# Pressure Distribution by a Pile in the Granular Mass*

By

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Shots are filled into a narrow rectangular box to a certain depth and a carbon microphone is laid in it. If the surface of granular mass is once vertically thrust into by a pile at the point $x$ from the microphone and then the thrust pile is pulled out, the current flowing through the microphone will change. In this case it can be considered approximately that the variation of the current accompanies with the pressure variation. As the pressure increase renders the resistance of the microphone small, its flowing current becomes large. Therefore, from the current, the pressure among these granules can be judged. The pressures at points at different distances from the pile can be easily determined by this method. These results are shown in Table 1 and $R$, the currents through the microphone, are plotted against $N$, the number of the thrust or withdrawal, in Fig. 2.

## (1) In the Portion Immediately Near the Pile.

When the pile is thrust into the surface of a sand mass, the microphone current takes greater value than its initial one. Next when the pile is withdrawn from the surface of the sand mass, the current always returns to its initial value. The microphone currents due to these thrusts or withdrawals can be shown in Fig. 3a. It is evident that the microphone currents are independent of the number of thrusts or withdrawals.

## (2) In the Portion near the Pile.

When the pile is thrust by hand into the surface of the sand mass, the microphone current takes greater value than its initial one as

* This paper was read by the author at the annual meeting of the Physico-Mathematical Society of Japan on 4th, April, 1938.

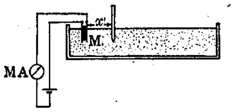
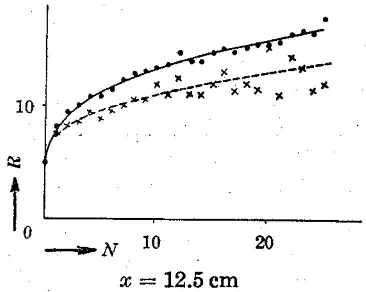



Fig. 1. {MA : Milliameter
M : Carbon microphone



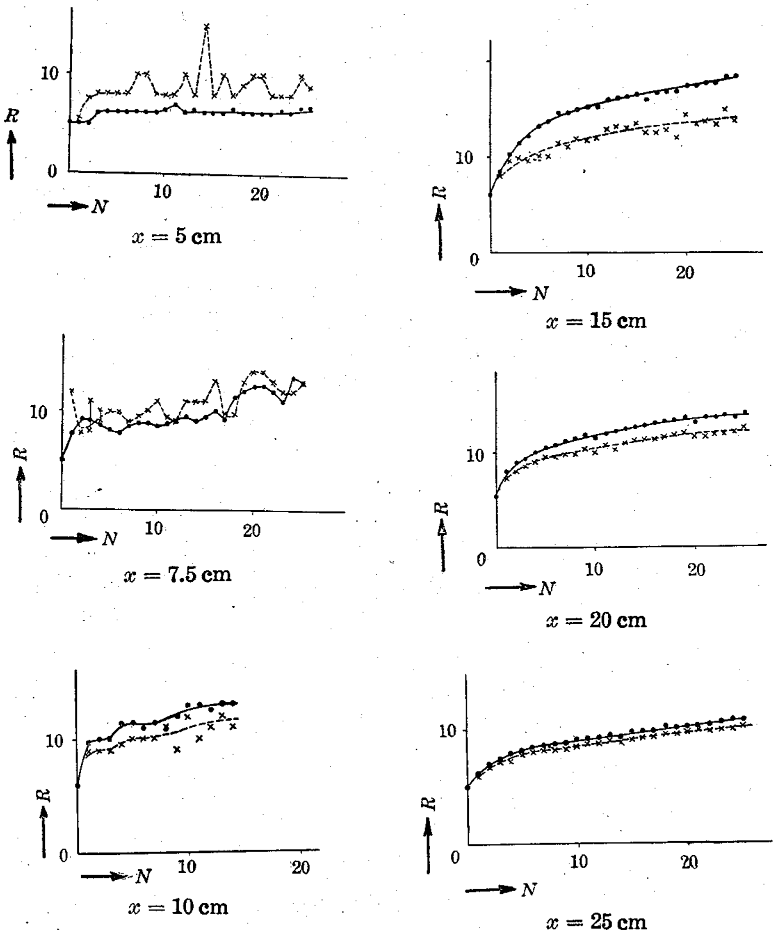




Fig. 2. {× indicates ↓ state
● indicates ↑ state

Table 1. Table of R.

| N | $x = 5$ cm. | | $x = 7.5$ cm. | | $x = 10$ cm. | | $x = 12.5$ cm. | | $x = 15$ cm. | | $x = 20$ cm. | | $x = 25$ cm. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ↓ state | ↑ state | ↓ state | ↑ state | ↓ state | ↑ state | ↓ state | ↑ state | ↓ state | ↑ state | ↓ state | ↑ state | ↓ state | ↑ state |
| 0 | / | 5.0 | / | 5.0 | / | 6.0 | / | 5 | / | 6.0 | / | 5.5 | / | 5.0 |
| 1 | 5.5 | 5.0 | 12.0 | 7.8 | 9.0 | 9.8 | 7.5 | 8.2 | 8.0 | 8.5 | 7.5 | 8.0 | 6.0 | 6.2 |
| 2 | 7.5 | 5.0 | 7.8 | 9.2 | 9.0 | 10.0 | 8.2 | 9.5 | 9.5 | 10.3 | 8.0 | 9.0 | 6.8 | 7.0 |
| 3 | 8.0 | 6.2 | 8-11 | 9.0 | 9.0 | 10.0 | 8.5 | 10.0 | 9.8 | 11.5 | 8.7 | 9.3 | 7.2 | 7.5 |
| 4 | 8.0 | 6.2 | 9-10 | 8.5 | 9.5 | 11.5 | 9.5 | 10.8 | 9.5 | 12.0 | 9.0 | 10.0 | 7.2 | 8.0 |
| 5 | 8.0 | 6.2 | 10.0 | 8.2 | 10.0 | 11.5 | 8.8 | 10.8 | 10.0 | 13.2 | 9.5 | 10.5 | 7.8 | 8.2 |
| 6 | 8.0 | 6.2 | 10.0 | 7.8 | 10.0 | 11.0 | 9.5 | 11.5 | 10.0 | 13 5 | 9.5 | 10.8 | 8 0 | 8.5 |
| 7 | 10.0 | 6.2 | 9.0 | 8.5 | 10.0 | 11.5 | 10.0 | 12.3 | 11.5 | 14.5 | 9.8 | 11.2 | 8.2 | 8.6 |
| 8 | 10.0 | 6.2 | 9.5 | 8.8 | 11.0 | 10.8 | 10.5 | 12.8 | 11.0 | 14.5 | 9.8 | 11.5 | 8.2 | 8.8 |
| 9 | 8.0 | 6.2 | 10.0 | 8.8 | 9.0 | 12.0 | 10.5 | 13.0 | 12.0 | 15.0 | 10.5 | 11.8 | 8.2 | 8.8 |
| 10 | 8.0 | 6.5 | 11.0 | 8.5 | 12.0 | 13.0 | 12.0 | 13.3 | 11.8 | 15.2 | 10.0 | 11.5 | 8.5 | 9.2 |
| 11 | 8.0 | 7.0 | 9.5 | 8.8 | 10.0 | 13.0 | 11.0 | 13.8 | 12.0 | 15.3 | 10.8 | 12.0 | 8.8 | 9.2 |
| 12 | 10.0 | 6.2 | 9.0 | 9.0 | 11.0 | 12.5 | 12.5 | 14.8 | 13.0 | 16.0 | 10.2 | 12.2 | 8.8 | 9.2 |
| 13 | 8.0 | 6.5 | 11.0 | 9.5 | 12.0 | 13.0 | 11.0 | 14.0 | 13.2 | 16.2 | 11.0 | 12.5 | 9.0 | 9.5 |
| 14 | 15.0 | 6.2 | 11.0 | 9.0 | 11.0 | 13.0 | 11.0 | 14.0 | 13.0 | 16.3 | 11.2 | 12.5 | 8.8 | 9.2 |
| 15 | 8.0 | 6.2 | 11.0 | 9.5 | | | 12.0 | 14.8 | 13.5 | 16.5 | 11.3 | 12.8 | 9.0 | 9.8 |
| 16 | 10.0 | 6.2 | 13.0 | 10.0 | | | 13.0 | 15.2 | 12.5 | 16.0 | 11.3 | 13.0 | 9.2 | 9.8 |
| 17 | 8.0 | 6.6 | 9.5 | 9.2 | | | 11.5 | 14.8 | 12 5 | 16.8 | 11.5 | 13.2 | 9.2 | 9.8 |
| 18 | 9.0 | 6.2 | 9.5 | 11.5 | | | 12.0 | 15.2 | 12.8 | 16.8 | 11.8 | 13.3 | 9.5 | 10.2 |
| 19 | 10.0 | 6.2 | 13.0 | 12.0 | | | 11.5 | 15.5 | 12.0 | 17.0 | 12.0 | 13.6 | 9.4 | 10.0 |
| 20 | 10.0 | 6.2 | 14.0 | 12.5 | | | 15.5 | 15.5 | 14.5 | 17.5 | 11.5 | 13.0 | 9.8 | 10.2 |
| 21 | 8.0 | 6.2 | 14.0 | 12.5 | | | 11.0 | 15.8 | 13.5 | 17.5 | 11.5 | 13.5 | 9.8 | 10.2 |
| 22 | 8.0 | 6.5 | 13.0 | 12.0 | | | 14.5 | 16.5 | 13.8 | 17.8 | 11.8 | 13.5 | 9 8 | 10.2 |
| 23 | 8.0 | 6.2 | 12.0 | 11.0 | | | 13.5 | 16.8 | 13.5 | 17.8 | 11.8 | 13.8 | 9 8 | 10.5 |
| 24 | 10.0 | 6.8 | 12.0 | 13.5 | | | 11.5 | 16.5 | 15.0 | 18.5 | 12.0 | 13.5 | 9.8 | 10.8 |
| 25 | 9.0 | 6.8 | 13.0 | 13.0 | | | 12.0 | 18.0 | 13.8 | 18.5 | 12.5 | 14.0 | 10.2 | 10.6 |

shown in case (1). Next when the pile is pulled out, the microphone current does not recover but takes a greater value than its initial value. In the secondary thrust, the current takes a greater value than that produced by the first thrust. In this portion, as is evident from Fig. 3b, it seems that the microphone currents somewhat depend on the number of thrusts or withdrawals but soon become saturated with their considerably large number.

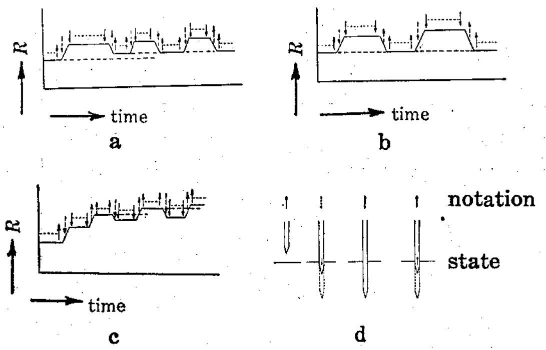



Fig. 3.

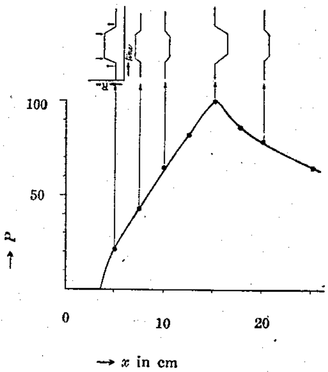



Fig. 4.

Table 2. Thickness of shot granules (No. 11)=6.1 cm. Width of rectangular box.=14 cm. $R$ is a reading of $MA$.

| $x$ in cm. | $R_\infty$ in ma. | $R_\infty - R_0$ | $P = [(R_\infty - R_0)/(R_{\infty\max} - R_0)] \times 100$ |
|---|---|---|---|
| 2.5 | 5 | 0 | 0 |
| 4.0 | 5 | 0 | 0 |
| 5.0 | 8 | 3 | 21.4 |
| 7.5 | 11 | 6 | 42.8 |
| 10.0 | 14 | 9 | 64.3 |
| 12.5 | 16.5 | 11.5 | 82.1 |
| 15.0 | 19 | 14 | 100.0 |
| 17.5 | 17 | 12 | 85.7 |
| 20.0 | 16 | 11 | 78.5 |
| 25.0 | 14 | 9 | 64.3 |

(3) In the Portion Very Distant from the Pile.

If the pile is thrust as before, the current takes a greater value than its initial one. Next when the pile is pulled out from the surface of the sand mass, the current takes a yet greater value than this. When the pile is secondarily thrust on, the current takes a smaller value than the former one. In the secondary pulling out, the current takes a greater value than that at the first pulling. The current seems to increase with the increase of the number of thrusts or pullings out but to be saturated with a considerably large number.

(4) The Pressure Distribution under Conditions of Withdrawal.

The number of thrusts $N$ and their corresponding current are shown in Fig. 1. $R_\infty$ indicates the value of $R$ when $N$ is large. Next the relation between $R_\infty$ and $x$ is tabulated in Table 2. The data shown in Table 2 are plotted in Fig. 4. As is evident from this table, in a domain of about 4 cm round the pile the shot granules are very loosely piled up. This seems to correspond to the slip line* produced when the sand mass is deformed and also to the viscous layer of snow shown by ski-sliding experiment.** But in the domain of 5 to 15 cm from the pile the arrangement of granules becomes gradually closely packed with the increase of distance.

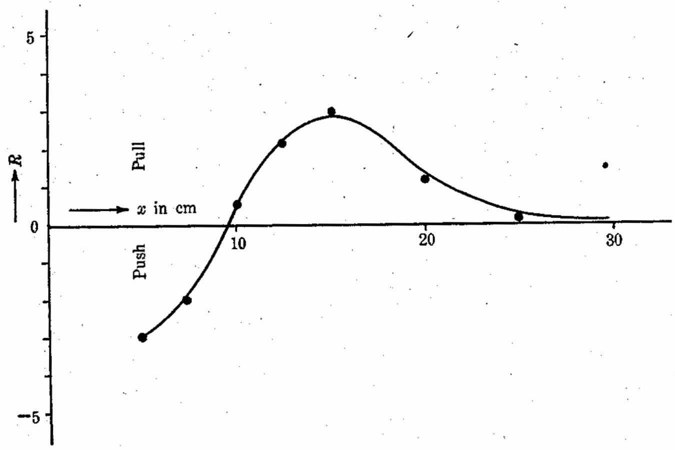



Fig. 5.

* The late Prof. T. TERADA and Dr. MIYABE described that the microscopic construction of slip line displays a mode similar to viscous material. See Bull. Earth. Reasearch Inst. Tokyo Imp. Univ. Vol. 4, p. 33.

** This experiment was actually carried out by Prof. U. NAKAYA to whom it was suggested by the ski-sliding theory established by the late Prof. T. TERADA. See Jour. Fac. Sci. Hokkaido Imp. Univ. Series II, Vol. 1. No. 9, p. 265.

In domains of greater distances than 15 cm from the pile the arrangement is step by step closed up with the distance.

(5) The Pressure Distribution under Condition of Thrust.

The pressure among the granules is increased at distances 5 to 7 cm and the increase of pressure is greater at shorter distances. The pressure among the granules is gradually decreased with distance and most decreased at the point of the pressure maximum in pulling out state. At still farther distances the pressure is decreased. This relation is shown in Fig. 5. It seems that this may be somewhat related to SHIDA's law of push and pull for the initial motion of an earthquake as noted in seismology.

In conclusion, the writer wishes to express his best thanks to Professor Y. IKEDA for his guidance.