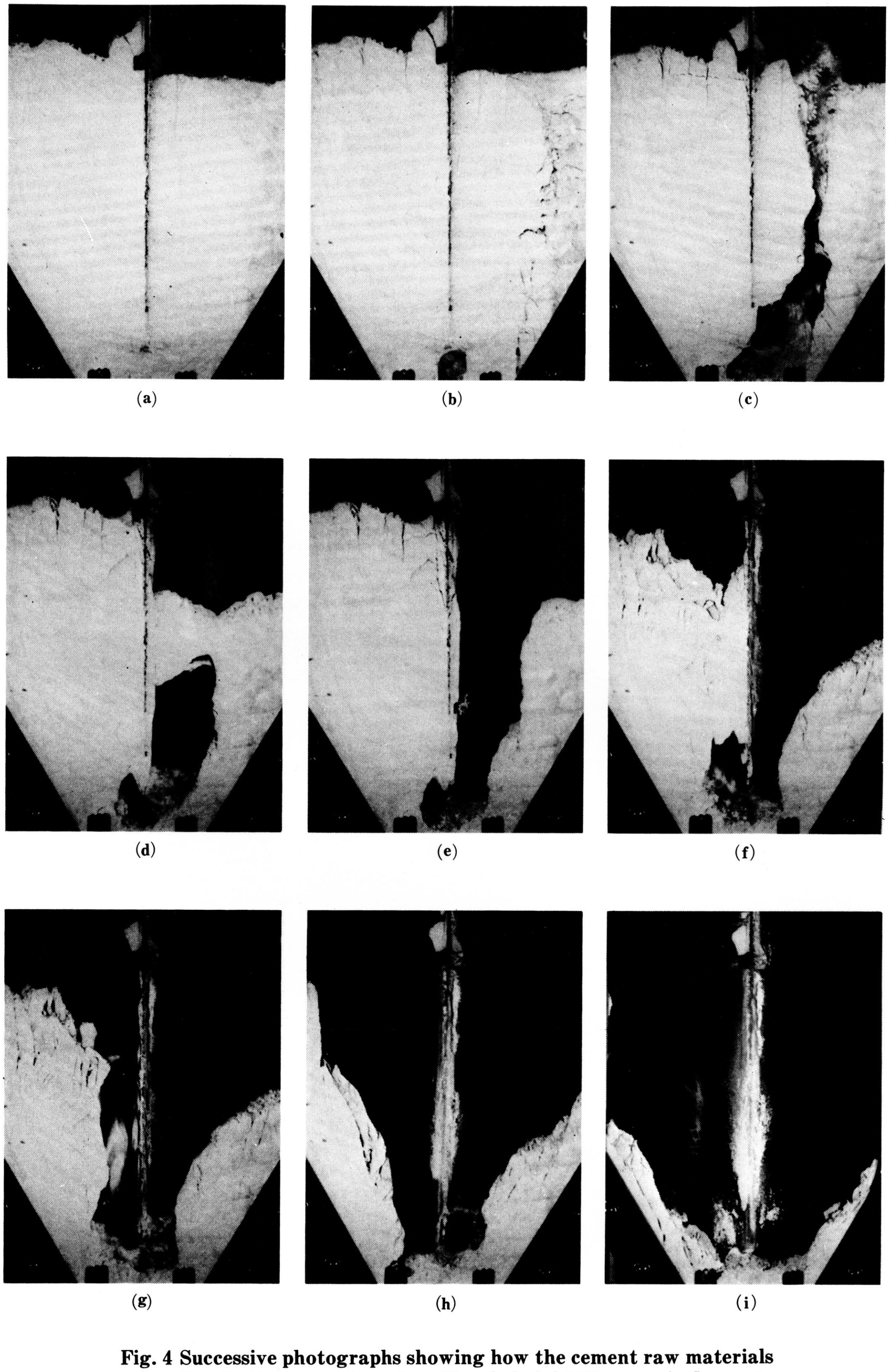


Fig. 3 Successive photographs showing how the glass beads flow in the conveying pipe. Nozzle height 200 mm ; air flow rate blowing in the tank 200 1/min.



(a) (b) (c) (d) (e) (f) (g) (h) (i)

Fig. 4 Successive photographs showing how the cement raw materials flow in the conveying pipe. Nozzle height 50 mm ; air flow rate blowing in the tank 200 1/min.