On the Propagation of Shock through Sand on the Beaches of Iwanai and Isikari.

By

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The velocity of shock through sand has been determined at the beach of Riyamunai in the suburbs of Iwanai and at the beach of Isikari in Hokkaido. As the results of the experiments carried out at the former place in the summer of 1935 were not sufficiently complete because of the bad weather conditions, the experiments were repeated with a little modification at the latter place in the summer of 1936.

As the velocities of shocks through granular particles are considered to be important in connection with dynamical properties of assemblages of particles or granular materials, they were studied in the laboratory by K. Yoneta, but it was also desired to carry out similar experiments under the condition of freedom from the effects of any boundary. This experiment at the sandy beaches mentioned above was carried out as one part of the studies with the aid of the Nippon Gakuzyutu Sinkôkai for the studies of the properties of granular particles.

Apparatus and Method.

The apparatus used is schematically shown in Fig. 1. As sources of shocks a peg and a hammer were used at Riyamunai and toy fire-works ignited by means of an induction coil at Isikari. Two needle electrodes thrust into the gun-powder of the toy fire-works were connected with the secondary terminals of the induction coil, as shown at the lower part of Fig. 1. By this method the number of success and non-success of ignition were obtained nearly equally. The toy fire-works were set in a small cylindrical can which was covered with paper to make the shocks stronger. Two telephone transmitters buried in the sand at distances a and b from the source of shock received the propagated shock waves. The modified currents of the transmitters caused by the shock, the d. c. components of them

(1) K. Yoneta, Kwagaku (in Japanese) Vol. 4, No. 8, p. 329 (1934).

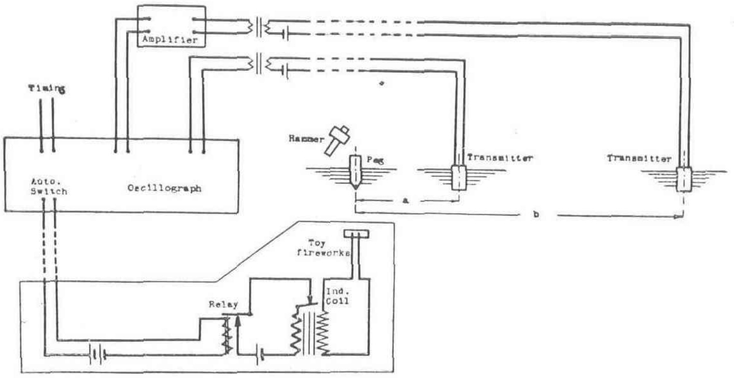

Fig. 1.

excluded through transformers, were taken in an oscillograph; the one from the nearer transmitter directly and the other through an amplifier. For timing a source of 60 cycles was used at Riyamunai and at Isikari an a.c. source of 500 cycles of calibrated variable vacuum oscillator. The velocity of the propagation of shocks was obtained from the differences of the distances a and b, and the interval of the times of arrival of the shock waves at those points. The synchronization of the shock and the shutter of the oscillograph was obtained simply by a signal when the hammer was used, and by making use of an automatic switch of the oscillograph which closed a relay circuit

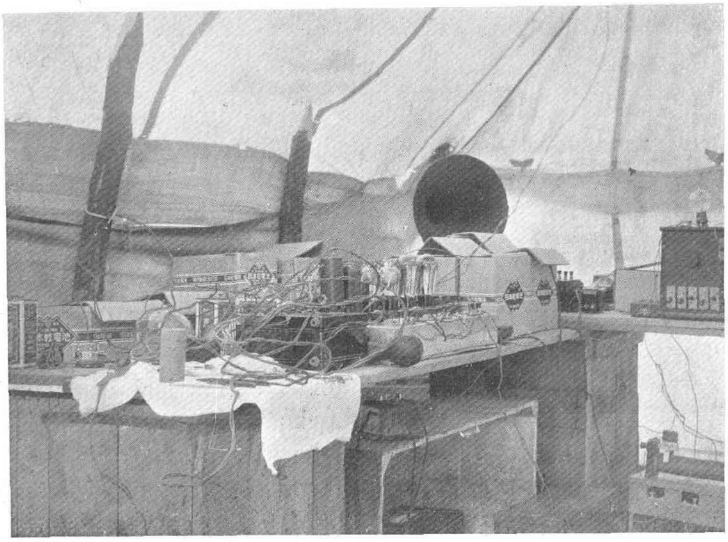

Fig. 2.

energizing the induction coil after a fraction of rotation of the drum loaded with photographic film from the instant of the opening of the shutter, when the toy fireworks were adopted. In the former experiment a resistance-coupled amplifier of rather high delicacy was used. However, in the latter experiment a three stage amplifier of transformer-coupled type was adopted, because that amplifier might be sufficiently fit for use for measuring the velocity of the wave front of the mechanical shock and yet might be operated accurately even in such field work. Fig. 2. is a view of apparatus in the tent erected for the experiment at Riyamunai.

Results.

Although the experiment at Riyamunai was incomplete due to bad weather, 4 available oscillograms were obtained yielding the following data :

Oscillogram	a in m.	b in m.	velocity in m/sec.
1	1.0	3.0	150
2	1.0	5.0	148
3	1.0	20.0	162
4	1.0	20.0	165

Fig. 3 shows the oscillogram No. 4: the upper trace is the shock wave received by the nearer transmitter, and the middle by the farther one, while the lower is the 60 cycles timing curve.

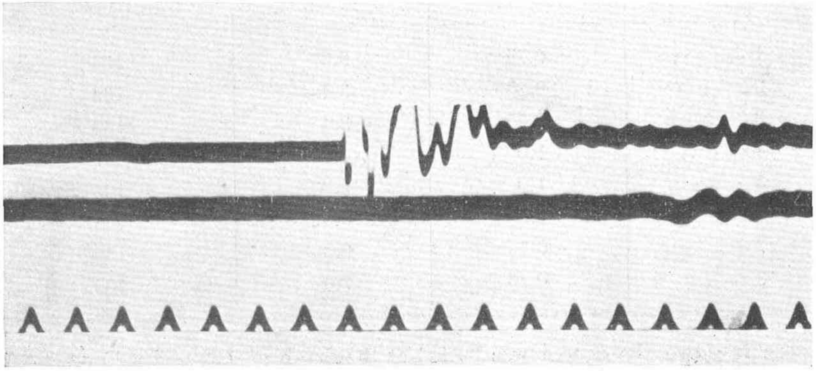

Fig. 3.

Following to the precedence of an indistinct wave caused by sound through the atmosphere, the shock wave arrives through the sand at a velocity about 150 m/sec. There would further appear many trains of waves which may be the so-called surface waves with peculiar characters which are experimented by K. Yoneta in laboratory, besides the waves due to ambiguous oscillation of trasmitter.

Next, the experiment at Isikari is described in the following. The sound due to the explosion of the gun powder is comparatively great. Therefore, when the transmitter and the source were buried near the surface of the sand, the sound waves through the atmosphere arrive first, followed by the shock waves due to the propagation through the sand itself. As the shock waves were confused on oscillograms from the transmitter nearer to the source, the wave front of them are not distinct. In this case, first, the instant of the explosion was determined on the oscillogram through extrapolation by making use of the velocity of sound in the atmosphere and the distance b of the farther transmitter from the source. Then the velocity of shock through sand was estimated from the distance b and the interval between the instant of the explosion and that of the arrival of the wave under question at the farther transmitter. When one or both of the transmitters and the source were buried at a depth of several dozen cm from the surface of sand, the shock through sand-air-sand was not clearly received, so the volocity examined was obtained simply.

The velocity of shock through sand is estimated to be 135-170 m/sec in each case as shown in the next table.

Oscillogram	a in m.	b in m.	velocity in m/sec.
1	0.75	3.5	168
2	0.55	3.4	166
3	0.55	3.4	160
4	1.0	4.0	157
5	1.0	5.0	163
6	0.75	9.0	135
7	0.75	9.0	145
8	-0.75	7.0	160

In the last two the source was buried at the depth of 0.65 and 0.40 cm respectively. Minus sign indicates that one of the transmitters was situated at the opposite side of the source to the other.

Accompanied with this wave of shock, there would be many trains of waves which are predominant on the oscillograms from the farther transmitter perhaps due to their small attenuation. Fig. 4 and 5 show Films No. 6 and No. 7 respectively: the upper trace shows the shock wave received by the farther transmitter, the middle one that by the nearer one, and the lower is the timing curve of 500 cycles.

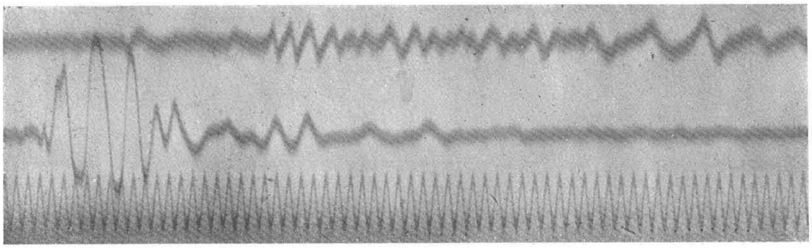

Fig. 4.

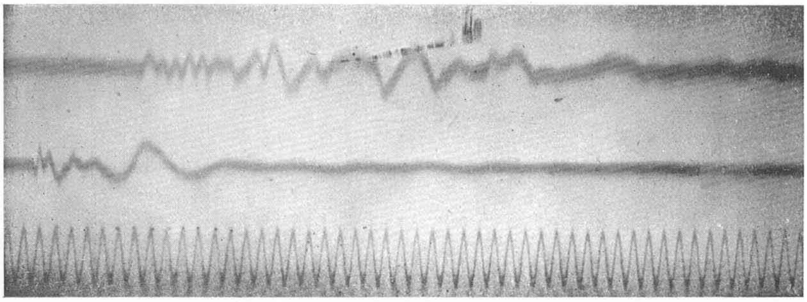

Fig. 5.

Conclusion.

In these experiments, the velocity of the front of the shock wave through sand was consistently obtained to be about 150 m/sec. This coincidence might have been due to the fact that the two sorts of sand resemble each other in the dimensions, appearances, etc. as shown in a preceding report of this series. The question how the dimension of particles, compactness of assemblage etc. may be related to the velocity of shock and the precise investigation on the trains of waves which might belong to other mode of propagation of shock remain for further experiments.

In conclusion, the writers' sincere thanks are due to the Nippon Gakuzyutu Sinkôkai for financial aid and to Prof. T. Yamada who kindly permitted them to use the portable oscillograph. Further they wish to express their thanks to Messrs. K. Kida, D. Sato, T. Mimura and S. Yamada who afforded the writers facilities for the field work.