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A Geophysical Study of Landslides
(Mechanism of Landslides)

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Abstract

In general, the form of soil mass movement is divided into four types, namely 1 slide of fluid type, 2 layer slide type, 3 protruding slide type of an intermediate layer and 4 multi-slide type. In order to investigate the mechanism of soil mass movement, the author and etal have analyzed underground soil mass movement by using the internal strain meters. When the author compared the relationship between the actual deformation of the vinyl pipe and the accumulated strain curve obtained from an internal strain meter in a laboratory test, he got what very much agreed with each other.

According to the results from the analyses of the internal strain meter, in the case of rather large landslide areas, there are two slide layers which are different in the direction and velocity of soil mass movement respectively. So it is clear that we can not analyze the stability of the landslide slope by information about the depth of a slide surface obtained only by boring and other physical prospecting in Tertiary type landslide areas.

I. Introduction

It is a matter of prime importance to elucidate the mechnism of landslides in order to prevent and predict possible future landslide movements. For this purpose two different approaches are now being applied ; one is to study the stability and the intensity of the soil mass from the soil mechanic aspect and the other is to make a phenomenal study by making a variety of surveys or researches from the geophysiacl aspect. The former is an attempt to calculate the stability of the landslide movement in terms of the balance of static force, [1) 2)] but it is extremely difficult to measure with precision the cohesion force (C) of the soil mass and the internal friction angle (φ) which should provide the foundation for this analysis. One reason is because it is practically impossible to obtain any undisturbed clay in the vicinity of a slide surface. For this reason a mathematical method to determine such a cohesion force and the internal friction angle [3)] is now being improved [4)] without trying to examine them on the basis of an actual survey. It is also a common practice that a circlic slide is presumed to determine the landslide stability when the cohesion force and internal friction angle are once obtained. However, it must be noted that this procedure is not always applicable fo actual landslides, because it is known that landslides do not always take place in a circlic form in many cases when slide layers are examined by the geophysical method.

The present writer conducted many surveys not merely to identify the location of the slide surface in a actual lanslide area using the internal strain meter designed by Yamaguchi and Tsumoto, but also to carry out research in regard to the slide movements of the soil mass as well as the spreading of such movements.

2. Measurement by internal strain meter

To determine a slide surface or the type of the soil mass movements in a landslide area there are several methods such as (1) geological survey by boring, (2) internal inclinometer and (3) slide surface measuring tube, all of which are being used in numerous measuring surveys. When a slide surface is to be determined by the boring mtehod, whether a clay layer exists or not has played a decisive role so far, but the slide surface does not always appear on top the clay layer[5], and it is also impossible to identify the slide surface by N-values only. Consequently it is utterly impossible to grasp the slide surface precisely merely on the besis of a geological cross-section view and N-values.

The internal inclinometer is to be installed in a bore hole so that the slide layer can be identified from the slant of the casing of a pipe or the movement of the underground soil mass. However, what can be detected is only concerned wih the slide layer. As an improved type of this instrument we have another instrument so designed as to be inserted.[6] The way to use this instrument is to drop tube, of which the diameter is slightly smaller than the inside diameter of the pipe, through this pipe from the gronud surface so that the upper portion of the boundary can be measured. The boundary between the bed rock and the slide surface is to be measured in such way that this tube with a continuous string connected to it is previously placed at the deepest bottom of the bore hole so that the deformed point of the pipe can be measured by the length of this string when this tube is pulled up as far as it can go.

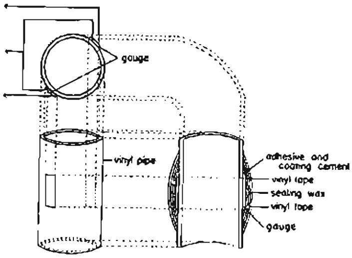

Fig. 1 The diagram of the internal strain meter

However, it can only measure the upper part of the slide layer in some cases, depending on the way the pipe is deformed and knowing moreover there is no way of knowing about further deformation after it is once deofrmed. Therefore, it won't serve the purpose in the case of multi-sliding layers or of the protruding slide of an intermediate layer.[7]

Now, it is the internal strain meter that is so designed to improve these weak points. This measuring instrument comprises a pipe made of vinyl chloride and on two sides of it strain gauges are placed at proper intervals, which is known as the '2-gauge method', by which any curvature of the deformed pipe is to converted into a strain value (Figure 1). In this case, needless to say, it is presumed that the pipe will be deformed in line with the soil mass movement. The particular type of internal strain meter which we are actually using these days is made in such a way that, "paper gauges", (gauging efficiency ≒ 2.0), being water-and damp-proof coated, are attached to a vinyl pipe at every 1 or 2 meter intervals.

3. Relation between an accumulated strainvalue and the deformation of a pipe

It is neccessary to measure the quantitative vlaues of the deformation of the pipe at each point without interruption so that we can know the state of the deformed pipe. Yet it is impossible to do so when we use the prevailing fixed gauge method. Therefore, in order to roughly find the deformed state of the pipe in which the internal strain meters are attached, the values of all strain gauges at each depth which are to be read when buried initially into a bore hole are put aside as 'standdard values' and the difference between each of these standard values and each of the measured values is to be added together in a regular succession starting from the value obtained by the deepest gauge, and each of the added values is to be put down on a sheet of graph paper, which is called the 'accumulated strain curve'. Whether such an accumulated strain curve obtained in the way described above can represent the state of the deformed pipe adequately or not is yet subject to re-examination. Hence, for that reason the present writer atsempted to find the relationships between the state of the defomed pipe and the accumulated strain curve by using a 'Pipe Deformation Measuring Device'[8] designed by writer and his colleagues.

With respect to the possible deformation of the pipe it is necessary to have a clear knowledge beforehand of the actual state of the soil mass movement. Now, the state of the underground soil mass movement that may possibly take place may be classified into the following four types :

Type A-The slide called 'fluid type' ; such a manner of the movement in which the rate of the slide movement of the soil mass is fasttest at the ground surface and yet no movement is made in the vicinity of the bed rock.

Type B-The slide called 'layer slide' ; the commonest type of the slide movement of the soil mass.

Type C-The silde called 'protrusion of an intermediate layer' ; such a manner of the slide movement in which only the soil mass of one layer between the ground surface and the bed rock begins to move, which may be considered as the cause of a depression or sinking zone within a landslide area.

Type D-The slide called 'multi-slide layers' ; such a manner of movements in which two or more different layers make respective slide movements at different times at different times at different rates of movement.

The internal strain meter was buried so as to be deformed in conformity with these four classified types of slide, and the results from the strain gauges were experimentally compared with the accumulated strain curve. Figures 2~6 show results of experiments for all four types of slides. The vinyl pipe used for this experiment was 2 meteres long, of which the outer diameter was 18㎜ and the inner diameter 12㎜. The extent of any strain was measured in such a way that it could be represented as 'positive' when the deformation was made in a convex shape in the direction of displacement of the pipe and as 'negative' when the deformation was made in a concave shape under the condition that the relationships between the actual deformation of the pipe and the experimental strain could remain exactly the same.

When the accumulated strain curve was further looked into, it came to be noticedthat some strain was registered by the strain gauge which had been fixed in the place regarded as a stationary point.

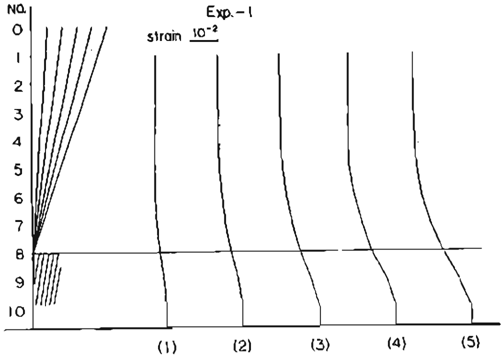

Fig. 2 Mud flow type slide ; figures in brackets show accumulated strain values estimated from the variation of electrical resistance of strain gages.

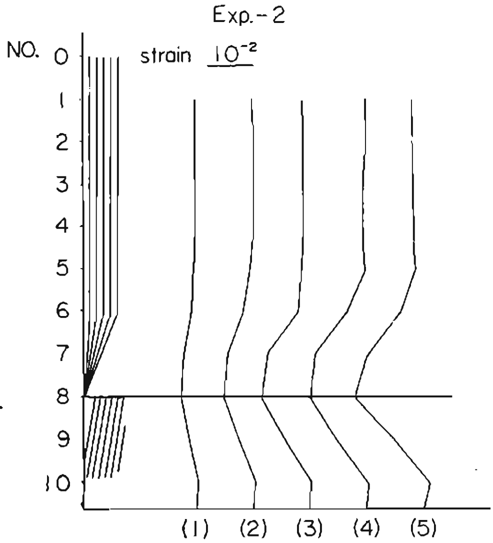

Fig. 3 Layes slide type; figures in brackets show accumulated strain values estimated from the variation of electric resistance of gages.

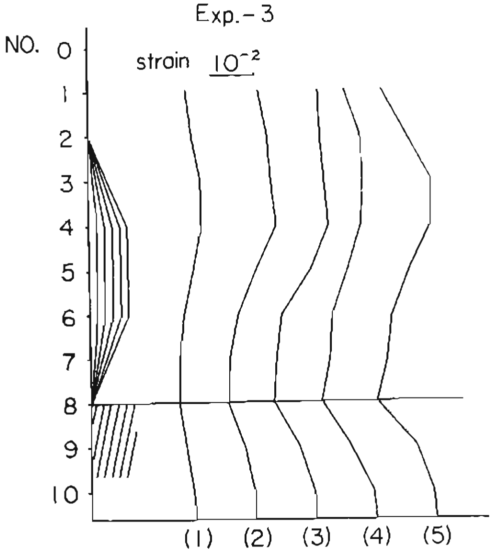

Fig. 4 Protruding of intermediate layer type; figures in brackets show accumulated strain values estimated from the variation of electric resistance of gages.

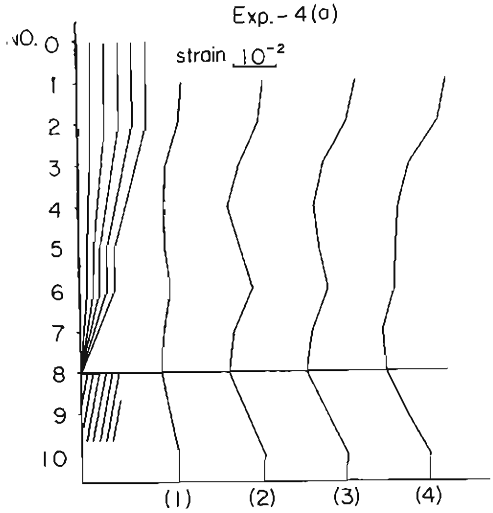

Fig. 5 Multi-sliding layer type ; figure in brackets show accumulated strain values estimated from the variation of electric resistance of gages.

This made us imagine that the strain gauge buried in the stationary layer in the actual landslide area might register some changes too. When the boundary beween the stationary point and movable point of the accumulated strain curve obtained by the experiment was checked, it came to notice that this boundary represented an infliction point of the accumulated strain curve (Figure 5). Therefore, it led us to the conclusion, judging from the accumulated strain curves obtained from the actual landslide area, that the extent of the strain near the boundary between the bed rock and the slide layer should be increased in the 'negative' direction starting from the deepest measuring point, or that the boundary between the bed rock and the slide layer should be located somewhere near the infliction point of the curve indicating a constant value.

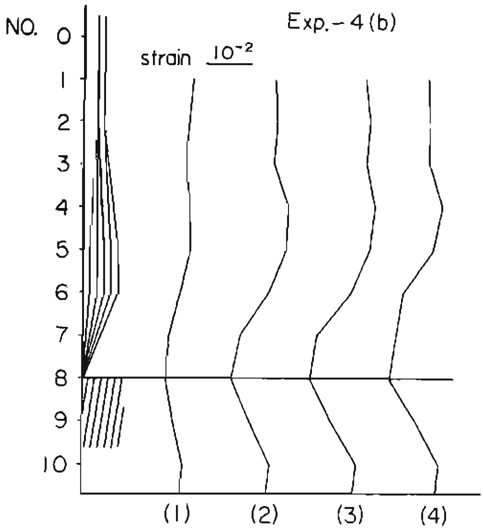

Fig. 6 Multi-sliding layer type ; figures in brackets show accumulated strain values estimated from the variation of electric resistance of gages

When the extent of displacement of the pipe is to be compared with the accumulated strain curve, granting that the displacement of the pipe does not take place in the opposite direction to the slide movement, the curve in proportion to the displacement of the pipe can be obtaind by drawing a symmetrical curve on axis Y when the accumulated strain curve is found to be of 'negative' value. From this point of view all slide movements of the soil mass may be classified into the following four types ;

Type A represents one of the simplest slides, which can easily be identified from the accumulated strain curve.

Type B speaking from the concept of the accumulated strain curve, is the curve which is likely to be taken for Type C. However, if the interpretation of the boundary of a stationary layer is applied, the extent of strains at gauges No. 8, 9 and 10 of Figure 6 can be excluded, and what is left to be done is only to examine the accu-

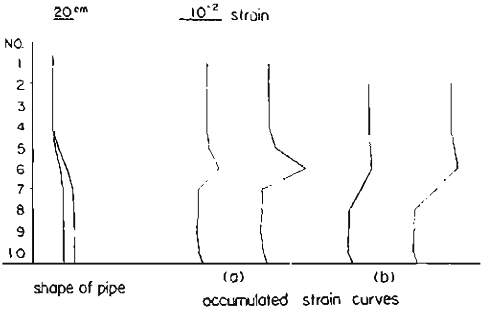

Fig. 7 The relation between pipe displacement and accumulated strain curves estimated from the variation of electric resistance of gages

mulated strain curves which are represented above the lateral line indicated on the accumulated strain curve of Figure 3. For this reason the accumulated strain curve can appear in a very clear line and this curve comes to stand in a fair proportion to the extent of the deformation of the pipe.

Next we will proceed to see the relationships between the displacement of the pipe and its accumulated strain curves, based on the assumption of a layer slide (Figure 7). This is an experiment on the assumption that the lower layer gives rise to the slide movement. As a result a triangular protrusion can be seen in the accumulated strain curve (Figure 7 (a)). When the accumulated strain curve is drawn only for the strains at Nos. 10, 8, 6, 4, and 2 by allowing a greater span for each measuring gauge, it looks as if part of the pipe represented by gauges Nos. 6~2 were deformed. The curve of this shape is of frequent occurrence in the results surveyed in an actual landslide area.

Thpe C for the purpose of easier understand of the relationships between the accumulated strain curve and the displacement of the pipe, the deformation of the pipe is shown symmetrically to left and right, but gauges Nos. 1~5 and Nos. 6~10 are not symmetrical with the accumulated strain curve (Figure 8). This suggests that it is difficult to detect the protruding phenomena of an intermediate layer from the accumulated strain curve. However, when the forementioned layer has great thickness, the case has already been made clear by the writer and his colleagues[5].

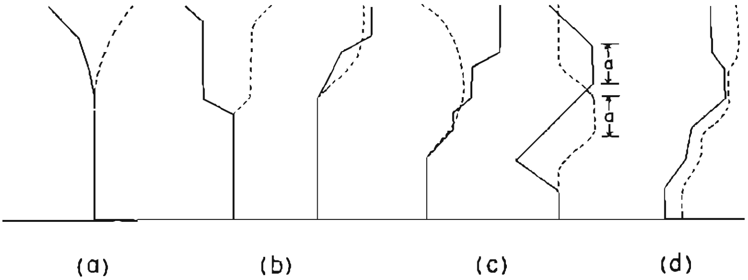

Fig. 8 Typical types of pipe deformation and those accumulated strain curves estimated from the variation of electric resistance of gages : (a), (b), (c) and (d) correspond to four slide types mentioned previously

Type D involves a presupposition of rather complex slides, i.e., a case of both upper and lower layers making sliding movements and moreover the volume of the displaced soil mass of the upper layer is greater in quantity than that of the lower layer. As far as the accumulated strain curve is concerned, it looks, as seen in Figure 5 and 6, as if the rate of movement of an intruding intermediate layer were greater. The relationshios between the typical accumulated strain curves and the deformations of a pipe in conformity with the four classified types of slides are shown in Fig. 8.

4. Mechanism of Movement

Since we have been able to obtain a fundamental pattern of the accumulated strain curves in conformity with the four hypothetical types through various experiments, it will in turn become possible for us, judging from the accumulated strain curves, to determine the exact state of the soil mass movement in any landslide area. Figures 9～16 represent typical patterns of the accumulated strain curves selected out of all surveys conducted in many actual landslide areas. The state of the deformed pipe is represented by line B. The slide of fluid-type A is substantially different from the layer slide of type B, but as far as the accumulated strain curve is concerned, the extent of strains is represented in the same manner at the zero section. Consequently, it follows that the distinction between type A and type B should be determined on the basis of data obtained both from the boring exploration and from the pipe drive-in test. If the depth from the surface ground is not more than 5 meters, the area should have the possibility of a slide of fluid type, but when deeper, a stronger possibility of a layer slide.

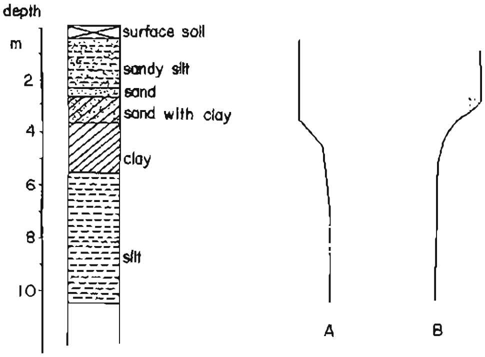

Fig. 9 The comparison of real pipe deformation (A), the one estimated from the variation of electric resistance of gages (B) and geological section ; B type

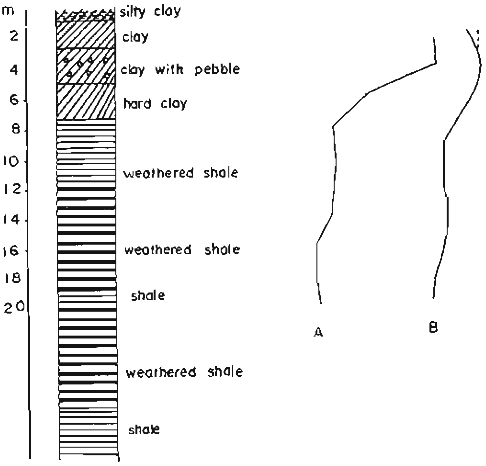

Fig. 10 The comparison of real pipe deformation (A), the one estimated from the variation of electric resistance of gages (B) and geological section ; A and B types

On the other hand type C represents the case where the pipe as a whole is deformed in a convex shape in the direction of the slide movement, it can be drawn distinguishably in the typical pattern of the accumulated strain curve (Figures 13 and 14). However, in a case where the layer having a certain thickness happens toslidee, it is rather hard to distinguish such a slide from type D, i.e., multi-slide layers. Yet in the case of an accumulated strain 'curve' as shown in Figures 15 and 16, while it is possible on the one hand to assume that the deformation of the pipe is identical with the accumulated strain curve, it is also possible on the other to assume that only one of the 'positive' or 'negative' distortions is permitted to be registered by the gauges because of the long spaces between the gauges the measuring the pipe deformation. Consequently it is rather hard to distinguish the protruding slide of an intermediate layer from multi-slide layers. Whenever the internal strain meters need to be buried, since it is, generally speaking, customary for a geological survey by

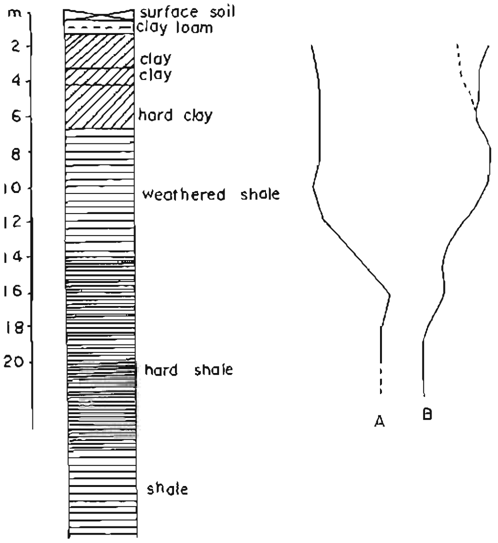

Fig. 11 The comparison of real pipe deformation (A), the one estimated from the variation of electric resistance of gages (B) and geological section ; A type

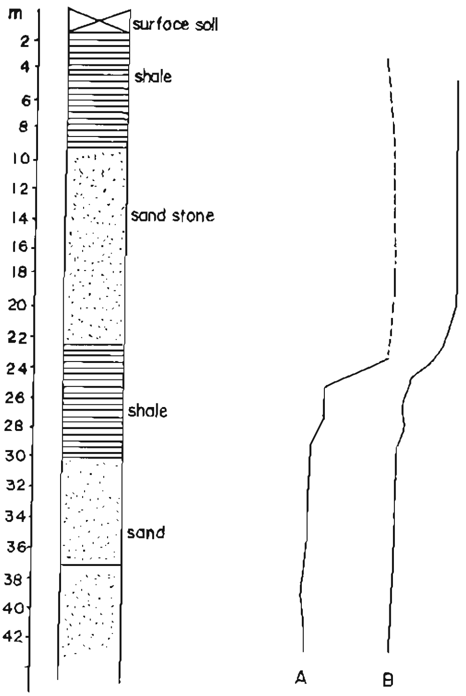

Fig. 12 The comparison of real pipe deformation (A), the one estimated from the variation of electric resistance of gages (B) and geological section ; B type

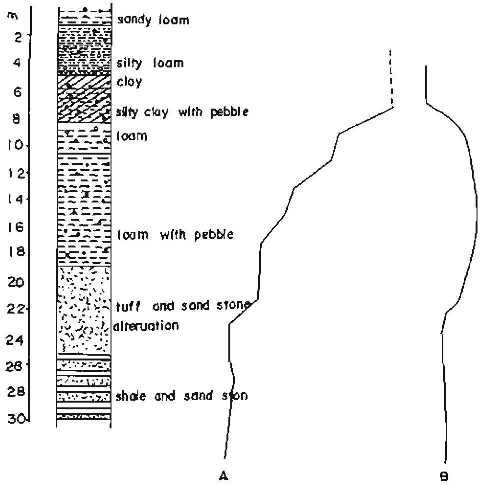

Fig. 13 The comparison of real pipe deformation (A), the one estimated from the variation of electric resistance of gages (B) and geological section ; C type

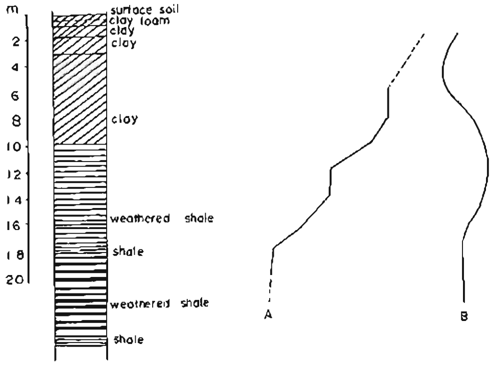

Fig. 14 The comparison of real pipe deformation (A), the one estimated from the variation of electric resistance of gages (B) and geological section ; C type

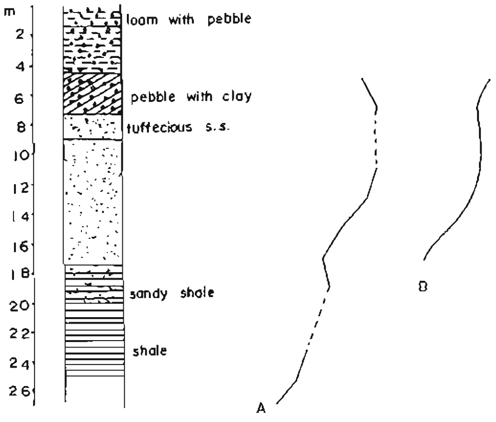

Fig. 15 The comparison of real pipe deformation (A), the one estimated from the variation of electric resistance of gages (B) and geological section; C or D type

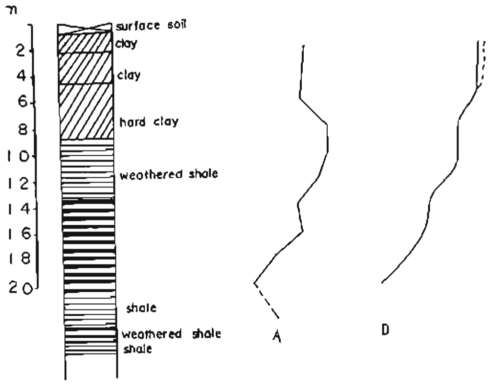

Fig. 16 The comparison of real pipe deformation (A), the one estimated from the variation of electric resistance of gages (B) and geological section; C or D type

the borring method to be undertaken in such an area, all these data must be made available for the determination of type B or D. Needless to say, a better way is of course to design a device that can measure strains with much closer intervals, which is now in the making.

Whenever any surveyor attempts to examine or determine the type of any landslide movement from the accumulated strain curve obtained in a landslide area, the surveys using the internal strain meters must be carried out at four

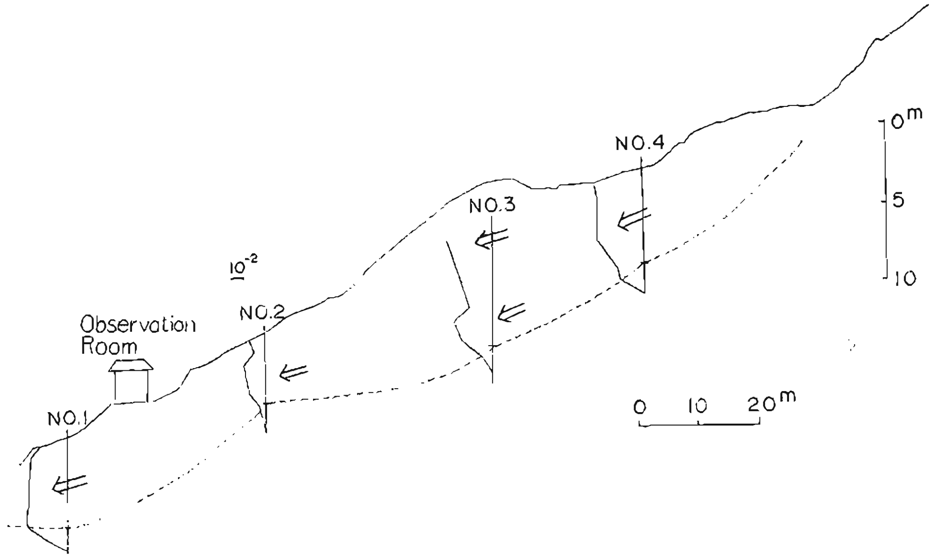

Fig. 17 The profile of landslide estimated from pipe deformations, the Tsukiike landslide area

or five different places at least on one selected vertical section of the landslide topography. Figure 17 is one of these examples. Now, when the soil mass movement was examined on the basis of the relationships between the deformation of the pipe and the extent of strain, the deformation of the pipe as shown in the Figure could be assumed. It was revealed that this area had a prominent compression from above.[9] Accodingly, one soil mass movement in the pattern of a layer slide at No. 4 was observed to be split into two separate slide movents at No. 3, i. e., one upper layer movement causing an upthrust in the vicinity of No. 2 and the lower layer causing movement. At No. 2 the movement of an intermediate layer apeapred to be prominent, and at the terminating part of landslide No. 1 the pattern of the layer slide was restored again. Because no upthrusting phenomenon at the terminating end of this landslide area was observed, though some pushing-out was observed, the final conclusion was that it was after all a layer slide.

Now, turning to another landslide area, the present writer attempted to take up the longitudinal landslide mechanism. When his survey was conducted in this connection in 1963, he could obtain accumulated strain curves on the grounds of which he thought it highly justifiable to think that there must have been two circlic slides between No. 1 and No. 4 as shown in Figure 18. Now, what should be particularly noted in this connection was the fact that two separa te slide layers were detected while measuring farther down to the depth of 30 meters ; in fact one of the two was the slide of a rather shallow layer of about 10 meters in depth and the other a deeper slide of about 20 meters in depth. Later in the course of one year's lapse when re-examining the analysed results of 1964 (Fingure 19), he found that the shallow slide movement was very vaguely represented on account of the disconnected electric line for the shallow strain gauges, but that the deeper slide which had shown up at the time of the 1963 survey turned out to be measured in a clearer way, and as a result it definitely became clear to him that it was unreasonable for him to assume that the bed rock was as deep as 30 meters.

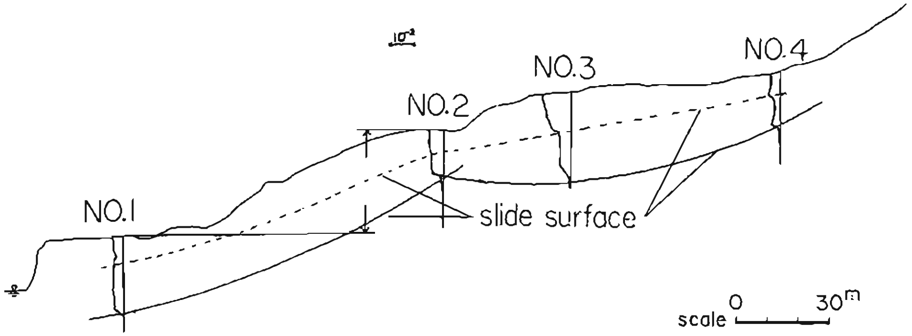

Fig. 18 The profile of landslide estimated from pipe deformation in the Kamenose landslide area after rainy season in 1965

The slide movement of the upper layer was prominent in 1963, and no deeper slide movement was ever measured in the earlier stage of his survey. But as time passed on, the silde movement of the deeper layer began to be

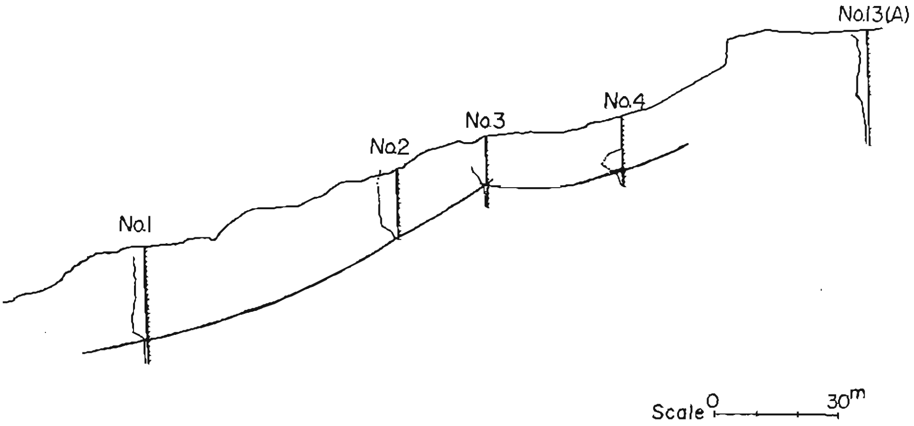

Fig. 19 The profile of landslide estimated from pipe deformations, in the Kamenose landslide area before the rainy season in 1965

represented in a gradually increasing tendency until the type of the layer slide orginating in a deeper layer came to be observed as shown shown in Figure 16. Consequently, in 1965 a 50 meter boring survey was additionally conducted so that the deeper slide movement could be confirmed by the internal strain meters. As a result (as shown in Figure 20) a slide surface at a deeper level than the one measured in 1964 was confirmed as shown in Figure 20. Generally speaking, when the slide surface is being investigated, in many cases one slide layer is taken into supposition in a slide area, but it is not so rare for two slide layers to be observed as pointed out in the case of this landslide area. Therefore, when the surveyor's attention is concentrated on the shallower slide only, the movement due to deeper layer is likely to be undetected.

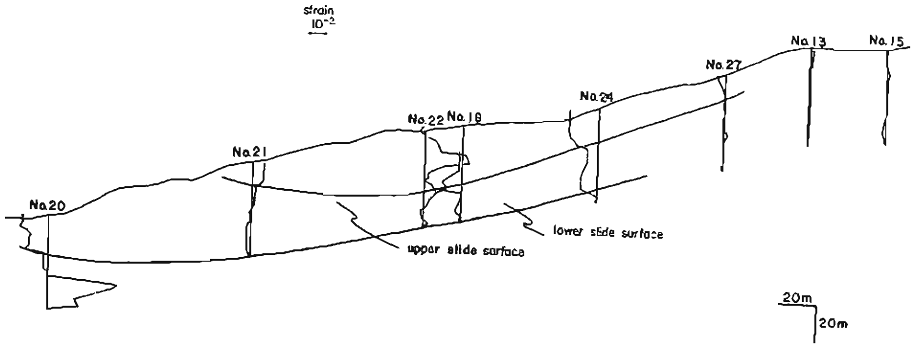

Fig. 20 The profile of landslide estimated from pipe deformations in the Kamenose landslide area in 1966

In this landslide area on February 1967 some cracks broke out and as the days went by, a strong slide movement was activated, developing into a large scale landslide, covering a total area of about 50 ha.. Just as soon as this slide began to take place, the deep layer slide cut off the electric lead-wire of the internal strain meters, making it impossible to keep on measuring.

5. Diunal variation of internal strain

By using the internal strain meters we can know the depth of a slide layer and the underground soil mass movement in such a manner as described in **4**. At the same time we can also obtain some information with respect to the underground soil mass movement from the changes in the extent of strain at each measuring point arranged at a different pre-determined level. The diurnal variations of the extent of strains at each depth are produced by the physical force directed against the pipe as a result of the actual soil mass movement. The strain gauge is so designed as to negate any noise created by heat by means of a thermal compensator. However, it was found that

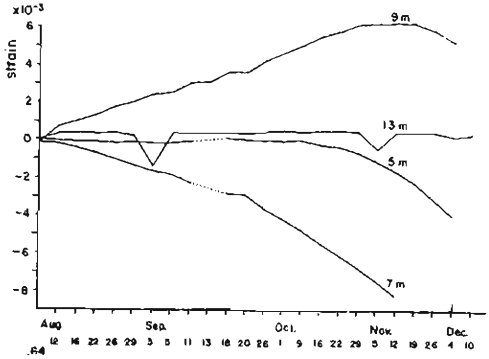

Fig. 21 Strain accumulation graphs at each depth of the internal strain meter

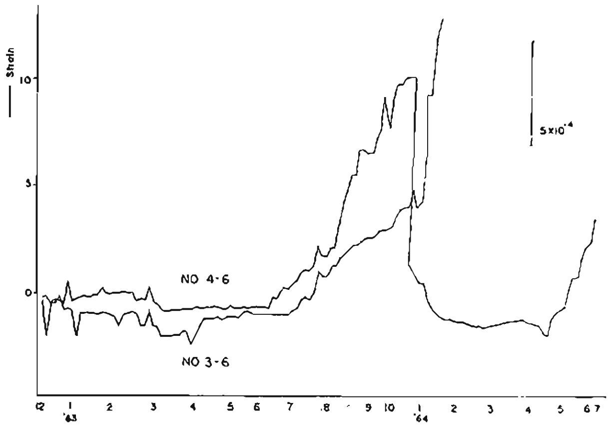

Fig. 22 The comparison of strain accumulation graphs at different locations ; No. 4 is located at a place above No. 3 on the same slope

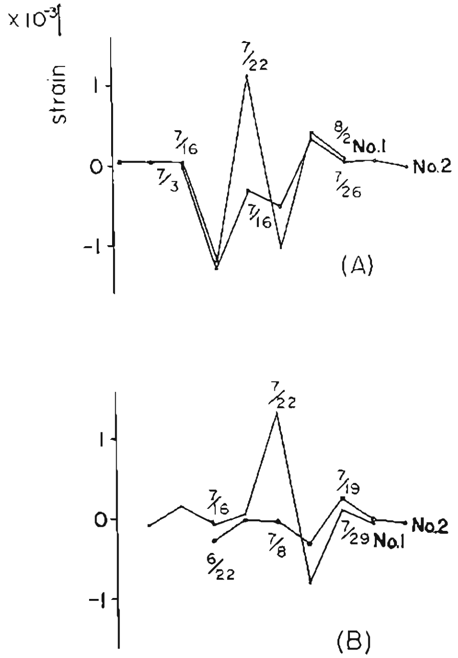

Fig. 23 Strain propagation graphs at different layers dobtaine by the internal strain meter ; A shows the comparison at the shallower layer, B shows the comparison at the deeper layer

some noise of less than 10^{-4} was produced while actually being put into operation.[10] Consequently, any distortion smaller than 10^{-4} is to be simply negated as a noise. According to the result obtained by Tsumoto who made an uninterrupted observation with respect to the extent of strains on a level ground which was not located in a landslide area, he asserted that any strain smaller than 5×10^{-4} including noise due to heat and other noises should be regarded as noise and further made the proposition that any strain which is larger than 10^{-3} and which is exhaled from the diurnal variation chart should be regarded as a strain produced by the soil mass movement.[11] Figure 21 is one of these examples, which shows clearly that the soil mass movement was giving strains at depths of 5, 7 and 9 meters respectively.

Figure 22 is the diurnal variation chart obtained from the Tsukiike landslide area, which shows how the slide movement had spread from point No. 4 to No. 3 in the course of about half a month. In addition we can find the rate of spreading of a slide movement by adopting such a method as to bring the maximum and the minimun of the curves together by sliding the lateral axis (number of days) of the diurnal variations obtained at two different measuring points. (see Figure 23)

6. Observation of displacement by a soil compression meter

As another method to estimate the nature of the soil mass movement we have a soil compression meter (Figure 24), which is designed by Yamaguchi.[12] This instrument is devised to measure the direction of compression caused by the soil mass on the basis of the deformation formed on the circumference of the pipe buried in the soil mass. In other words, it is so designed as to register the 'positive' compression when it is given in the direction of the movement and 'negative' compression when it is given in the perpendicular direction of the movement. The present wirter conducted a survey using these instruments in two landslide areas in Tsukiike and Kamenose. They were buried at eight different places, each of them at 20 meter intervals along a line from the originating point to the terminating point of the Tsukiike landslide area.

At each measuring point no regular tendency was observed, but it was observed on 28th February that compression increased simultaneously at No. 8

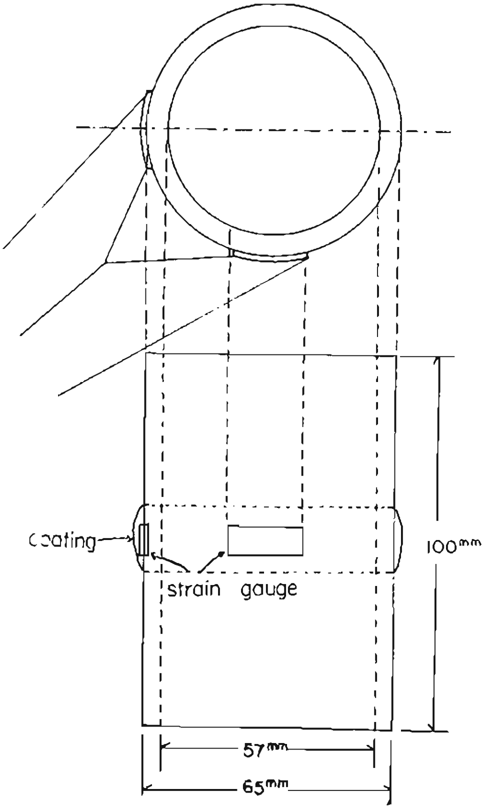

Fig. 24 The diagram of the soil compression meter

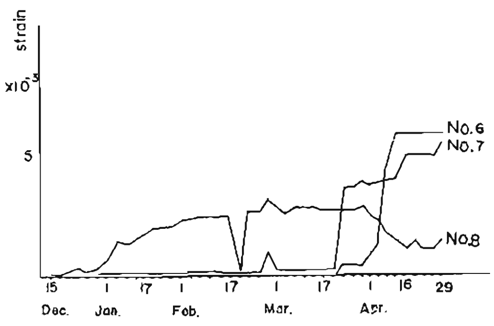

Fig. 25 The variation graphs of compression force at the Tsukiike landslide area

and No. 7 respectively to the extent of 4m~7m and 2m~6m and it appeared to the present writer that the soil mass of about 20m was making a movement of an almost similar nature. (Figure 25)

Another example of applying this device is the Kamenose landslide area. The results measured at one particular place out of all the others where the soil compression meters were buried will be taken up here for the present discussion. The soil mass on the slope along Shimizudani in this landslide area kept moving in the inclining direction of the slope at a moving rate of approximately 1~10 cm per year since 1952.
In the course of making a survey of this movement using internal strain meters cracks appeared on the upper part of this landslide area in the middle part of February 1967 and the rate of this slide movement tended gradually to increase from March. The surveyed result of the distribution of cracks at this stage,[13] is shown in Figure 26, from which it was attempted to find the soil mass movement but it became impossible pursue these cracks at area A in the drawing. There was in those days neither a settled opinion with respect to this movement of the soil mass, nor sufficient observed data enabling us to arrive at any conclusion. However, thanks to our two compression meters which were fortunately buried at two different places in area A, we could continue our survey with respect to the state of the slide movement of this area.

In the early part of March 1967 there had already appeared

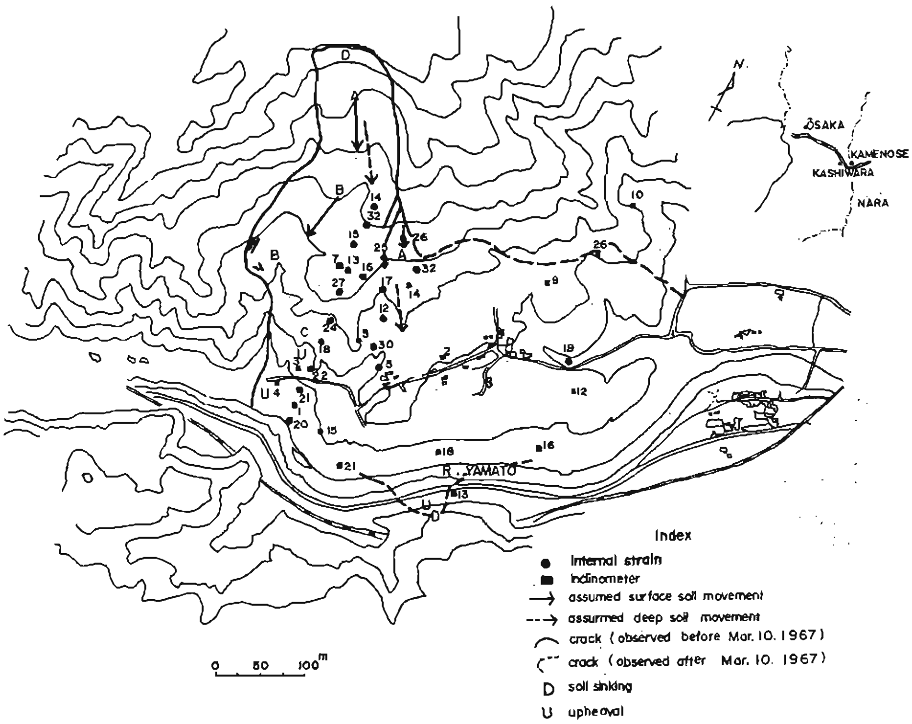

Fig. 26 The location map of internal strain meters in the Kamenose landslide area

an upthrust of the soil mass on the right hand bank (area B) of this cracked area, but no such crack phenomenon existed in area C. Consequently it at first seemed as if the collapsed soil mass had moved in the direction indicated by arrows, leaving a newly formed cliff behind.

The soil compression meters were so devised as to register 'positive' compression when compressed in the direction of the arrow. Consequently, when the values obtained by the soil compression meter was 'positive', it should mean that compression was in the direction of the arrows. Now, the results measured at the two points are shown in Figure 27. According to soil compression meter No. 25, compression was in the following two directions : 'positive' for 25m, 33m, 37m, and 'negative' for 31m, 27m, 21m, 19m, 17m, 11m, while according to No. 26 on the other hand 'postive' for 31m~43m and 'negative' for 5m~29m. Consequently it was seen that compression at No. 25 and 26 was on the shallow layer in a perpendicular direction in relation to the direction of the cracks and on the deeper layer in a downward direction.

Then the present writer formed the view from these phenomena that the perpendicular movement in relation to the cracks was dominant in the shallow layer in area A, and that the soil mass made the slide movement in the direction of the arrows at No. 26 and 25 since the 'positive', compression was on the deeper layer of area A.

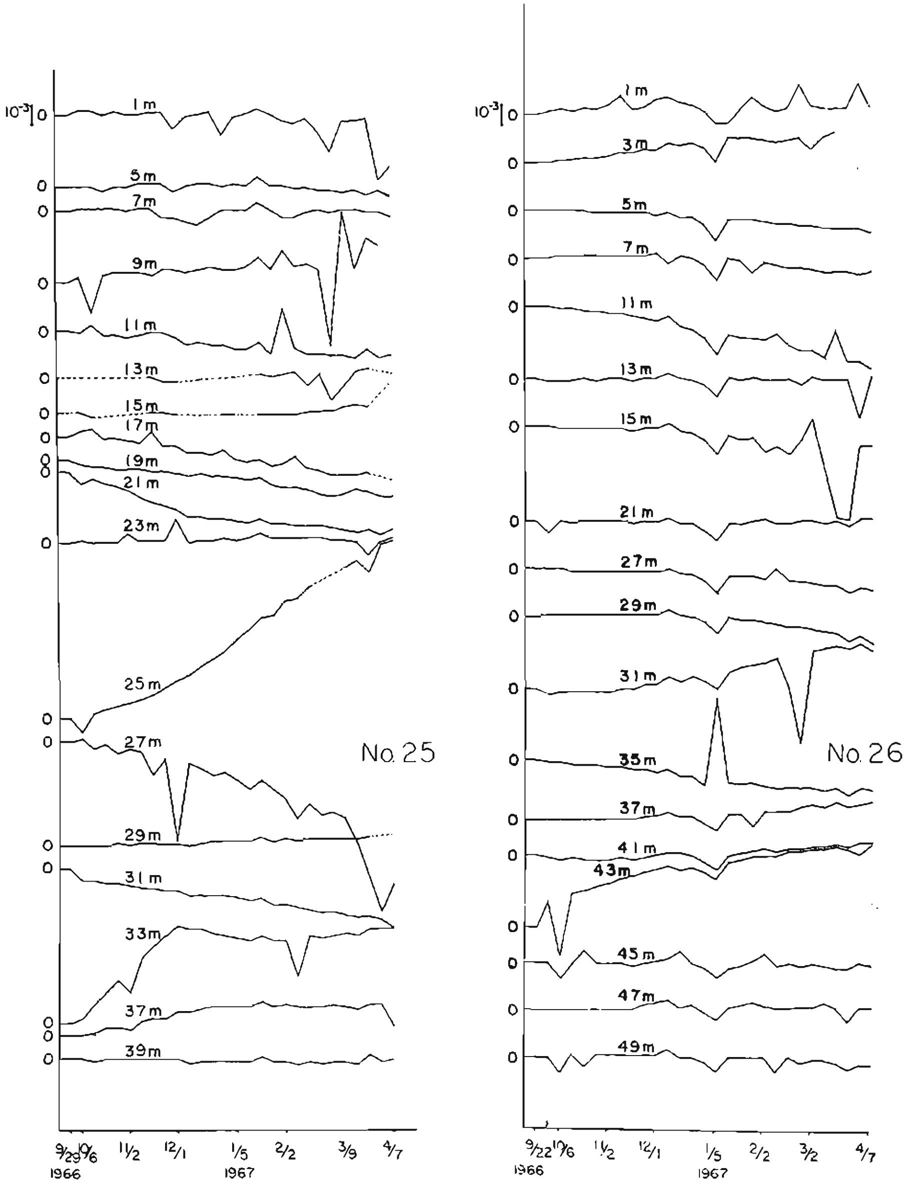

Fig. 27 The records of the soil compression meter at No. 25 and No. 26

Viewing the problem in this way, the writer probed the high possibility, with respect to the landslide movement that had taken place in the middle part of February 1967, that the shallow layer made the slide movement in the direction of A and C, but that the deeper layer moved in the direction indicated by the arrows indicated in a dotted line.

Now, in bore hole No. 25 were buried the internal strain meters in addition to the forementioned soil compression meter. Therefore, the present writer

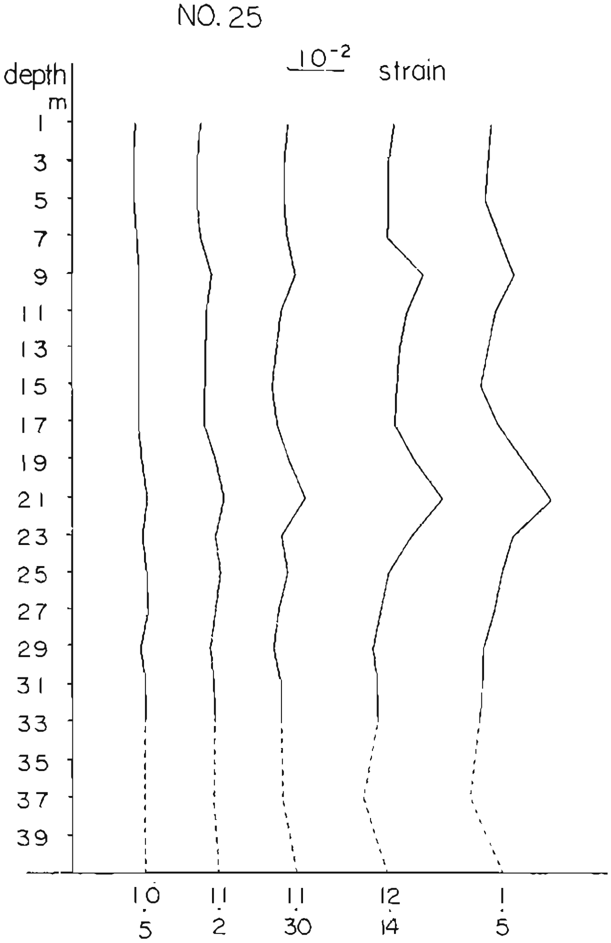

Fig. 28 The variation of accumulated strain curves at No. 25

will take up the results of this internal strain meter for the further discussion of this slide movement. Figure 28 shows records up to about one month prior to the occurrence of the upper cracks. On 5th January 1967 prominent changes in the accumulated strain curves had already been noticed. The accumulated strain curves had already been noticed. The accumulated strain curves obtained by the experiment of Figure 7 were exactly identical with those obtained at No. 25 Now, this provided us with eloquent proof from the internal strain curves at No. 25 that the layer deeper than 23 meters made the slide movement in a parallel direction (toward the River Yamato) to the slope. Consequently, it proved that the results of the soil compression meter were consistent with those of the internal strain curves and at the same time it clarified tha that direction of the movement of the upper soil mass was different from that of the lower layer. During the period from the later part of March to the early part of April the scale of this landslide began to be extended until an upthrust came into existence at the terminating point of this landside in areas C and D as shown in Figure 27.

In this way the setting up of the soil compression meter paved the way not only for clarifying the spreading of the landslide movement but also for understanding the two different directions of the slide movement made by the upper and lower layers.

7. Conclusion

The present writer conducted a number of surveys to clarify the state of underground soil movement using the internal strain meter. Its fruitful results have yielded the following classification of all landslides as far as those of the Tertiary type are concerned ; (A) Slide of Fluid Type, (B) Layer Slide Type, (C) Protruding Slide of an Intermediate Layer and (D) Multi-slide Layers.

It has been confirmed by a number of his experimental studies that these four types can be distinguished to a certain extent by the accumulated strain curves.

It has also been made clear that we can examine, when the diurnal variation chart of the extent of strains can be additionally prepared, whether compression from the upper part is prominent or whether pulling from the lower part is prominent at the critical time when the slide movement begins to spread.

It has been so far reported[14] that, as far as the slids surface survey is concerned, the depth of the slide surface varies with seasonal variations. However, it has been made clear that, once the concept of a sliding layer is introduced, even if several slide surfaces exist in one slide layer, these slide surfaces can still be included in the category of one and the same mechanism.

Nevertheless, the two different slide surfaces- an upper layer (12 meters deep) and another lower layer(30 meter deep) - can't being sttributable to one and the same mechanism. Contrarily they comprise rather duplicated slide layers and it has been found that a large scale landslide takes plece in the lower one of such duplicated slide layers. Furthermore, it has been confirmed by the soil compression meter and the internal strain meters that these two slide layers do not always move in the same direction.

It has also been found that the internal strain meters are adequate enough to determine the extent and the state of the soil mass movement, but the joint use of the soil compression meter serves to acquire a better knowledge of the minute state or the nature of the soil mass movement.

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