A BASIC STUDY ON TECHNOLOGY OF INDUCING ARTIFICIAL AVALANCHE BY EXPLOSIVE DETONATION INSIDE THE SNOWPACK

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ABSTRACT: Avalanche inducing technology to ensure the safety of the potentially dangerous area practiced in Japan relies on blasting off the snow layer with the explosive loads imbedded within the snowpack. The exact mechanism of inducement of an artificial avalanche with this method, however, is difficult to elucidate and calls for a basic study of the detail of what is happening.

The present study describes the measurement of the pressure spreading in a snowpack, a snow pit study around the blast point and experiments of artificial avalanche under a variety of combinations of the loading dispositions.

As a result, it is found from the experiments that the formation of a smooth sliding surface was the most important in successfully inducing an artificial avalanche.

Therefore, the loading method to form a smooth sliding plane was studied. The experiments showed that a new loading method successfully induced an artificial avalanche.

KEYWORDS: explosives, artificial avalanche, wet snow, full depth avalanche

1. OBJECTIVE OF THE STUDY

Inducing artificial avalanche has been practiced in Japan ever since 1960s. Selection of explosives and the loading method, however, relies heavily on experience and next-to-nothing sound scientific basis. Snow is often wet and heavy in Japan and the effective method to remove potential danger of full-depth avalanche in such a region is said to plant explosive charges deep inside the snow layer. This study investigates the effect of loading condition on the snow layer by making scientific measurement inside the snow layer. The loading method here refers to the volume of the explosive charge placed in a drilled hole and the snow cover above it.

The effect of blasting the snow layer is clearly seen as forming a destruction hollow around the explosive charge. In some cases blasting effect is seen to exhibit lines of cracks on the snow surface. Furthermore in some cases, where excessive amount of charge is used or the snow cover over it is too shallow, explosive gas or smoke may erupt out to the air. This phenomenon apparently affects the effect of the explosive detonation and this is the main subject of this study.

This study makes observation and measurement over the gas eruption, formation of destruction hollow and propagation of over-pressure at the time of detonation and try to find out the method offloading, i.e. volume of a charge, snow cover over a charge and spacing in plan of charges, to most adequate for inducing an artificial avalanche. The outcome of this study should help increase the safety by preventing over-use of explosive charges and reducing unnecessary gas eruption.

2. STUDY FIELD

The study field, as shown in Fig.1, is located at the mountainside area of the Hokuriku region of Japan, very notable for heavy snow, with elevation of 510m. This site is safe in using explosives to allow multiple number of tests in close proximity.

Fig.1 Studied Field

3. CHOICE OF EXPLOSIVES

Explosive chosen is HighJex (made by Japex) a kind of water gel explosive. This product has excellent quality in safety, water-proof and anti-shock property and shows little degradation of quality as explosive under low temperature. Detailed specification is given in Table 1.

A charge of explosive is manufactured in a unit of 100g. To form a charge of more than 100g, a number of 100g charges are bound together by adhesive tape and only one detonator cap is used(Fig. 2).

For drilling a hole in the snow layer to place an explosive charge, a hammer-like drill as shown in Fig. 2 is used. This drill is composed of a bar made of cast iron 10cm in diameter with cone shaped end. The bulbous shape of the end helps to remove the snow inside the drilled hole. The explosive charge is loaded at the end of the drilled hole and snow is filled inside the hole.

Table. １ Specification of explosive charge

Classification (Product Name)	water gel explosive (High Jex)
Condition	Gluey
Detonation Velocity(m/s) [JIS]	5,500～6,000
Gap Sensitivity	2.5～5.0
Sensitivity Detonated at Low Temperature	-25℃
Water-Proof Performance	Excellent
Drop Hammer [JIS]	8 class
After Detonation Fume	Excellent
Force of Explosive （l・atm）	8,327
Diameter of explosive Length of explosive	25mm 177mm
Amount of Explosive for one	100g

4. SNOW DEPTH TO THE EXPLOSIVE CHARGE AND THE VOLUME OF CHARGES

4.1 Experimental Conditions

Snow stratigraphy at the time of the experiment is shown in Fig. 3 and Fig. 4. The whole layer holds wet snow with very high water content. Snow depth is 200cm,average density 498kg/m^{3,} whole snow weight 995kg/m$^{2.}$ On observation of gas eruption and shape of the destruction hollow, a video-camera is used at the time of detonation and snow pit study is conducted afterward.

Experimental conditions are, as shown in Fig. 5, 6 cases which are run with choice of charge volume of 100,300 and 500g and snow depth over charges of 1.0 and 1.5m. These 6 cases were positioned in a straight line and run simultaneously.

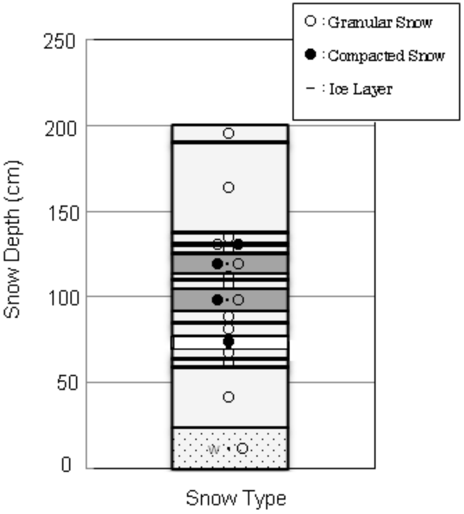


Fig.3 Snow type

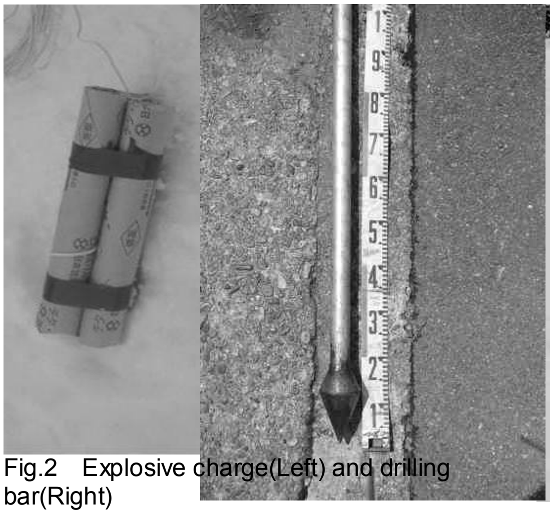
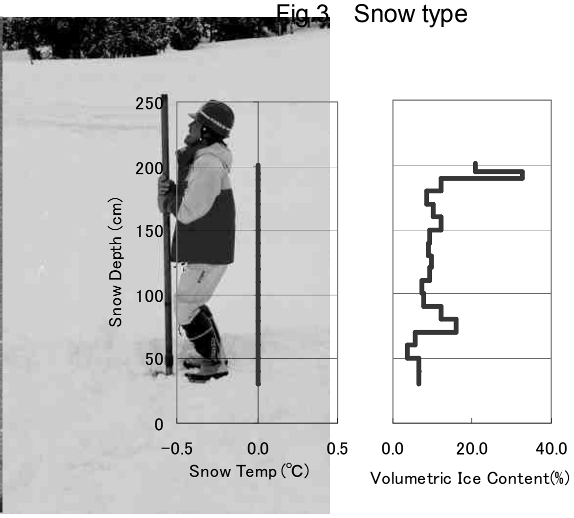


Fig.2 Explosive charge(Left) and drilling bar(Right)



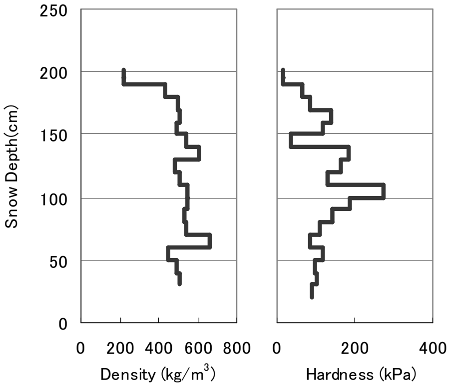


Fig.4 Snow survey result

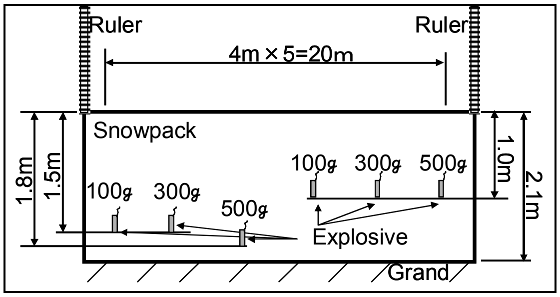


Fig.5 Schematic diagram of charge loading

4.2 Effect of explosive Detonation on the Snow Surface and Snow Cross Section

Fig. 7 shows the height of gas eruption measured from the video-camera pictures for each condition. Cracks appeared on the snow surface extending in a circular shape and Fig. 8 shows the measured diameter of the circular cracks. For charge volume of 100,300g, crack diameter grows as the snow depth becomes small, whereas for charge volume of 500g, the crack diameter gets larger for the case of snow depth 1.8m thanfor the case of snow depth of 1.0m. This is probably due to the fact that for the case of the snow depth of 1.0m, most of erupting gas escaped out to the air.

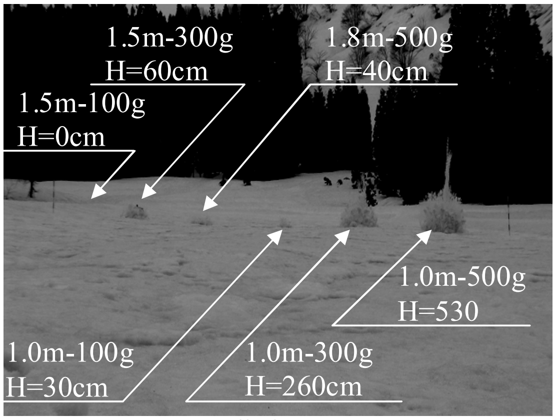


Fig.6 Blowing off of snow at detonation

Fig.7 Height of gas eruption

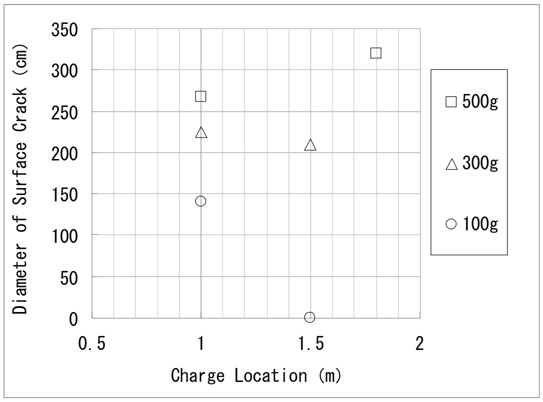


Fig.8 Diameter of surface crack

4.3 Measurement of the Hollow

After explosive detonation, the snow layer around the point of detonation is dug (pit study) and the exposed snow cross section is studied.

The result is shown in Fig. 9. For the cases of the snow dept of 1.0m and charge volume of 300 and 500g, the destruction hollow is cone shaped as gas eruption is so enormous to make the hollow protrude into the air. For other cases, the hollow, though distorted to some extent, is spherical.

Fig. 10 shows comparison of the measured and calculated diameter of the destruction hollow. Calculation formula for the destruction hollow diameter was originally given by Morisue *et al*.(1997) and later by Machida *et al*.(2006) as a practical formula.

The latter formula is given as follows:

$$R = 3.307 - \sqrt{12.648 - 7.267\left(\frac{FL}{dVH^{1/4}}\right)^{1/3}} \qquad (1)$$

in which R is the radius of the destruction hollow, F is force of explosive （l・atm）, L volume of explosive(kg), V the detonation velocity(m/s), H snow depth above the detonation point(m).and d=1.2.

Fig. 9 and Fig. 10 show that measured R and calculated R corresponds well when the hollow is spherical, whereas such is not the case with non-spherical hollow.

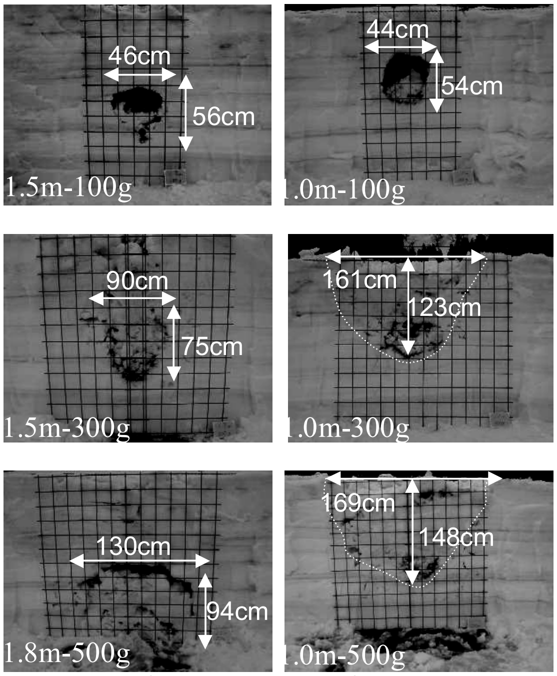


Fig.9 Cross section cut after blasting

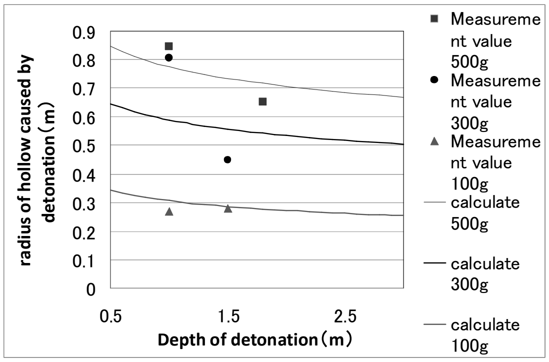


Fig.10 Radius of detonated hollow

4.3 Measurement of the Detonation Pressure

Measurement of the detonation pressure propagating inside the snow layer is made with semi-conductor pressure transducers which are fixed on a steel bar and positioned at the specified height over the ground surface. The specified height in this case is chosen as 0.5,1.0,1.25, 1.5m. A schematic diagram of the pressure recording system is shown in Fig. 11. With this device, the pressure measurement is carried out with all 6 cases of experiment at specified horizontal distances from the point of detonation.

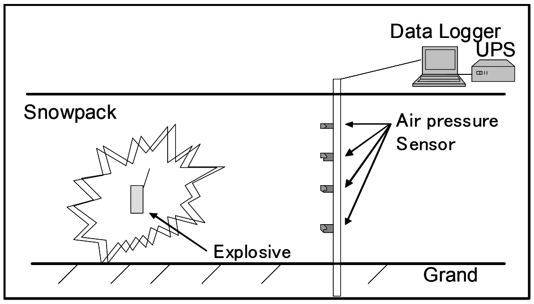


Fig.11 Method of measuring pressure

Figs. 12 to 14 show the plot of the maximum detonation pressure at a specified horizontal distance from the point of detonation versus distance over the ground. In this experiment, snow depth is 2.0m.

The measured maximum detonation pressure obtained at the same horizontal distance shows the marked difference between the values for snow depth of 1.0m and 1.5m. This is probably due to gas eruption out of the snow surface. This difference by the way is small for the values obtained at the snow surface and snow depth of 0.50m. This is reasoned to reflect the fact that the distance from the detonation point is large in these cases.

To summarize the result of the detonation pressure measurement, It is found that the charge weight and snow depth have a tremendous effect on the snow layer. Also, gas eruption is shown to give attenuation effect on the detonation pressure. All considered, the most adequate weight of a charge for wet snow is judged to be 300g.

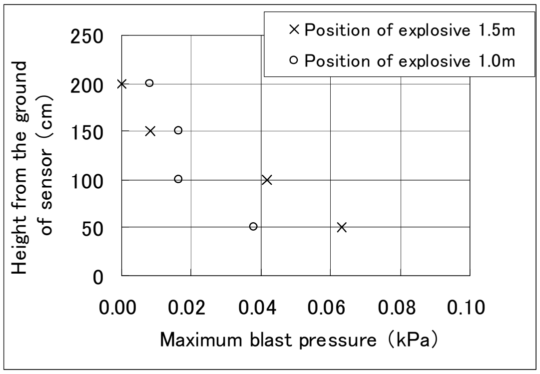


Fig.12 Maximum detonation pressure
(The weight of the explosive is 100g.The horizontal distance from the loading point is 1m.)

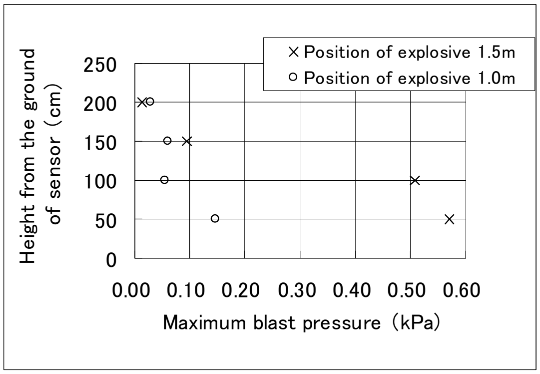


Fig.13 Maximum detonation pressure
(The weight of the explosive is 300g.The horizontal distance from the loading point is 1m.)

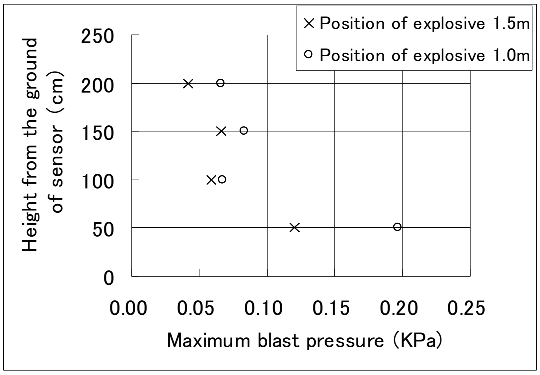


Fig.14 Maximum detonation pressure
(The weight of the explosive is 500g.The horizontal distance from the loading point is 2m.)

5. Creation of Starting Plane on Avalanche Inducing Experiment

5.1 Purpose

A small sized avalanche inducing experiment was carried out using 300g charges based on the result of the previous chapter. The Japanese practice of inducing avalanche with explosive detonation stipulates that the depth to place an explosive charge had better be placed gradually shallower at the downstream end of the snow layer. How gradual has not been written however. Fig.15, for example, shows the experimental result in which this idea was taken into account and yet avalanche inducing was unsuccessful. This is because the way to gradually reduce the detonation depth makes the whole snow layer clog and prevented the whole layer from sliding down. This result implies that the 'gradual reducing' of the detonation depth has to be done with so much caution as to create the smooth sliding surface.

Fig15 Failure case inducing artificial avalanche

5.2 Formation of sliding Plane with the Explosive

Fig. 16 shows the idea of this study of dividing the snow layer concerned into destruction zone and sliding plane forming zone. Over the destruction zone, explosive charges are placed on the cross stitch shaped grid with spacing of 2m in plan and at the bottom of the snow layer. Over the sliding plane forming zone, disposition in plan is so decided as to form continuity in destruction hollows, i.e. spacing of 1m and the detonation depth is so decided as to form a linear plane with angle β. Thus, the depth of loading can be calculated by the following equation. Additionally, the detonation depth is kept to be more than 0.8m to avoid the effect of gas eruption.

The reported study in this paper uses two β values: 0° and 15°.The experimental slope held snow depth of 300cm and the slope angle is 45°.

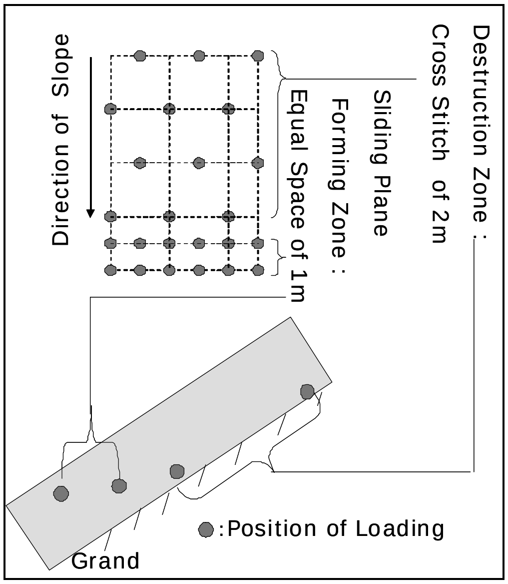


Fig.16 Concept of loading pattern

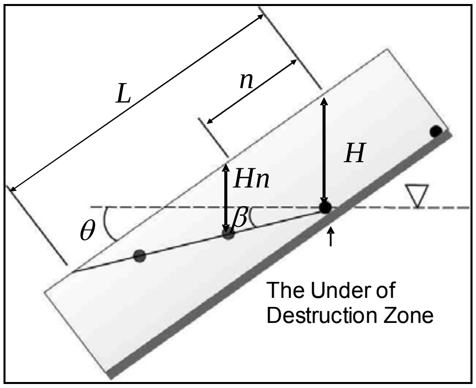


Fig17 Method of loading at the sliding plane zone

$$L = \frac{\cos\beta}{\sin(\theta-\beta)} Hn \quad \cdot\cdot\cdot (2)$$

$$Hn = \frac{L-n}{L} Hn \quad \cdot\cdot\cdot\cdot (3)$$

H :Depth of Loading
θ :Slope Angle
n :Interval of Loading
β :Angle of Loading
L :Length of Sliding Surface Area
Hn :Depth of Loading Slipping Surface Area

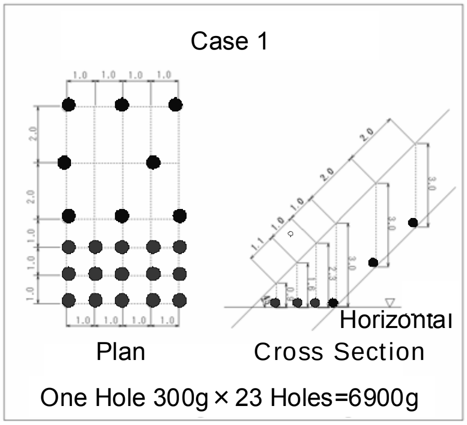


Fig.18 Disposition of explosive charges to induce an artificial avalanche for case1

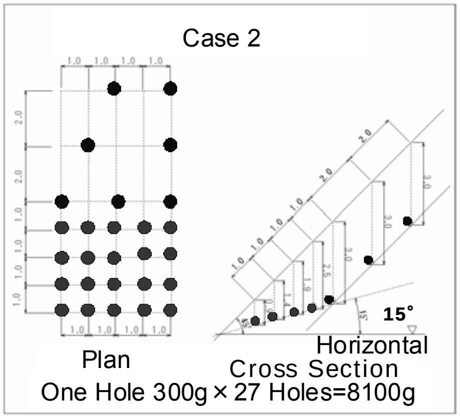


Fig.19 Disposition of explosive charges to induce an artificial avalanche for case2

5.3 The Result of Avalanche inducing experiment

Fig. 20 and Fig. 21 show ,respectively, the slope before and after the experiment, demonstrating the avalanche induced in both cases. Measurement after the detonation exhibits snow left behind the detonated area of 11 m^3 and 1 m^3 for case 1 and 2 respectively.

Fig. 22 and 24 show the cross section areas of the sliding plane zone after detonation for case 1 and case 2, respectively. Fig. 22 shows the continuous layer of black soot which is observed to confirm formation of the sliding plane.

Fig. 23 shows that the sliding plane over the remaining snow layer is 6°. This value is very mild compared to sliding surface of surrounding zone indicating checking effect on the snow remained there. It is also noted that the detonation points all slide down to some degree .Shallower the snow over the detonation point, more movement.

Fig. 24 shows the cross sectional area of the sliding plane zone of case 2, demonstrating the formation of the sliding plane initiating the avalanche. Fig. 25 shows that the sliding surface over the destruction zone is 45°,the upstream end of the sliding zone 22°, and downstream end 31°. It is then concluded that Case 2 gives better result than case 1.

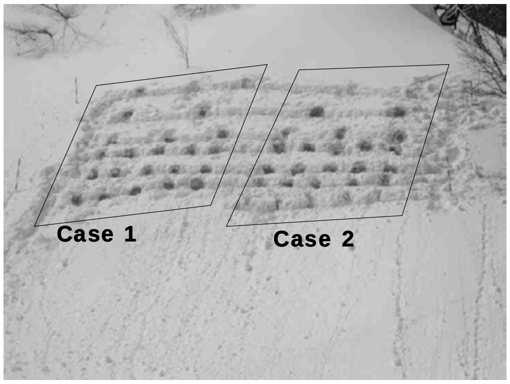


Fig20 Before the experiment

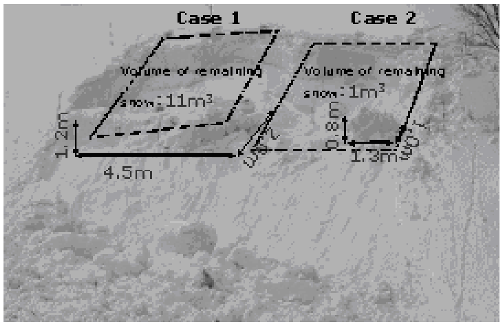


Fig21 After the experiment

Fig22 Cross section areas of the sliding plane zone after detonation for case 1

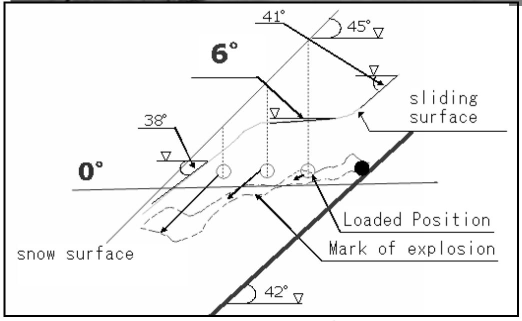


Fig23 Measurement result after detonation in case1

Fig24 Cross section areas of the sliding plane zone after detonation for case 2

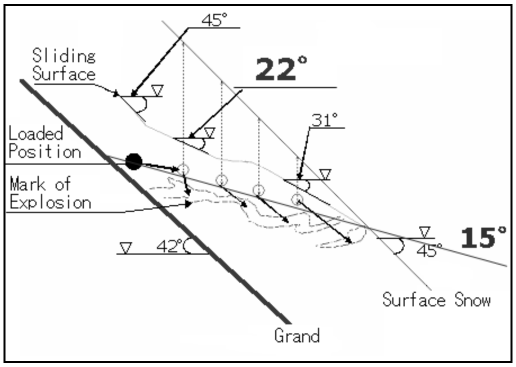


Fig25 Measurement result after blasts in case2

6. CONCLUSIONS

This paper showed the effectiveness of the water-gel explosive (Brand name=HighJex) in destruction of the snow layer and inducing an artificial avalanche. It is found out that for shallow snow depth over the explosive detonation explosive gas tends to emanate to reduce the effectiveness.

This is reflected to excessive use of explosive charges so that the most adequate charge weight to be loaded inside the snow layer is 300g per one detonation point. The destruction hollow created by detonation is closely studied and the formula by Machida(2007) is found to give a good result.

As for the avalanche inducing experiment, explosive charges are placed in a cross stitch pattern with a spacing of 2m in plan for the destruction zone and with a spacing of 1m for the sliding plane forming zone and the result showed successful inducement of avalanche. Especially on formation of the sliding plane at the downstream end of the snow layer, it is found that the experiment with forming it as a 15° plane yielded a good result.

7. REFERENCE

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