# THE TIME-DELAY METHOD OF AVALANCHE CONTROL[1]

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## Introduction

In the northeastern district of Honshu (main island), Japan, a winter can be divided into three characteristic seasons: early winter season (end of December - end of January), midwinter season (end of January - end of February) and snowmelt season (end of February - beginning of April, sometimes up to end of May in mountain regions).

The general condition of snow cover in the northeastern district of Honshu, Japan, is powder snow in early winter season, consolidated snow in mid-winter season, and wet coarse-grained snow in the snowmelt season. Ground avalanches are most active during the snowmelt season, and cause severe damage to traffic in this district. To protect highway traffic in the district against snow avalanches, a number of methods of avalanche control and protection have been applied.

A snow slope will generally be stable, if the driving force of gravity ($W\sin\Theta$) is less than, or equal to, the sum of the mechanical strengths (compressive, tensile and shear strength) and the resistance force to glide by friction at the bottom of snow. Under such a stable condition, we can release an avalanche by supplying an artificial driving force which can be generated by an explosive.

The author has endeavoured to exploit the technique of avalanche control by the use of dynamite, using time-delay blasting. This generates a kind of avalanche with very different type of motion compared to natural (ordinary) avalanches.

The time-delay method has worked well on slopes 100-300 m long (up to 800 m in maximum) and with 30°-48° steepness.

## Principle of the Time-Delay Method

The principle of the time-delay method is illustrated in Fig. 1. Successive blastings (I, II, III, ...) are made at appropriate time intervals (T=0, 0.25s, 0.50s, ...).

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[1] A 16 mm film of avalanche blasting by the time-delay method was presented at the Avalanche Workshop.

Explosion I plays two roles:

1. Builds up a highly compressed snow on its uphill side.

2. Excavates a hole in snow cover into which the compressed snow block can fall in by successive explosion of II.

Explosion II plays three roles:

1. Pushes the compressed snow block downward, giving a rolling motion.

2. Builds up highly compressed snow on its uphill side.

3. Excavates a hole into which the uphill compressed snow block can fall in by successive explosion of III.

Repeating such actions in series with a proper time interval (0.25 seconds in Fig. 1), a snow cover on slope is split into a number of snow blocks rolling down the slopes. By this method, the energy of an avalanche can be divided into a number of smaller units.

As shown in Fig. 1, it was observed that successive blasting is most effective when the first detonation consists of both a horizontal and vertical charge, and each successive detonation consists of a vertical charge.

By adjusting the depth of blasting, a thin snow layer (10-15 cm thick) can be left in place to protect the slope surface and vegetation from avalanche motion. Thus, this method can diminish damage caused by avalanche control.

As shown in Fig. 2, it is also possible to release slab avalanches by simultaneous initiation of explosives at the top and bottom of the slope, and then have delayed detonation propagate down slope. We found this system to be very useful for releasing avalanches for scientific research (e.g., measuring speed and impact force).

The last method works most effectively for damp slabs of new snow, although it is applicable for all kinds of snow condition. Experimental results indicate that a snow block of 60-80 cm in diameter is optimum. If a snow block is too big, the block does not roll down. Overcharging, and short spacing result in poor production of snow blocks.

## Blasting Efficiency

Efficiency curves to minimize the amount of dynamite were determined from the data of more than 100 avalanche release experiments conducted at the northeastern district of Honshu, Japan. It was found that economical explosive charges for blasting slabs with thickness 1 m, 2 m, and 3 m were respectively 250 g, 300 g, and 400 g. It is possible to compute the spacing of these charges using the graph shown in Fig. 3 which gives slope parallel spacing as a function of slope angle. The cross-slope spacing is recommended as 1.25 times the slope parallel spacing determined from Fig. 3.

The time interval of blasting depends on the moisture content of the snow. To obtain squeezing or compression, rather than shattering, a short interval of blasting (0.25s) is recommended for dry snow. For damp or wet snow, the time interval should be increased (0.5s to 0.75s).

Blasting experiments were conducted using dynamite packed in three types of pipes (vinyl-chloride, dry bamboo, and fresh bamboo). It was found that packing dynamite in vinyl-chloride pipes gave the farthest distance of fracture propagation by a factor of four.

## Conclusion

Merits of the time-delay method are:

1. Operation of avalanche control is carried out safely when the snow cover is stable, in early winter and mid-winter seasons. Thus, it provides less ground avalanche in snowmelt season.

2. Sloping ground and vegetation are protected from avalanches both by a thin snow layer on the slope surface which remains after the blast and by gentle rolling motion of snow-rolls.

3. As the avalanche debris is clean, without trees and rocks, removal work of the debris is remarkably easy and speedy.

## Reference

Kobayashi, Fumiaki, and Fujino, Akinori. 1970. Engineering Measures Using Explosives for the Prevention of Avalanches. Seppyo, Vol. 32, No. 3, pp. 63-70.

Discussion

PERLA: The use of electric time-delay detonation allows many interesting possibilities for avalanche control. However, one should use the method with caution due to the problem of static electricity in the mountains.

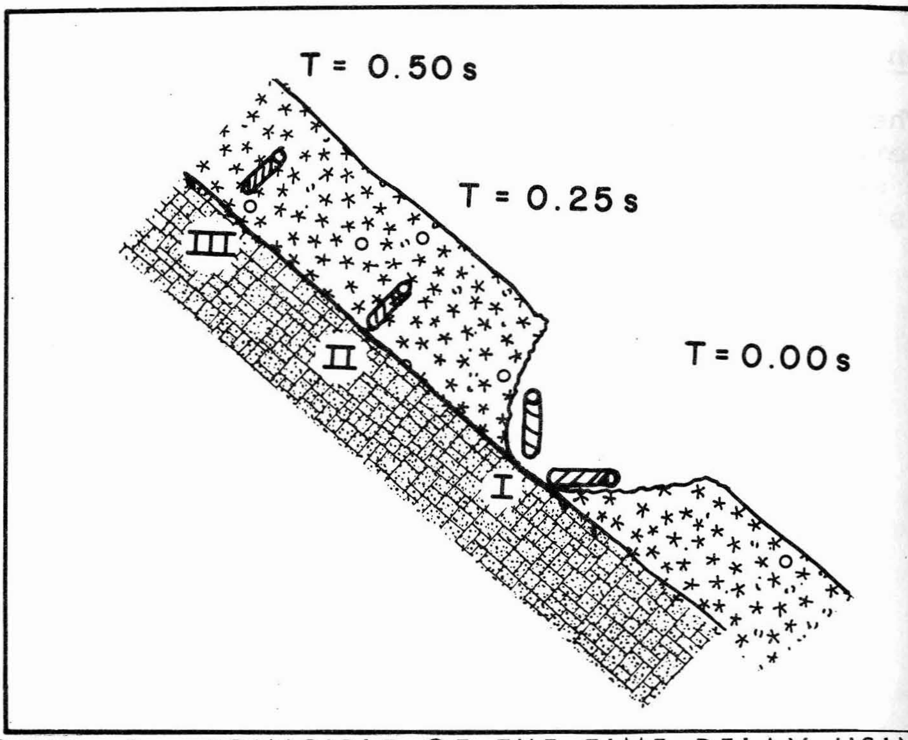


FIGURE 1 PRINCIPLE OF THE TIME-DELAY USING ELECTRIC DETONATORS DELAYED IN INCREMENTS OF 0.25 s. EXPLOSIVE I CONSISTS OF DYNAMITE LOADED VERTICALLY AND HORIZONTALLY. THE REMAINING EXPLOSIVES ARE LOADED PERPENDICULAR TO THE SLOPE.

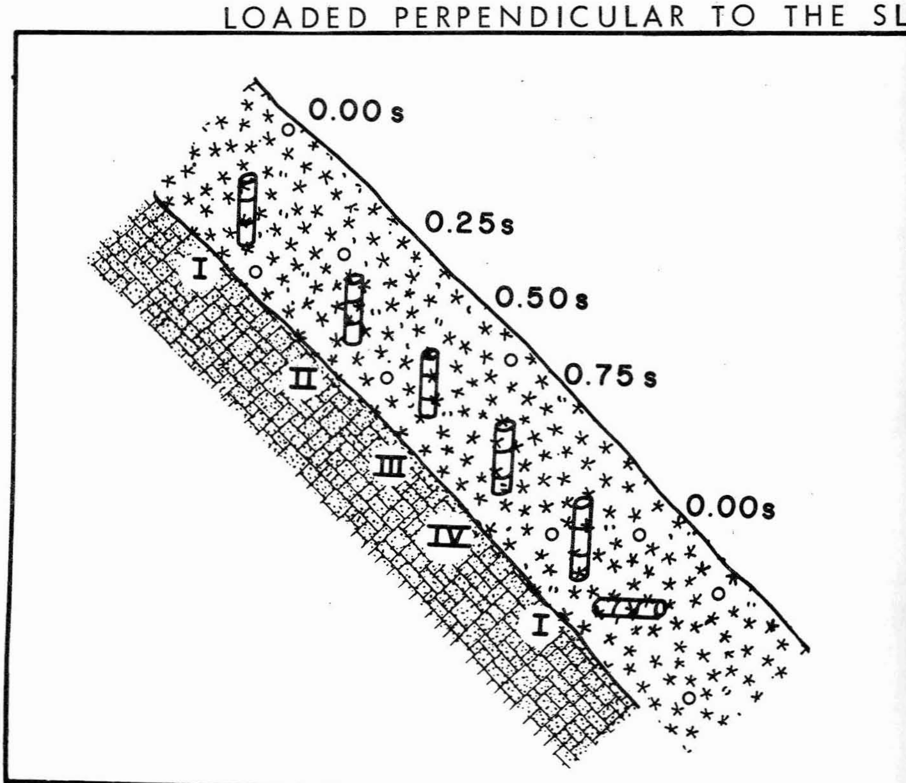


FIGURE 2 SLAB AVALANCHE RELEASE BY SIMULTANEOUS DETONATION AT TOP AND BOTTOM OF SLOPE

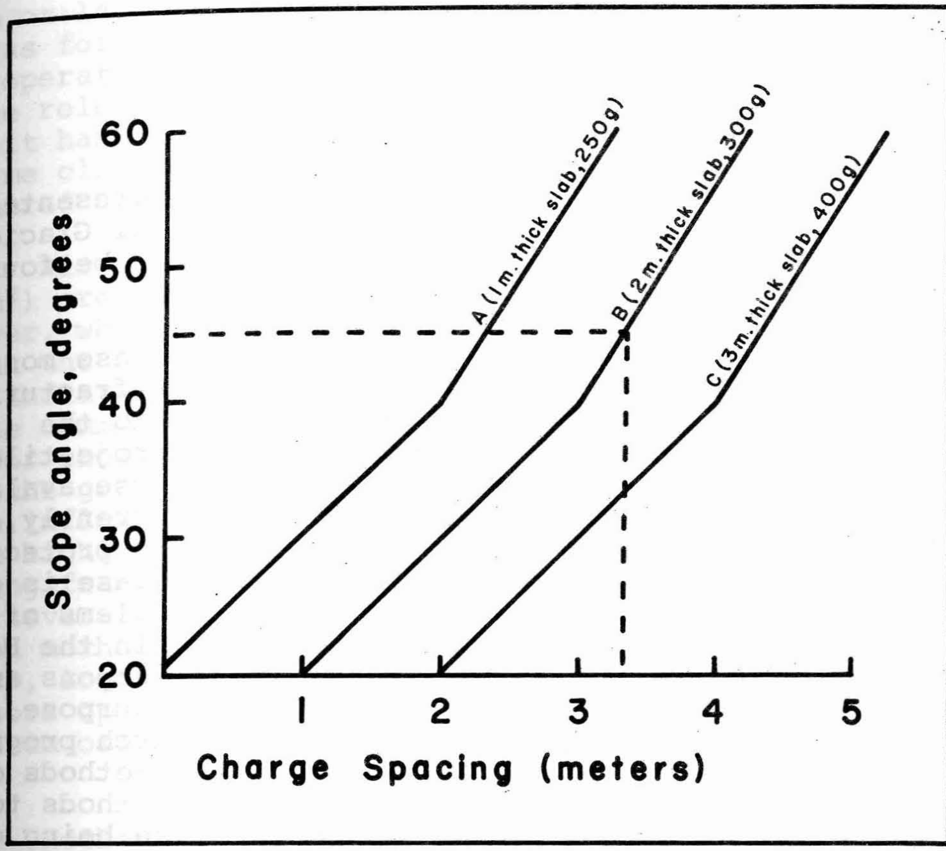


FIGURE 3 ECONOMIC CURVES A, B, AND C FOR BLASTING RESPECTIVELY 1 m, 2 m, AND 3 m THICK SLABS WITH RESPECTIVELY 250 g, 300 g, AND 400 g OF DYNAMITE. THE ABOVE EXAMPLE (DOTTED LINES) SHOWS THAT BLASTING A 2 m THICK SLAB ON A 45° SLOPE REQUIRES THE 300 g CHARGES TO BE SEPARATED APPROXIMATELY 3.3 m