11. The Relation between the Earthquake Damages and the Structure of Ground in Yokohama.

By Syun'itiro OMOTE,

Earthquake Research Institute.

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1. Introduction.

It has long been known that destruction by earthquakes has a close relation with the geologic structure of the ground of the place. But our knowledge of the relation between the two is still very imperfect for the lack of concrete evidence, and it is now being earnestly hoped that it should be expressed in more definite terms. We now want to take Yokohama as a favourable example and proceed with the study of the earthquake damages and the condition of the ground. For, on the one hand, the subsurface geologic structure of Yokohama is now clearly known thanks to the 297 borings carried out by the Division of Reconstruction Bureau[1] soon after the Great Kwanto Earthquake of 1923, and on the other hand the details of the distribution of the different degree of seismic damages due to the same earthquake have recently been made fairly clear over the whole city, so that it may be said that sufficient data are provided by Yokohama for the investigation of the relation between the seismic damages and the condition of the ground.

2. Topography and earthquake damages.

In the previous paper[2] we prepared a map of Yokohama showing the distribution of the ratio of totally destroyed houses. From this map a sort of iso-seismic lines have been drawn, as represented in the map of Yokohama in Fig. 1 by a family of heavy lines. Topographic contour lines at every twenty meters are also given in the same map by a family of thin lines. We at once become aware that serious damages were restricted to the lower parts of the city, and that on the hilly ground damages were definitely slight. We are, however, able to point out some places which were exceptions to the above rule; we shall revert to the case of these places later on.

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1) Reconstruction Bureau, *Geology in Tokyo and Yokohama.* (1929).

2) S. OMOTE, *Bull. Earthq. Res. Inst.*, **27** (1949), 57.

3. The thickness of alluvium and the degree of earthquake damages.

A thick layer of alluvium overburdened by a thin layer of reclaimed soil covers the lower regions of the city of Yokohama. It is generally

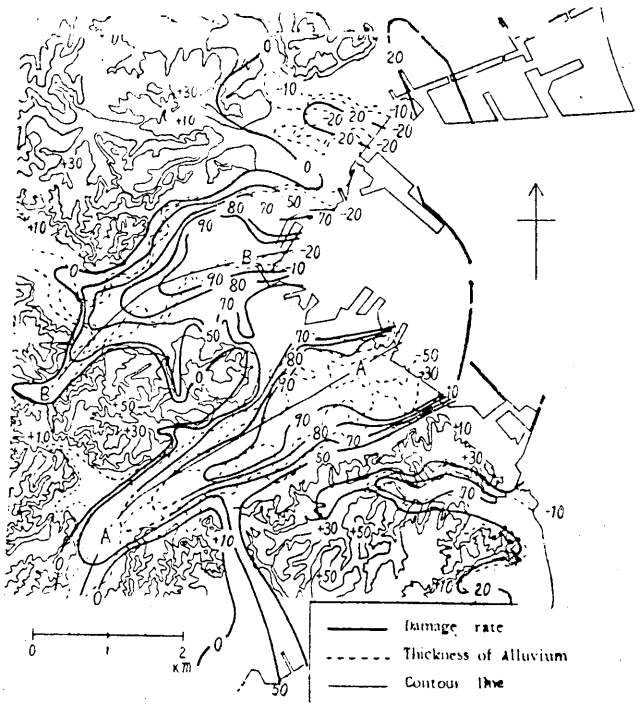

Fig. 1.

held that the degree of damages has the closest relation with the thickness of alluvium, and so here, to begin with, we will examine this relation. According to the geological maps prepared by the Reconstruction Bureau, the alluvium of Yokohama is subdivided into three layers: upper, middle and lowere. The respective contour lines in the geological maps showing the thickness of the three layers are so like each other that it does not appear likely that there should exist any specially close relation between the degree of damages and any one of these layers. These considerations necessitate that the relation between the damage rate and the thickness of the whole of the alluvium instead of the respective layers should be studied. The thickness of the alluvium along the lines A'-A and B'-B in Fig. 1 is shown by white circles in Figs. 2 and 3, and the damage rates in the same areas by black dots in the latter Figures. Comparison

of these Figures will show that the thicker the alluvium is, the larger is the proportion of the destroyed houses. As seen in Fig. 1, the alluvium plain in Yokohama is divided into two parts, namely A-plain and B-plain. With regared to each of the unit areas whose damage rates have been

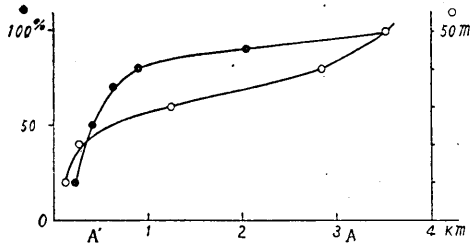

Fig. 2. ●; Damage rate along A'—A line
○; Thickness of alluvium along A' —A line.

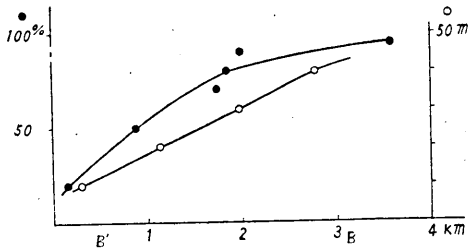

Fig. 3. ●; Damage rate along B'—B line
○; Thickness of alluvium along B' —B line.

calculated in the previous paper, the mean thickness of the alluvium has also been calculated, and the results have been summarized in Figs. 4 and 5 respectively for A and B plains. From these figures we can see that the thickness of the alluvium layer is closely related to the damage rate.

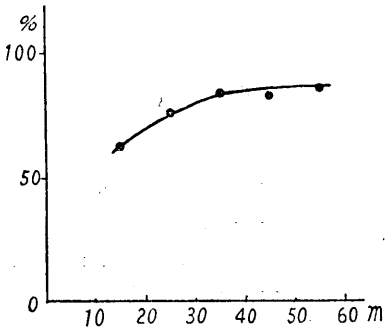

Fig. 4. Relation between thickness of alluvium and damage rate in the A-plain.

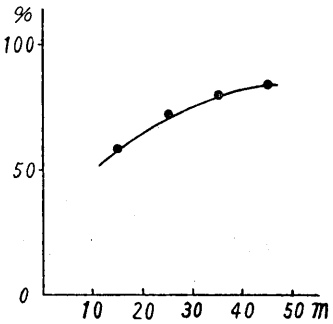

Fig. 5. Relation between thickness of alluvium and damage rate in the B-plain.

We notice in particular that as the thickness of the alluvium exceeds some thirty meters the damage rate suddenly becomes conspicous. It appear probable that the thickness of some thirty meters of the alluvium constitutes a sort of critical value.

4. The thickness of reclaimed superficial soil and earthquake damages.

The uppermost thin layer that covers the alluvium in Yokohama is largely composed of artificially reclaimed mud. As these reclamations belong to quite recent years it will be easily suspected that this thin layer of weak mud will have played an important role in the earthquake damages. The reclamation of Yokohama has been carried out on repeated occasions, and the changes that took place in the coastal lines of the Yokohama harbour at each occasion will be seen in Fig. 6 in the chronological order. We notice at once that severely damaged areas are in good accord with the reclaimed ground. The relation between the thickness of this mud layer and the damage rate due to the earthquake motions will be seen in Fig. 7 (A-plain) and Fig. 8 (B-plain). The relation between the uppermost mud layer and the damage rate is clearly discernible in B-plain, though it is not so marked in A-plain.

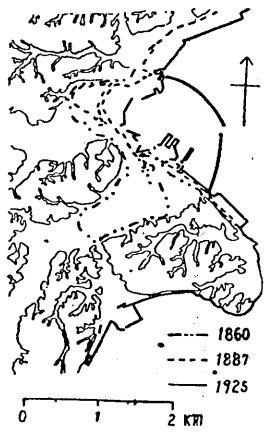

Fig. 6. Changes of shore lines in Yokohama.

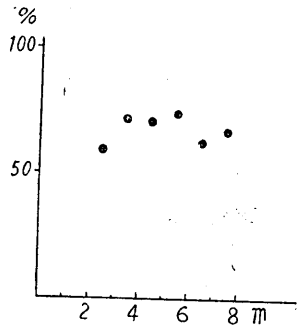

Fig. 7. Relations between the damage rate and thickness of reclaimed mud in the A-plain,

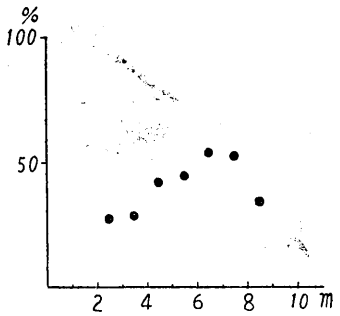

Fig. 8. Relations between the damage rate and thickness of reclaimed mud in the B-plain.

5. Some notes on the above observations.

It must not be overlooked here that in Yokohama it happened that in the area where the alluvium was thick, the reclaimed mud layer was also thick, and consequently it is very difficult to decide at present which layer was chiefly responsible for the earthquake damages. It is our earnest wish that more detailed studies will be made in the near future to give some definite conclusion to this point. Now, if we carefully compare

Fig. 7 with Fig. 8, we learn that black dots in the latter Figure are arranged roughly in a line while those in the former are not. An explanation to this will be as follows: Fig. 7 represents the relation between the thickness of the reclaimed mud and earthquake damage rates in A-plain. The thickness of alluvium is so large in this plain that the greater part of the earthquake damages in this area were due to the alluvium, and the effect of the overlying reclaimed mud layer was completely overshadowed. Contrary to this, in B-plain it appears that the thin alluvium layer had no essential relation to the earthquake damages, the overlying reclaimed mud having been solely responsible for them. But if we minutely examine the map in Fig. 1. we at once notice that there are many points that do not follow the general tendency just discussed. For instance: a) though there was a thick layer of reclaimed mud in the areas near Yokohama station, the damages were not serious there; b) on the contrary, in the central part of Yamashita-cho and the areas immediately to its north, more than 90% of the houses were destroyed though they stood on sand spit overburdened by very thin reclaimed mud; (it must be admitted, however, that most of the houses in Yamashita-cho were not made of wood); c) a part of West-Tobe, where the ground is hilly, suffered very high rate of damage, but this was the result of the landslide that took place there at the shock of the earthquake; d) as to the large damage rate in Yato, the explanation is that the houses in that district were rough cottages easily collapsible under the shock.

6. Conclusions.

In the above discussion we restricted our attention to the destruction of wooden houses, but the earthquake disasters naturally include not only the destruction of wooden houses but also that of many other structures such as brick or concrete buildings, towers, chimneys, bridges, railroads and harbours. But since the mechanism of the destruction of wooden houses may differ very much from that of other structures, the relation between the condition of the ground and the damages of other structures will be studied on some other occasion. The result of our present study will be summarized as follows:

1) The thickness of the uppermost layer of reclaimed soil has a close relation with the earthquake damages.

2) Places where thick alluvium overlies the ground suffer serious damages.

3) As the thickness of alluvium exceeds thirty meters the damage rate also increases conspicously.

4) On the sand spit or compact sand-shores earthquake damages are

often very slight.

5) Exceptions to the above conclusions may be pointed out, but the particular conditions of these places must be carefully investigated.

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