5. *Relation between the Earthquake Damage and the Nature of the Ground.* (*Case of Wooden Houses and Peat Bed.*)

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1. Introduction.

The magnitude, M, of Tokachi-oki Earthquake, March 4, 1952, was 8.1 and the numbers of totally-destructed, semi-destructed and slightly damaged houses in the southern and eastern parts of Hokkaido were about 1,400, 5,400 and 15,000 respectively.

The peculiarity of this earthquake concerning the damage to buildings is that such main buildings as public offices were damaged more seriously than ordinary houses. The reason is that the wooden ordinary houses in Hokkaido have small beams and the roofs are made of light stuff. In short, the upper-construction is very light in those houses.

The district which suffered from this earthquake includes a peat region of considerable area, which is an unprecedented case.

In the present paper, first, the results of the seismic prospecting made at two places within the peat region where the shock was "very strong" are stated. Then, as these two places were extremely different from each other in the degree of

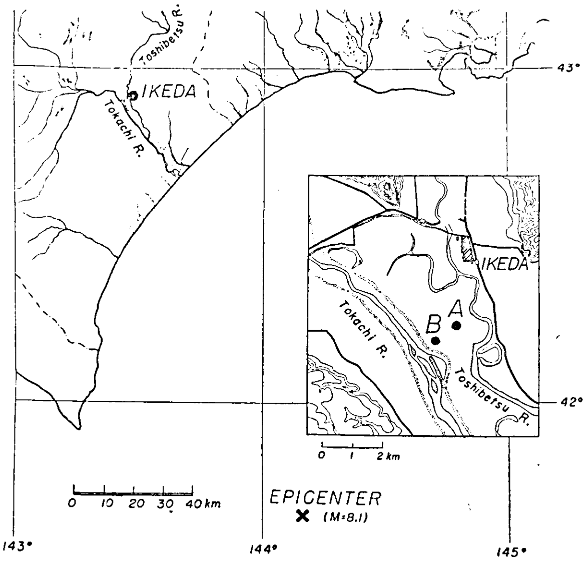

Fig. 1. Map of the examination places.

the damage done by the earthquake, the causes for this fact is searched by using the data obtained from the seismic prospecting.

2. Results of seismic prospecting.

(i) Date of prospecting: July 17 and 18, 1952.

(ii) Places of prospecting: The cultivated land hemmed in by the Tokachi River and the Toshibetsu River. The surface is of clay bed associated with peat-soil.

Place "A": Kawai, Tokachi-Ikeda-machi (about 2.2 km SSW of Ikeda Station).

Place "B": 〃 (about 2.9 km SW of Ikeda Station).

The places of seismic prospecting are shown in the map of Fig. 1.

(iii) Results of prospecting: Figs. 2 and 3 show the travel time curves of the initial motion at place "A" and "B" respectively. The velocities of two media and thickness of the surface layer obtained from Figs. 2 and 3 are shown in Table I.

It is found from Table I that the velocity of P-waves in the peat bed is not of a particular value compared with that in ordinary regolith bed. This must be due to much quantity of clay contained in the peat-soil. (Another seismic prospecting[1] was performed in crossing the Toshibetsu River which is at the distance of 5 km from the places mentioned above. The results were as follows: v_1= 300 m/s, v_2=1,600 m/s, thickness=several meters, and the second layer = gravel bed associated with clay. Though the measured line was about

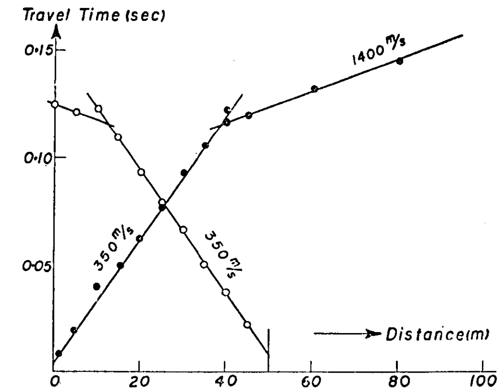

Fig. 2. Travel-time curves at the examination place "A".

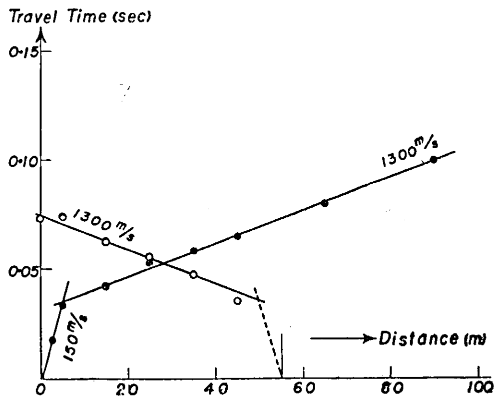

Fig. 3. Travel-time curves at the examination place "B".

1) K. WATANABE, "Geophysical Prospecting", 1937, Appendix A), 10), d).

200 m in length in this case, no data about the third layer are seen.)

Table I.

Examination place	Velocity of P-waves (m/sec)		Thickness of 1st layer (m)
	1st layer	2nd layer	
A	350	1,400	15
B	150	1,300	2

3. The examination of the results obtained from the seismic prospecting.

The farm houses in the district within which the place of prospecting "A" is, were damaged only slightly. On the contrary, the farm houses in the district of place "B" were so heavily damaged that almost all houses had to be rebuilt. Also in the latter district, many horses working in the fields stumbled during the earthquake, while in the former district such things never happened.

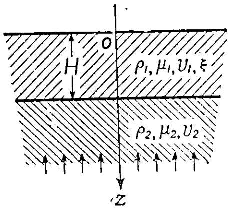

Fig. 4.

These facts show that the earthquake motion was larger in "B" district than in "A" district.

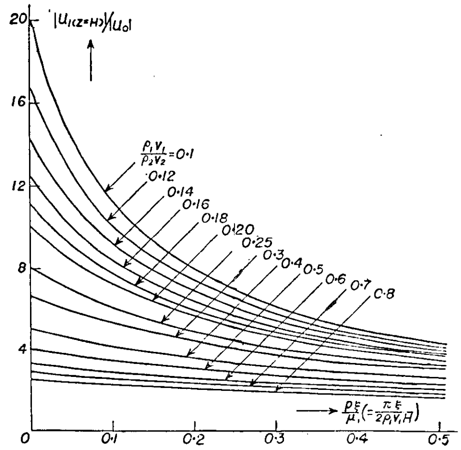

Fig. 5. $u_{1(z=H)}$ and u_0 represent the amplitude of surface motion and of incident wave at lower boundary respectively. ξ, μ_1, ρ_1. v_1, H and p represent viscosity coefficient, rigidity, density, velocity, thickness of surface layer and frequency respectively.

Now the authors will try to explain the above-mentioned facts using the results of seismic prospecting.

Let us assume that seismic waves is the superposition of waves of various period and the largest amplitude at the free surface is caused by the wave of which the period is equal to the synchronized one of the surface layer.

The theoretical investigation[2] in case a semi-infinite elastic body is beneath a surface layer with solid viscosity and S-waves propagate perpendicularly across them gives the result shown in Fig. 5.

2) K. KANAI, "Relation between the Nature of Surface Layer and the Amplitudes of Earthquake Motions", *Bull. Earthq. Res. Inst.*, **30** (1952), 35, Fig. 5.

(To simplify the problem, the solid viscosity in lower layer is neglected, because it is without influence upon the final results.)

As values of ξ/v^3 concerning various materials in the earth crust are always of same order[3], it is supposed, for the present, that $\xi/v^3=10^{-7}$ C.G.S. Poisson's ratio of the materials of the first and the second layers at the observing points, "A" and "B", is assumed to be $\sigma=0.48$[4]. The densities of the materials are assumed to be $\rho_1=1.5$ and $\rho_2=2.0$.

Under such assumptions, introducing the results obtained from the seismic prospecting at "A" and "B" districts into Fig. 5, we get the following results. (The values in the parenthesis are when Poisson's ratio $\sigma=0.25$).

$$\begin{array}{ll} \text{"A" district;} & |u_{1A(z=H)}|/|u_{0A}|=7.6\ (7.3), \\ \text{"B" district;} & |u_{1B(z=H)}|/|u_{0B}|=15.2\ (13.5). \end{array} \qquad (1)$$

(I) Suppose the amplitude in any period of the incident waves which come to the boundary to be constant, that is to say, $|u_{0A}|=|u_{0B}|$ in equation (1), then the ratio between the amplitudes of displacement at the ground surface of "A" and "B" districts becomes

$$|u_{1B(z=H)}|/|u_{1A(z=H)}|=2.0\ (1.8). \qquad (2)$$

In this case the ratio between the amplitudes of acceleration at the ground surface of "A" and "B" districts is

$$|\alpha_{1B(z=H)}|/|\alpha_{1A(z=H)}|=20\ (18). \qquad (3)$$

(II) Assuming that equipartition of energy holds for the waves of various periods in the incident waves, viz. $|u_{0A}|/T_A=|u_{0B}|/T_B$ in equation (1), the ratio between the amplitudes of displacement on the ground surface of "A" and "B" is given as follows:

$$|u_{1B(z=H)}|/|u_{1A(z=H)}|=0.62\ (0.58). \qquad (4)$$

In this case the ratio of the amplitudes of acceleration on the ground surface of "A" and "B" is expressed as

$$|\alpha_{1B(z=H)}|/|\alpha_{1A(z=H)}|=6.2\ (5.8). \qquad (5)$$

(III) Though nothing definite can be said before finding the correct

3) K. KANAI and K. OSADA, "The Result of Observation concerning the Waves Caused in the Ground by Building Vibration", *Bull. Earthq. Res. Inst.*, **29** (1951), 514, Table II.

4) Reference data:

K. MANAI, *Bull. Faculty Eng., Hokkaido Univ.*, **6** (1952), 77, Table 2.

H. KAWASUMI and others, *Monthly Colloquium, Earthq. Res. Inst., Tokyo Univ.*, Sept. 16, 1952.

Bull. Disast. Prevent. Res. Inst., Kyoto Univ., **2** (1949), 6, 17; **3** (1950), 1, 3, 7.

value of Poisson's ratio, the periods of the waves at "A" and "B" which have predominant amplitudes become $4H/v_s=0.9$ sec ($\equiv T_A$) and 0.3 sec ($\equiv T_B$), using the foregoing assumption $\sigma=0.48$ and the values of Table I. The natural period of top-light farm houses which are peculiar to Hokkaido seems to be approximate to the period of predominant amplitude at "B" district, viz. $T_B=0.3$ sec.

In summarizing the calculated results in case of (I), (II) and (III), it is found that in case of a great earthquake the houses in "B" district will be under worse vibrational condition than those in "A" district. Therefore, why the damage differs extremely in two district so close to each other may be explained from the present investigation.

4. Concluding remarks.

In applying the data obtained from the seismic prospecting to the results of vibration problems concerning the surface layer with the consideration of solid viscosity, numerical calculations were carried out. In Tokachi-oki Earthquake of March 4, 1952, there was much difference in the damage at two districts very close to each other. The cause for that is to some extent explained from the results of the present investigation.

In conclusion, we wish to express our thanks to the officials of the Construction Section in the Bureau of Development, Hokkaido, for the financial aid granted us for the present investigations. We also wish to express our thanks to Assistant Professor Y. Sakai and other staffs of the Faculty of Engineering, Hokkaido University, Assistant Professor T. Shiga of the Faculty of Engineering, Tohoku University and the staffs of the Town office of Tokachi-Ikeda, Hokkaido, who cooperated heartily with us in our experiments.

5. 震害と地盤の性質との関係（泥炭地にある木造家屋の場合）

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1952年3月4日の十勝沖地震の震害地である十勝平野の泥炭地で弾性波試験を行い，その結果を使って地震時の地盤の振動的性質を研究した。

即ち，弾性波試験の場所は震害程度に大きな差違のある2ケ所をえらんだ。次に，固体粘性を入れた表面層の振動問題の解に，弾性波試験で得た数値を代入して計算を行った。

その結果として，震害の大きかった地域は，地震動の変位振幅，加速度振幅のいづれについても，震害の少かった地域よりも大きいことになり，震害程度の差違の一つの説明になる。

又，大震害のあった土地の卓越周期は約 0.3 sec，小震害の土地のそれは 0.9 sec 位となり，この地方の農家の固有周期は 0.3 sec 前後と考えられるから，この意味でも，震害程度に差違が生じ得ることになる。