A Study on the Analysis of Land Slide in the Kashio District

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Synopsis

A land slide occurred at Kashio Town near Nigawa Railway Station on the Imazu line of the Hankyu Electric Railway Co. on July 13th, 1951. During this landslide the foundation rose. The inclined surface which had kept balance during the last ten and over years slid, though little change was noted in the external condition. The authors investigated the cause of the land slide from the physico-chemical standpoint.

1. Local condition at Kashio

The location of the landslide is shown in Fig. 1, the photographical features in Fig. 2 and the nature of soils in Fig. 3. As is clear from Fig. 2, the land slide occurred at the saddle, a position where water springs even at the ground surface. The section after the slide and the natural features made clear by boring are represented in Fig. 4 (A), (B).

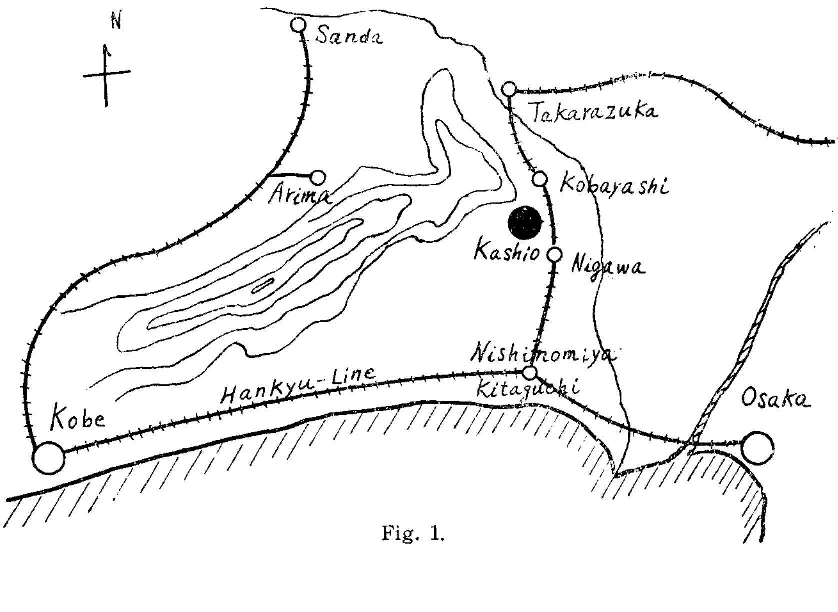

Fig. 1.

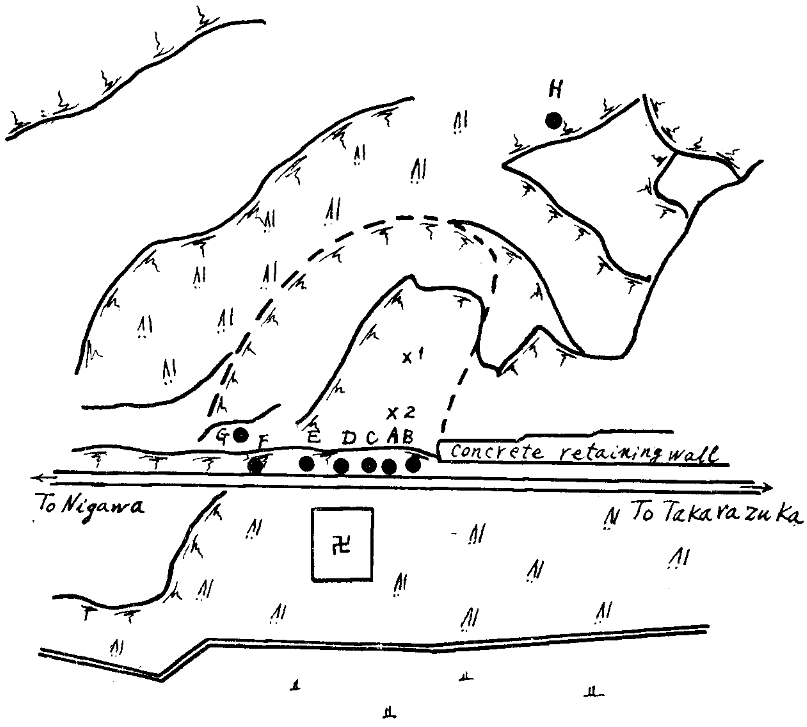
H
G
F
E
D
C
A
B
x 1
x 2
Concrete retaining wall
To Nigawa
To Takarazuka

Fig. 2.

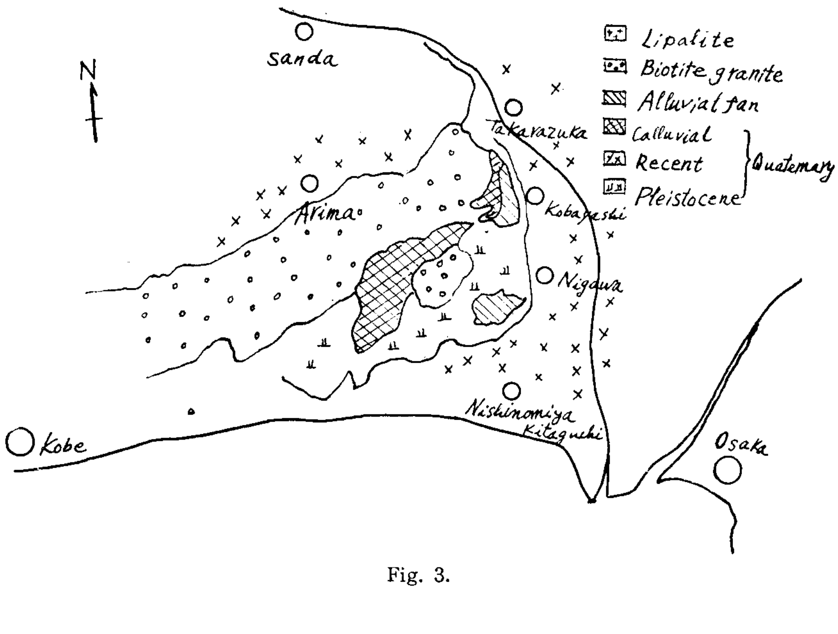
N
Sanda
Arima
Takarazuka
Kobayashi
Nigawa
Nishinomiya Kitaguchi
Kobe
Osaka
Lipalite
Biotite granite
Alluvial fan
Calluvial
Recent
Pleistocene
Quaternary

Fig. 3.

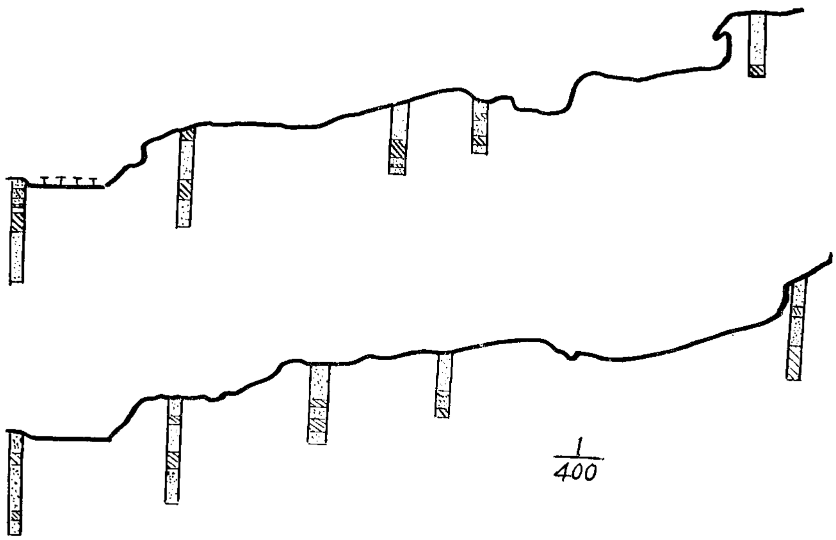

Fig. 4 (A).

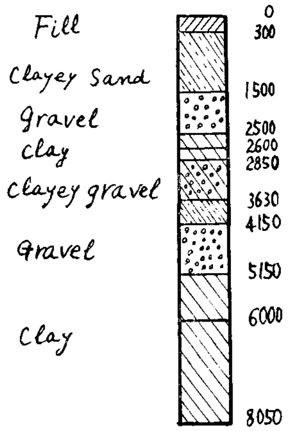

Fig. 4 (B).

2. Chemical analysis

The soil and the rain water of the Kashio district were chemically analysed. The places where underground water and soil samples were taken are marked A, B, ··· and 1, 2, ··· respectively. The underground water from A, B, ··· and F were collected into glass bottles from drainage holes, and the soils were taken out with a soil auger.

The underground water samples were analysed quantitatively by spectral analysis and poralography, then quantitatively for all the existing cations and anions. The soil samples were leached with 1N–NH_4Cl solutions and 1N–NaCl for 24 hrs., and then filtered. The filtrates were analysed quantitatively for the cations and anions. The exchange capacity was determined by the ordinary 1N–ammonium acetate method.

The results of the chemical analysis are shown in Table 1 and Table 2. From the results of the analysis, it was found that there was no appreciable difference between the underground water and rain water. However the Ca content alone of the underground water was much larger than that of the rain water itself.

The calcium leached out from the content with the underground water.

Table 1.

Samples	Unit	A	B	C	D	E	F	G	H
atom. temp.	°C	32.5	31.0	31.8		32.2	32.2		27.5
water temp.	°C	22.2	26.5	22.1		23.5	20.8	19.0	25.0
pH		5.6	5.8	5.8	6.3	5.9	5.8	5.8	5.4
alkality	m.e./l	8.2				30.24	16.80	7.92	6.20
HCO_3' free	m.e./l	8.2				30.2	16.8	7.9	6.2
carbonate	p.p.m.	2.4				1.8	22.1	11.00	12.8
acidity	m.e./l	2.8				2.1	25.1	12.5	14.5
dissolved O_2	p.p.m.	0.9				0.8	0.7	1.1	0.8
Cl′	mg/l	1.4				2.2	2.4	3.5	1.6
PO_4'	mg/l	36.6				26.3	23.8	29.5	31.0
SiO_3''	mg/l	36.7				29.0	31.3	27.5	38.9
$Ca^{\cdot\cdot}$	mg/l	70.8				103.1	64.7	62.9	65.0
$Mg^{\cdot\cdot}$	mg/l	11.7				13.3	16.9	19.4	18.1
colour		slight muddy	colourless			slight muddy	light yellow		
velocity of flow	c.c./sec.	23.3	2.7	3.3		1.3	50.0		

Table 2.

Sample	Unit	Ion exchange capacity	$H^{\cdot}$	$Na^{\cdot}$	$K^{\cdot}$	$Ca^{\cdot\cdot}$	$Mg^{\cdot\cdot}$	$Fe^{\cdot\cdot}$	$Al^{\cdot\cdot\cdot}$	$Mn^{\cdot\cdot}$	$NH_4^{\cdot}$
rain water	m.e./l			0.07	0.16	0.07	0.01	0.0005	0.02	—	0.0002
ground water	m.e./l			0.07	0.18	1.13	0.02	0.00008	0.02	trace	0.003
blue clay leachate	m.e./100g	21.0	1.0	0.82	0.65	14.42	4.03	0.0027	0.01	0.045	0.238
red clay leachate	m.e./100g	12.5	2.8	1.12	0.10	8.37	0.13	0.0077	0.03	0.05	—

3. Shear-test

It is acknowledged that the shearing strength of a given soil sample changes variously according to the quantity and the quality of the absorbed cations. The order of the strengh of soil, exchanged by H-ion at first and by others secondarily, is given as NH_4, H, K, Fe, Al, Mg, Ba, Ca, Na and Li, as the result of Sullivan's experiment.[1] The author also recognized that the position in the plasticity-chart moves almost parallel to A-line by the ion-exchange.[2] From this fact, and the fact that the quantity of exchanged Ca in Kashio-soils is very large, but is merely three-fourths of the quantity of the saturation, there will be a great difference in the shearing strength and other characteristic between Ca-soils that exist and saturated Ca-soils that are presumed to have existed. Concerning stability, it is considered that there is great difference in the safety factor. Taking these points into consideration, the authors compared natural-soils with saturated Ca-soils by the shear-test, as the shearing strength of soils differs with the moisture-content. In this case, various proportions of water were added to sample of Kashio air-dried soils and were left to stand for 24 hrs, after which the shear-test was made. To determine the value of the moisture-content, the four values were measured after the shear-test and the average takes. The particle-size distribution curves of the soils are represented in Fig. 5, and the results obtained by the shear-test are represented in Fig. 6 and Fig. 7.

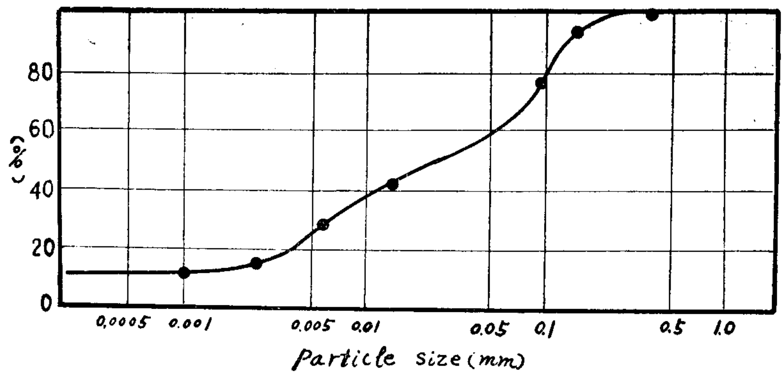

Fig. 5.

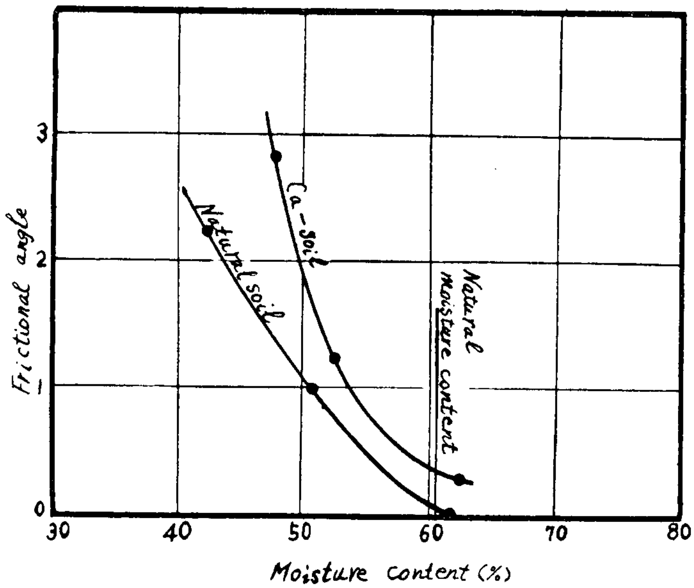

Fig. 6.

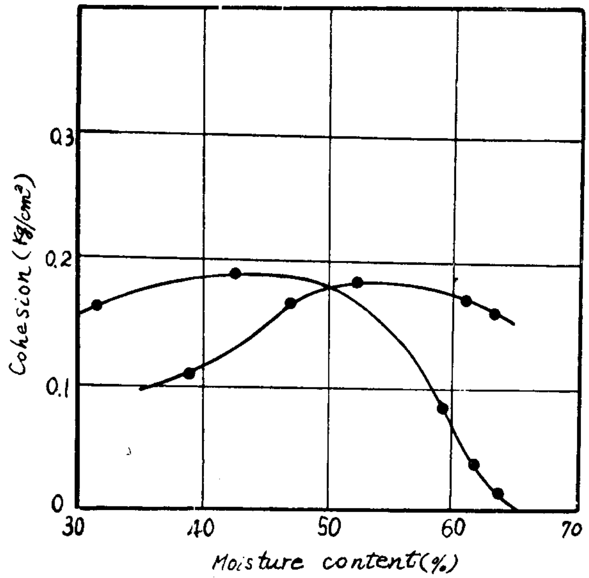

Fig. 7.

Judging from the above results, when the moisture content is normal, the frictional angle is 0.45° and 0.06°, and cohesion 0.163 kg/cm², and 0.08 kg/cm² for the Ca-soils and the normal soils respectively.

4. Stability analysis

Fig. 8 indicates a longitudinal section of the terrain. In Fig. 8 the oblique line is nearly a straight line before the slide, and so if it is assumed as a straight line,

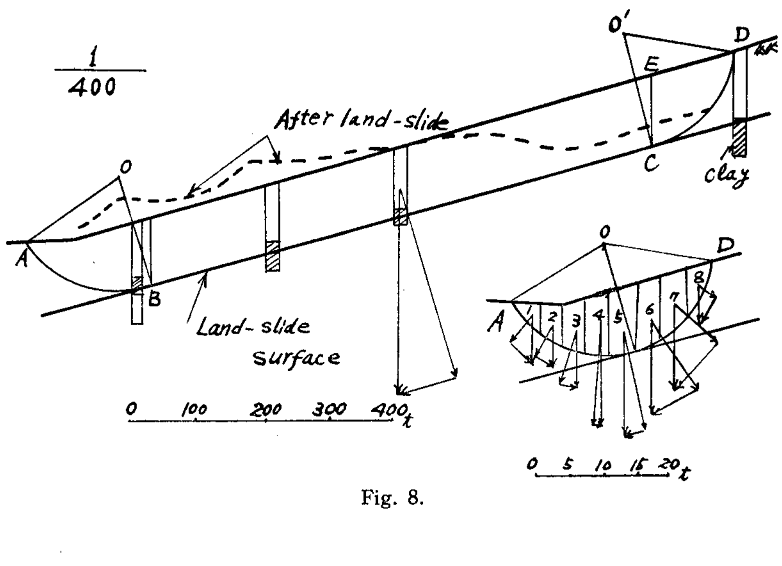

Fig. 8.

the plane of the upper border of the clay layer, considered the sliding surface, is nearly parallel to the surface of the earth.

It is considered that the sliding surface of the upper and lower end of this straight line is round. The results of the stability computation of the straight and round sliding surface is shown in Table 3 and Fig. 8.

Table 3.

Sample	Unit	Cl′	SO_4''	PO_4''	SiO_3''	Acidity	Alkality	Free carbonate
rain water	mg/*l*	3.04	0.019	—	—	0.0498 m.e./*l*	—	0.0398
underground water	mg/*l*	1.14	0.044	0.080	40.54	2.77 m.e./*l*	0.247 m.e./*l*	2.44

The factor of safety computed by the angle of friction and the cohesion from Table 4 is shown in Table 5; namely the factor of safety of Ca-soil is 1.3, while that of the natural soil is 0.6. Therefore, in soil which is saturated with Ca and is statically stable, the adhered Ca is substituted by other cations and by this it is considered that the strength of the soil is changed and the land sliding is brought about.

Table 4.

Parts	1	2	3	4	5	6	7	8	Sum	□FBCE
$A(m^2)$	3.7	4.0	5.9	9.1	10.1	9.9	8.7	5.1	56.5	193.0
$g(t/m^3)$	1.65	〃	〃	〃	〃	〃	〃	〃	〃	〃
$W(t)$	6.1	6.6	9.7	15.0	16.7	16.3	14.4	8.4	93.2	318.5
$T(t)$	−4.6	−3.9	−3.4	−1.5	3.6	8.3	10.6	6.9	16.0	75.2
$N(t)$	4.3	5.4	9.0	15.0	16.3	13.1	9.2	2.8	75.1	308.1
$L(m)$									20.4	37.4
$\varphi(°)$									139	

Table 5.

	θ	$\tan\theta$	$c(t/m^2)$	M_s	M_r	D_s	D_r	S	Natural water content
Ca-clay	0.45	0.0079	1.63	134.4	306	75.2	63.2	1.3	—
natural soil	0.06	0.0018	0.68	134.4	127	75.2	26.0	0.6	60.21%

5. The counter-measure

From the above investigation and research, the measures to be taken hereafter against this land slide are considered as follows:

1) The necessary step to prevent future land slide is to maintain the terrain in its present state. To make a big change in the local topography, especially to bank the upper part of the surface of the slope or add other loads, would very likely cause a new land slide.

2) For the period that the present state can be maintained the practice of chemical analysis and the test of soil properties, are useful in predicting the occurrence of land sliding.

3) A positive measure for maintaining the stability of the slope is to dig holes near the upper border of the slope and supplement Ca-ion.

Bibliography

1) Sullivan, J. D., Physico-chemical Control of Properties of Clays, Trans. Electrochem. Soc., 1939.

2) Matsuo, S., Characteristics of Consistency of Soil Shown in Plasticity Chart, Proc. First Japan National Congress for Applied Mechanics, 1951.