# Winter Road Safety
# -A Case Study in Azumi Village, Nagano-

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**Abstract**

This comparative and case study, undertaken from May 2000 to February 2004 at locations in Washington, Alaska and finally Nagano, Japan, focuses on a winter thoroughfare called the Kamikochi Norikura Super Rindo (herein: Forest Road) in the Azumi Village, which has been accosted with avalanche incidents and accidents for a number of years despite large investment in avalanche protection measures. In Japan, problems that are associated with winter both mountain travel safety to outdoor recreation safety are in many ways characterized by the issues which surround the risk management planning, use and management of this road. The problem in Azumi is of how to reduce the avalanche hazard along the Forest Road.

In this paper, as an introduction and general overview in support of the ideas and concepts brought up body text, the current situation of avalanche work worldwide and in Japan is presented. One tendency seen in Japan is for heavy reliance on permanent measures such as the 88 snowfences constructed on the Forest Road at a huge expenditure (153,353,000 JPY) in Azumi over the last 23 years. Avalanche forecasting is also rare, as demonstrated by only recent inclusion snowfall parameters for road closure purposes in Azumi. In North America and Europe, active avalanche control, which is the process of artificially releasing avalanches through explosive use, is popular as a temporary measure. Such protocol is often used to and complement to permanent measures such as earthworks or snowfences which redirect or reduce velocity of snow flow. In Switzerland alone 10,000 kg explosives are used annually in avalanche control work.

For the purposes of this study, operating models of bombing routes using hand-deployed charges and bomb trams which carry explosives to avalanche start zones as seen on field trips and inspected in Highway departments and ski areas in the US are proposed as a solution for the Forest Road in Azumi Village, Nagano, and investigated with respect to applicability, safety of use, legality, etc. The only legally hand-deployable charge in Japan, and major topic in this study is a new product called ACE (Avalanche Control Explosive) the research of which is facilitated through elementary on-snow testing.

Through the course of this study it became evident that underlying the snow safety issue are issues in forest policy, road use planning, measure selection and funds appropriation. Delving further, it became clear that village and higher government may not have had access to a full range of internationally accepted options in the search for answers to problems of avalanche hazard reduction. In Azumi this inaccessibility to technology has resulted in expensive construction of inadequate permanent protection measures.

Assuming that a program including active control could be formally made available to road managers at an attractive price, either deployment of charges by hand or light cableway would be suitable, albeit

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with some Japan-specific modifications. ACE are relatively low in total energy and their use would require some modification in size, and with respect to tram use it would be necessary to solve small engineering problems and determine which type of charge is explosive material bakes best economic and operational sense for the village. Both measures would require increasing the caliber and accuracy of the current forecasting program as well as unprecedented cooperation with road maintenance crews.

**Key words:** avalanche control, explosives, fireworks, forest policy

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## 1. Avalanche Industry Background

### 1.1. History and world situation

Avalanches have been a problem since people started living in mountainous areas. The destructive power of avalanches is immense, and potential losses are great. Primary industries affected are transportation and construction. Destruction of lives and property have a trickle-down effect throughout society. Losses are in time in the transportation of goods, people, and reduced ability to produce or spend. Tourism and tourist locations are especially susceptible to adverse effect.

Danger of loss or injury due to avalanche is commonly referred to as avalanche hazard. Since the 1960's the general hazard level has been increasing with the increase in use of mountainous areas by human society for work and recreation. With this increase in use has come a tripling of avalanche deaths over the last 50 years. Of this total number, the majority of fatalities occur during the pursuit of recreation. Fatalities in buildings, on roads and worksites are being slowly reduced. Overall, the percentage of mountainous area use has been growing at a faster rate than losses due to avalanche, yet many losses still occur.

In case of most developed countries, the situation has come to be that where a considerable public problem of avalanche hazard reduction has been identified, it is generally addressed. High use areas or areas with repeated accidents or near-misses tend to receive attention quickly, where smaller less utilized areas take second fiddle. There has been a longstanding tradition of snow study and are a numerous measures available to industry and consumers, especially in recent years.

As technology develops, different materials and methods are introduced or old ones modified. However, although technology transfer is often quick but generally faster when profit is involved. Not always are all locations or individuals privy or necessarily capable of utilizing the recent information and technology to adequately reduce avalanche hazard. Even if all options to solve a specific avalanche problem are available, peripheral issues of supply, regulation and acceptance often surround the issue of avalanche hazard reduction program implication or maintenance. For example, in the US WWII surplus

Table 1 Nagano avalanche warning parameters

| Nagano Prefecture avalanche warning guidelines | | | | | |
|---|---|---|---|---|---|
| type | snow on ground | new snow | water equivalent | wind speed | temperature |
| slab avalanche | ≳50cm | ≳20cm | ≳10mm | ≳10m/s | not calculated |
| | ≳50cm | ≳30cm | not calculated | not calculated | not calculated |
| full-depth release | ≳70cm | ≳70cm | not calculated | not calculated | ≳5°C above avg. |
| | ≳70cm | ≳70cm | not calculated | not calculated | not calculated |
| all others | Avalanche activity not forecast / no warnings issued when weather data values do not fall within the above parameters | | | | |

rounds were the mainstay of many programs using recoilless rifles, however as ammunition supply dwindled, shells became harder and harder to attain, which has led to a slow phasing-out of the use of such armaments, and the requirement to find alternative measures.

### 1.2. The Japan situation

Japan's avalanche problems are similar to those of other developed countries, however often thought to be a step behind in implementation. Permanent measures are the status quo, and programs utilizing temporary measures are rare, in part due to the difficulty getting around explosives regulation. In the world of commercial winter recreation, responsibility for out-of-bounds travel is shirked of by ski areas, and backcountry travelers often seen as mavericks. Proactive application of avalanche forecasting technology to facilitate safer travel area wide or even in specific problem areas generally does not occur. Such is the case at the government level as well. Even today, governments only make provision for general issuance of area wide avalanche warnings based on a very primitive system of broad parameters (see Figure 1), whereby either everywhere has no warning issued (and could be perceived as safe), or a avalanche warning is issued (and everywhere in the region could be understood to be dangerous). The system makes only generalized predictions and in localized areas, although extreme danger could exist even when no warning is issued, especially in the case of recent heavy wind transport or sudden temperature increase.

In the Japanese recreational consumer realm, avalanche awareness is on the increase and avalanche education is becoming more proliferated. This is part due to a renewed understanding of the overall avalanche issue, regular news coverage of winter avalanche incidents, and the late 1990's onset of a backcountry ski and snowboarding boom in which consumers are being made to understand that when traveling in the backcountry they need to arm themselves with specialized safety gear and the knowledge to use it. Backcountry safety and avalanche awareness teaching is available to a wider market segment than ever before.

### 1.3. Internationally accepted practices

Hazard reduction measures for roads, ski areas, buildings, etc., take many forms and are implemented at all times of development. Basically these fall into the two following categories of permanent protection measures, and temporary protection measures. These are sometimes described as "static" or "active" or "hard" or "soft." Permanent, static or hard measures are physical things like snow sheds, and temporary, active or soft measures usually refers to the application of special methodology, like closing a ski run or road when avalanche danger is assessed as high. A number of major measures, and their use, non-use or possibility of use in the Azumi Case Study Area are listed the below (see Table 2).

Table 2 Internationally accepted practices and their application at Azumi

| | Preventative measure | Used at Azumi? | Usable at Azumi? |
|---|---|---|---|
| permanent | Re-route road—road realigned to avoid avalanche terrain | NO | NO |
| | Snow shed—covers road protecting from avalanche | NO | YES |
| | Snowfence—structure slows or stops snow movement | YES | YES |
| | Tunnel—passes under avalanche terrain avoiding hazard | NO | NO |
| | Earthworks—redirect and slows flow preventing loss | NO | NO |
| | Reforestation—anchors snow, reduces flow rates, eco-friendly | YES | YES |
| temporary | Pre-slide closure—area or building closed before avalanche | YES | YES |
| | Post-slide closure—prevents secondary accident | YES | YES |
| | Signage—reduces number of persons in slide area at one time | YES | YES |
| | Forecasting program—allows timely closure, active control | NO | YES |
| | Active control—artificial release to mitigate slide size, timing | NO | YES |
| | Avalanche education—people learn to reduce risk themselves | Some | YES |
| | Work crews use established practices—like beacon use | NO | YES |

### 1.4. Merits and demerits of permanent and temporary measures discussed

Permanent measures exist in the form of bridges over, or tunnels under avalanche terrain, or other structures used to anchor snow or re-direct or reduce the destructive power of flowing snow. Permanent measures can result in a higher level of risk reduction, but usually come at a higher cost. Construction fees are great, building causes environmental damage, and eventually steel and concrete used must be disposed of and / or replaced. Construction of permanent measures may also result in overbuilding, as, for example, a snow shed is constructed permanently it may only be needed 10 times per season. Protecting achieved in summer it is higher than required and often seen as wasteful if not an eyesore. Scale of project, terrain, budget or environmental restrictions are limiting factors in the establishment of permanent measures. Often low use levels, or the low perceived need for risk reduction, may not warrant high expenditures.

On the other hand, programs including temporary measures may have lower set up cost, but especially do require constant maintenance, and often seasons of dedication by experienced personnel. Environmental disturbance occurs with the use of explosives, although wildlife has often migrated elsewhere or is in hibernation. Such programs often require coordination of different departments of different industries labor costs man also be considered high.

### 1.5. Active control & Western explosives history

Temporary measures are often utilized to complement, or make up for deficiencies in programs utilizing permanent measures. These are often as simple as road closure. A great portion of these involve forecasting and programs of active avalanche control. active avalanche control is the intentional triggering of slides and done by ski cutting, by using explosive or exploding projectiles for slide size and timing mitigation on order to minimize the chance of natural slides that might otherwise result in the loss of life, property or time.

Avalanche control is done all over the world by highway departments, ski resorts, mining operations, railroads, utility companies and other industries and has nearly a 100 year history in America; North American miners use of explosives for avalanche work is referenced in literature as early as 1910. Especially after WWII, the large body of military explosives application knowledge in the Europe and North America was of a great asset to the development protection programs used on National, State and private lands. In the West currently, both the public and private sector are allowed to maintain use

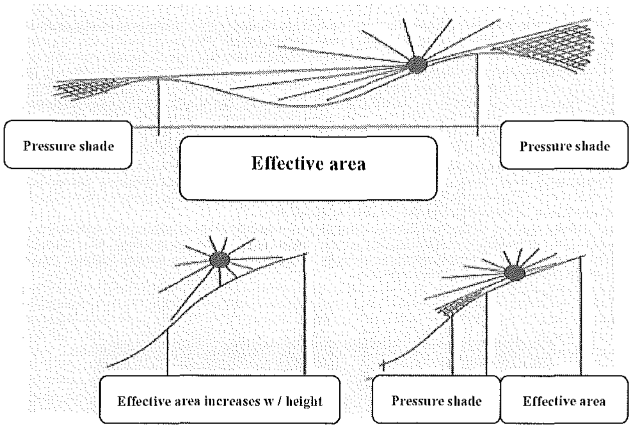


Figure 1 Explosion effective zone and shadow area
Drawing based on original SLF document

explosives as well as fixed and mobile artillery in programs of active control.

Avalanche control involves forecasting snow instability, and applying explosive charges to generate elastic stress waves to initiate shear fracture propagation which can artificially release unstable snow. Artificial release is this is done during times of intentional road, railway, ski area, etc closure to ensure the safety of users from the effects of a controlled release. In transportation scenarios, after active control work, snow deposits are then cleaned up by snowplow crews and then the thoroughfare re-opened. A staff member skilled in avalanche forecasting is integral to programs of active control to ensure best results when timing artificial release activities.

Generally, successful avalanche release by explosives depends on the stability of the snowpack, the total explosive energy of the charge and the location of the explosion relative to the slope and the snow surface. Stress waves created by the explosion attenuate rapidly within the snow, and carry farther through the air ensuring better fracture propagation. Charges detonated aerially above the snow surface stress the snow over a wider area than those exploded in or on the snowpack.

### 1.6. Temporary measures for consumers

At the consumer level, one is primarily limited to temporary measures such as avoidance of problem areas or limiting entrance to avalanche prone slopes and run out zones during times of anticipated snow stability. Programs to inform, educate and protect individuals during non-commercial recreational pursuits have become popularized since the 1970's through various government and private education bodies.

### 1.7. Japan measures and avalanche explosive use history

On some roads financial or other resources may not exist to facilitate adequate reduction of snow slide or slush or ice flow hazards, or existing permanent protection measures may not provide adequate level of hazard reduction. Busy roads receive priority attention because of the higher likelihood of accident. As for larger-scale public projects throughout the country where there is funding available, there is a heavy reliance on permanent measures such as snowfences or earth mounds. Instigation of seemingly all-mighty technology lends to the attitude that government is or has addressed most of avalanche problems with potential to effect significant portions of society, which in turn has the ability to bring about complacency. In most cases some level of residual risk is generally accepted, so road closures are utilized on a retroactive basis.

Use of explosives is limited as their use highly regulated. Access to materials is difficult for both the public and private sectors. However rare, forms of active control can be seen such as on roads in Niigata, where in springtime large quantities of dynamite are used to effectuate full depth release. Recently, although ski areas permitted under the pretense they are situated in low hazard terrain, avalanches are common and ski area managers have begun to use active control. At Arai Snow Resort in Niigata, the home of the most progressive avalanche program. Nonetheless, at Arai the starting wage for an experienced avalanche tech is a mere 830 JPY per hour, indicating the low value placed on the particular skill set of the avalanche worker.

Current explosives law does allow for use of dynamite but stringent regulations covering manufacture, storage, and carriage result in high cost and reduced efficiency. To date, Arai Snow Resort is the only ski area known to regularly utilize dynamite for avalanche control. Arai was developed recently with Utah's Snowbird as a model and with avalanche control program input from Vail snow safety specialists.

## 2. Azumi case study introduction

### 2.1. Azumi as a representative problem

The problem area addressed in this case study is a two-lane corridor located in Azumi Mura (herein: Azumi Village) called the Kamikochi Norikura Super RINDO (herein: Forest Road). It is the sole winter access road between a well-reputed hot springs area called Shirahone Onsen (herein: Shirahone Hotsprings) and Azumi Village proper.

The road crosses slide paths for at least 1 km before passing through the Hirukubo tunnel at the pass. Areas, on the other side of the tunnel are less problematic, yet slide prone. Recent avalanche accidents on this Forest Road and other thoroughfares indicate existing avalanche protection plans including both currently utilized temporary and previously constructed permanent protection measures demonstrate an inadequate level of hazard reduction.

Illustrating the ineffectuality of the existing system are values taken from reports of the New Years' holiday period incident in 2003. On the 5th of January 151 persons were involved in or directly effected by a series of avalanches along the road (Table 3). This resulted standing by or deployment of 112 rescue personnel and 48 vehicles, and resulted in a huge expenditure of resources and significant losses in damage and lost business. The 2002-3 winter season was of particular notability as were accidents and the total number of days where a partial or total closures (22 days) was imposed.

### 2.2. Economic impact review

The economic activities of the Shirahone Hot Springs Resort businesses have flourished and become extremely are important to Azumi village, especially in light of declining ski patronage at the local ski areas. The highest rate of tax collection occurs in Shirahone. Businesses reported that revenue loss during a 3-day holiday period due to avalanche related road closure was estimated at 10,000,000 JPY. Especially since the earning potential is so great in holiday times during winter, it is imperative that a balance be achieved between the risk of keeping the road open and reward from using it. Both actual closures as well as the threat of closure have serious negative economic impact on Shirahone Hotspring's tourism-based economy. The current volume of traffic now may warrant the additional expenditures on hazard reduction, but the same may not have been true when the road opened for business during winter. Certainly the economic potential did exist, but it is unclear if this was factored into the equation allowing national funds allocation for preventative measures.

### 2.3. Road responsibility ownership and programming features

The Forest Road was not always a public thoroughfare. With its roots as a forest work and logging road, with funds from the national government and as a major public works project the Forest Road was

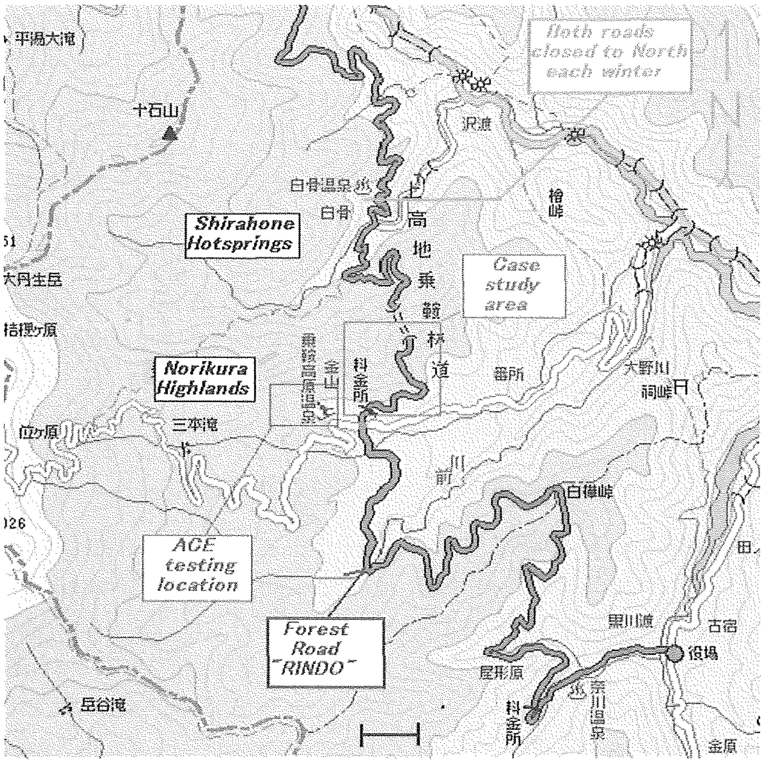


Figure 2 Forest Road and Azumi area map

Table 3 Fire Bureau report of Forest Road avalanche accident details

| January 5, 2003 Forest Road accident statistics | |
|---|---|
| Deployed official vehicles | 24 |
| Officials and staff deployed and on standby | 112 |
| Involved (victims) | 151 |
| Injuries | 2 |
| Number of vehicles buried | 16 |
| Cost of deploying vehicles and staff | 2,700,000 JPY |
| Cost of damage to official vehicles | 1,000,000 JPY |

opened from Nagawa Village through Azumi to Shirahone in 1977. Almost immediately the road began to be formally be used for winter travel as well. With the long-term existence of the hot springs, and the addition of year round access, business flourished. At the same time the Forest Road becomes the sole lifeline for the hotsprings in winter.

Responsibility for maintenance of the roadway was juggled back and forth between public forestry corporations, with Azumi being responsible for the snowplowing since 1977. For the last few years, the local foresters union has been entrusted with the all road maintenance except this snow removal. Consequently the union and has collected for passage from each vehicle. Every fall the Forest Union hands the road back over to the Village, who does not collect a toll,

Currently during the winter season road management for the case study falls with the Azumi Village government, headquartered some 40 minutes away by automobile. As the only route to or from Shirahone during this season, the village does not charge a toll for passage, yet must maintain operation during a season with equal or higher operating costs than the opposite season.

A major features of the winter road management is that village government has is a policy of post

Table 4 Forest Road developments and management history

| date | date (Japan) | Road development and management history |
|---|---|---|
| 1970-1976 | S40-S46 | National Public Corporation for Forestry Development construction of 38 km Forest Road with national funds |
| 3/1977 | S47/3 | road management responsibility transferred to Nagano Prefecture |
| 4/1977-4/1984 | S47/4-S54/3 | road management transferred to prefectural "Artificial Forests Public Corporation" |
| 4/1977 | S54/4-H14/3 | road management transferred to Nagawa and Azumi Villages |
| 4/1977 | S55/11 | Azumi begins winter snow plowing and use of road |
| 1980 | S55 | 73.6m snowfence construction |
| 1981 | S54/3 | road management subcontracted back to prefectural "Artificial Forests Public Corporation" |
| 1981 | S56 | 55.2m snowfence construction |
| 12/1982 | S57/12 | "Artificial Forests Public Corporation" name change to Nagano Forestry Corporation |
| 1983 | S58 | 41.4m snowfence construction |
| 1989 | H1 | 87.4m snowfence construction |
| 1990 | H2 | 36.8m snowfence construction |
| 2001 | H13 | 52m snowfence construction |
| 11/2001-2002/3 | H13/11-H14/3 | road management resumed again by the 2 villages, management subcontracted to Azumi Foresters Union of the Nagano Forestry Corporation |
| 2002/3 | H14/3 | the villages as authority for Forest Road enacted into law |
| 2002/4 | H14/4 | road management subcontracted directly to Azumi Foresters Union |
| 2002 | H14 | 55m snowfence construction |
| 2003 | H15 | 32m snowfence construction |
| 2003/12 | H15/12 | winter road management subcontracted directly to Azumi Foresters Union |

rotation insuring that no one person is in one department for a long time. Due to this fact no single person has had long-term ownership of responsibility for road safety, and consequently, there has been no compilation of historic snowfall or snow slide specific data, hence encumbering the process to rational decision making with respect to snow safety. This needs to be addressed. With respect to avalanche accidents, until recently, have been managed as they occur with little foresight or prior planning.

At the village government level, few resources have been allocated to addressing the problem. Realistically, even if village government has become cognizant of the true potential hazard to life and property and adverse effect on the economy, at the time of writing there reportedly also remains the possibility of eventual permanent winter Forest Road use discontinuance, which precludes any chance funding. The challenge is now to, during the potentially short lifetime of the contemplated Forest Road use, bring the corridor up to standard, through means acceptable to decision makers, and affordable to their constituents.

## 3. Development of Azumi programs

### 3.1. Azumi budget constraints

The corridor was identified some years ago as a problem area immediately after the road was improved and formally opened to winter travel. Since the Village had no funds for large-scale projects, budget was made available for permanent measures at the national level. Lands surrounding and above the Forest Road are public, and work done on them is managed by the Prefecture Forestry Department. The agency assumed responsibility to design and implement a plan and allocate funds for a major avalanche protection scheme.

### 3.2. Measure selection

Of the wide range of technology available, not all options are necessary applicable to the scale of the problem in Azumi, or to the legal situation in Japan, like the military-grade weapons used abroad in avalanche control (Figure 3). A permanently mounted rifle like the one shown in Figure 3, this could not be used legally in Japan.

During the design phase use period a number of options for avalanche accident prevention have been available. Since the establishment of both the improved Forest Road and designation and of tree stands located above as Avalanche Protection Forests , and in line with Japan's tendency to rely heavily upon permanent measures, both artificial avalanche prevention forests plantation as well as a total of 88 concrete and steel I-beam snowfences (complemented by yet further plantation of approximately 100 trees per construction year) have now been established in avalanche zones which threaten the Forest Road (see Table 5). Original plantation was from 1970-79 by Azumi Village government.

### 3.3. Forest planning, measure selection and funds appropriation issues

Government regulation has steered the course of road protection program development. Once open, the winter Forest Road use situation at Azumi dictated an improvement in safety and reduction of hazard, and the measures selection was left up to the Nagano Forestry Department.

The system for awarding work at the Department, is one of direct ordering from the Forestry Department of engineering plans developed internally with assistance from a pre-appointed group of non-government consultant businesses of the Nagano Ringyo (Forestry) Consultants Association. The Associa-

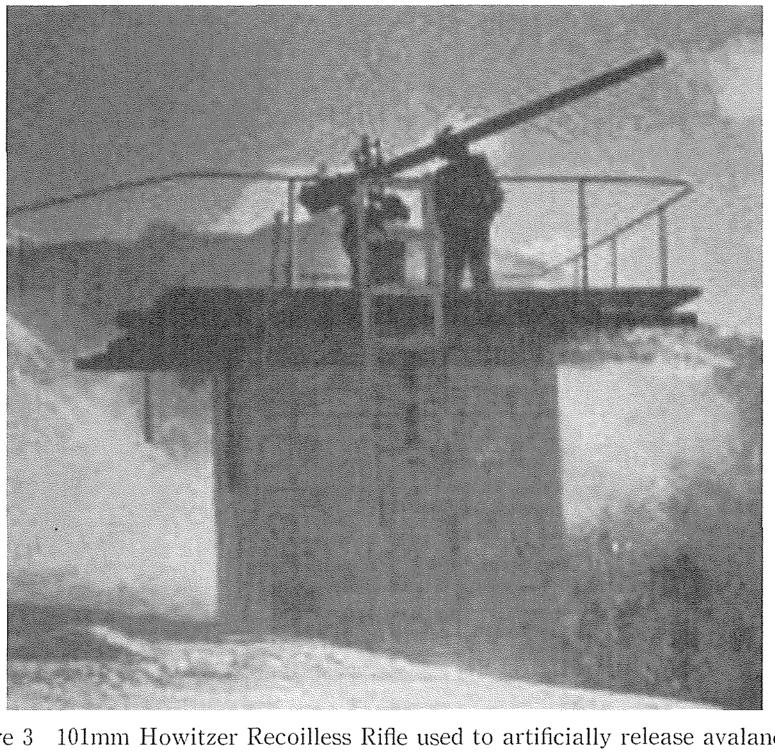

Figure 3 101mm Howitzer Recoilless Rifle used to artificially release avalanches
Alyeska Resort photo, Girdwood, Alaska, USA

Table 5 Forest Road snowfence costs

| Forest Road snowfence costs 1980-2003 | | | | | |
|---|---|---|---|---|---|
| date | date (Japan) | snowfence length | cost (JPY) | Approx. cost (USD) (1$ = 100¥) | cost per meter (JPY) |
| 1980 | S55 | 73.6m | 12,600,000 | 126,000 | 171,195 |
| 1981 | S56 | 55.2m | 11,650,000 | 116,500 | 211,050 |
| 1983 | S58 | 41.4m | 15,903,000 | 159,030 | 384,130 |
| 1989 | H1 | 87.4m | 29,901,000 | 299,010 | 342,116 |
| 1990 | H2 | 36.8m | 12,420,000 | 124,200 | 337,500 |
| 2001 | H13 | 52m | 28,000,000 | 280,000 | 538,461 |
| 2002 | H14 | 55m | 28,000,000 | 280,000 | 509,090 |
| 2003 | H15 | 32m | 14,879,000 | 148,790 | 464,968 |
| total | 23 | 433.4m | 153,353,000 | 1,533,530 | |
| | | | | | |
| averages | - - - | - - - | 6,667,521/yr | - - - | 353,837 |

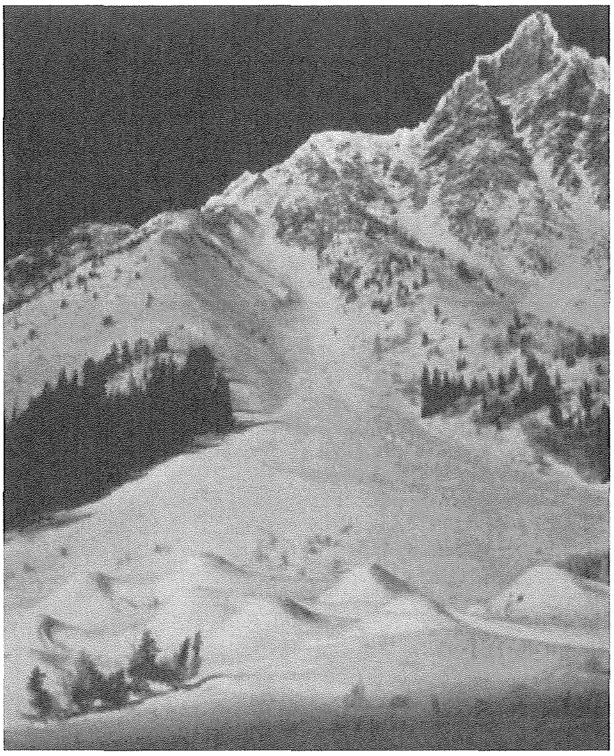

Figure 4 Large-scale permanent measures
(not suited to Azumi due to large size and land requirements)

tion rents space in the same or adjacent building as the Prefecture Forestry Department offices in a cozy arrangement. With respect to many projects originated in the Forestry Department, department, unlike other general bidding processes, Requests For Proposals are not sent out in the engineering stages, but designs are requested directly from the association member businesses. Once designs are decided upon, projects also are often not put out to bid but awarded to select pre-approved companies through a process called "ZUII KEIYAKU" or in English: "private" or "discretionary" contracting. For both tendered and discretionary contracting, it is a requirement that the recipient of the work must offices in the prefecture, and or sometimes the primary member of the company must be a registered taxpayer (i.e.: residing) in the locality where the work is occurring.

This process, common throughout Japan, disallows outside competition affects both pricing and technology introduction. Through this system, any contractor in Tokyo or elsewhere with desire to receive public works projects in the prefectures suddenly needs to maintain an office and staff in those individual prefectures year round. Pricing is driven up in this way. Granted consultancy firms currently in charge of the designs may have lengthy experience and a long list of qualifications the fact remains that in case of the Forest Road, ineffective systems including have been installed at tremendous expense to the taxpayer and the environment.

Snowfences are of simple design, are relatively simple to install, and were perhaps easily argued as the most practical solution for the corridor. The seem especially inexpensive if compared with today's cost per meter for snow shed construction (see Table 6).

Table 6　Snowfence / snowshed cost comparison

| Azumi area snowfence / snowshed cost comparison | | | | |
|---|---|---|---|---|
| tender date | tender date (Japan) | type | cost per meter (USD) (1$ = 100¥) | cost per meter (JPY) |
| 1980-2003 (avg.) | S55-H15 (avg.) | snowfence | 3,538.37 | 353,837 |
| 2002 | H14 | snowshed | 25,153.84 | 2,515,384 |

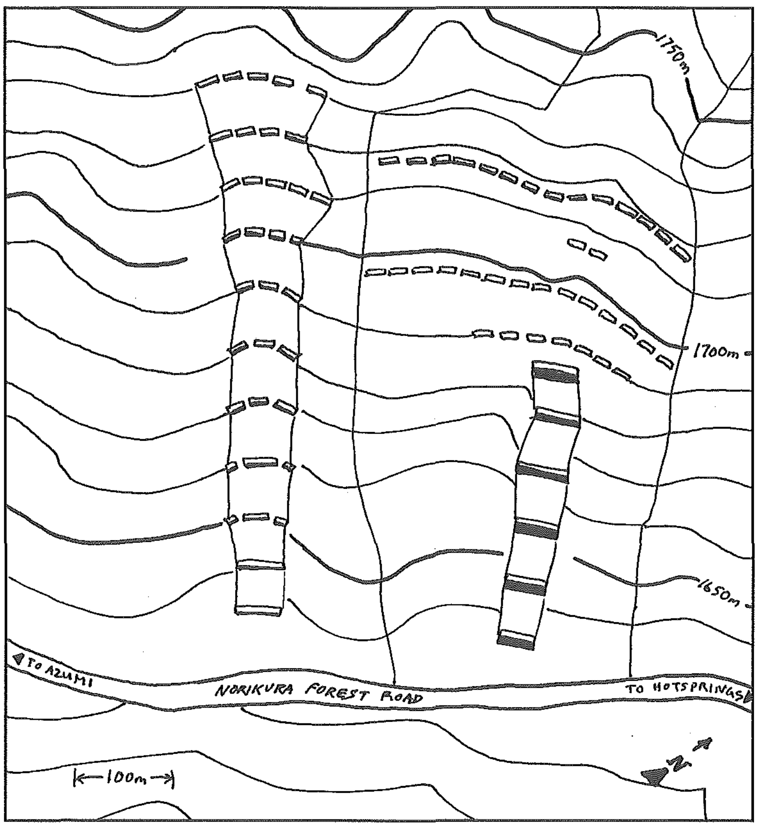


Figure 5　Map showing Azumi Forest Road, avalanche slide paths and snowfence locations (2003)

Figure 6 Azumi snowfences
Yoshikage Ito photo

Figure 7 Avalanche forecaster investigating snow stability
(this technique not used in Azumi)

### 3.4. Permanent measures analysis

During the course of road use, which has now lasted over 23 years, accidents occur almost every season. Even now with near total fence coverage and established artificial forests, all types of snow movement is not prevented. Dry powder avalanches during storms are especially problematic. Fences in existence in 2002-3 winter proved to function on a year average about 5% of the time, and in a 120-day season about on an average of about 16% of the time. The figure is extremely low on a year round average because there is no need for avalanche protection or the existence of structures such as snowfences for greater than 240 days annually. In 2003, of the 120 or so days of winter the road still required closure all or part of 22 days.

### 3.5. Recent additional temporary measures

In Winter 2003 additional temporary measures were adopted by Azumi Village. These include infrequent road closures, the decision for which is based on a blanket figure of ≧30 cm of new snow, rather than being based on the combined results of forecasting model for snow stability as found in most countries. The decision to reopen is made collectively and weighs primarily on input from a local "snow savvy" inn owner and local plow crews.

## 4. Active control in Azumi

### 4.1. Forecasting and active control proposed

It is advisable the current Azumi road protection program be upgraded to include a more modern, accurate system of avalanche forecasting. This would improve the decision-making capabilities of road managers so that road closure can provide safety, while open time and public benefit is maximized. If funds were available to make further improvement, the next option for low cost, small-scale improvements to the current avalanche safety plan could be to use temporary measures, inclusive of active control.

### 4.2. Active control methodology recap

Due to the dangerous nature of the work, in active control inclusive program of avalanche protection, only highly reliable methods and materials should be utilized. Workers are required place charges in avalanche start zones, but these are dangerous places for humans to be. The ability for remote placement utilizing hand deployment or other delivery systems is required to ensure safety of workers, as is the exclusive use of high-reliability explosives and igniters.

### 4.3. Japan explosives regulation recap

In Japan both high speed and slow speed explosives are available for use in avalanche work, yet they are covered by different sets of regulations. Under current Under Japan Law two regimes of materials classification exist for explosive devices. They are: "Explosives and Explosive Devices," (covers dynamite, pentolite, ANFO, and other high speed explosives used in avalanche work) and "Pyrotechnical Devices" or "fireworks" (covering mostly black powder based devices). Although these two groups of regulations may involve the use of generally similar materials, each category has come to have its own freestanding set of rules, which are more or less autonomous and independent of one another.

Figure 8 Western delivery system for exploding projectiles
Dopplemeyer Photo of Blaster Box, Austria. Crews remotely deploy charges from a safe area.
This system may be modified to comply with Japan regulations.

Under the Explosives and Explosive Devices classification, current Japanese regulation states that high detonation velocity explosives such as dynamite may not be thrown, dropped or launched in any way or carried in a helicopter or other aircraft by non-SDF entities. This means that if dynamite or other high -speed explosive substitute were used in accordance with Japan regulation and currently utilized domestic methodology in a program of active control, then avalanche workers must be unnecessarily exposed to avalanche risk during the placement procedure by virtue of having to manually place explosive charges in the avalanche start zone. According to practitioners, it was found that this problem has long been one of many stumbling blocks in the progress of active avalanche control protocol in Japan. For this reason, in Japan high detonation velocity explosives generally go unused in avalanche work.

### 4.4. Azumi active control solutions

There are methods and products potentially available in each Japanese explosive category and which utilize remote placement. These could be of use in the Azumi situation. One option from the Explosive Devices Category is to transport high-detonation velocity explosive charges to the avalanche start zone using a bomb tram. The option from the Pyrotechnical Devices category is to utilize new technology termed "ACE" (discussed later in this paper) via hand deployment. Currently, utilization of both of these means are rare to nonexistent, so scenarios utilizing the technology were considered for use on the Forest Road and are evaluated herein.

## 5. Hand deployment and bomb tram alternative research and methods

Travel was undertaken to Alaska and Washington State in America to investigate the nature of specific active control programs of avalanche protection at Ski Areas and Highway Departments. Locations visited were Alyeska Ski Area, Girdwood, AK, (Spring 2001 and ongoing visits) in State of Alaska (herein: AK) Department of Transportation (herein: DOT) Girdwood Station, Girdwood, AK (January 2002), Alpental Ski Area Pro Patrol Avalanche Safety, Snoqualmie, WA (December, 2002), and Washington State (herein: WA) DOT Avalanche Safety Division, Snoqualmie, WA (December, 2002).

### 5.1. Alaska active control situation

The Chugach Range has excessive snowfall and steep slopes. In the Girdwood area, Alaska Railroad, State of Alaska Department of Transportation (AK DOT), State Park Service, National Forest Service, Alyeska Resort and local heli-ski company all share weather and other information used in snow stability forecasting.

Table 7 Sites visited and measures investigated

| Date | Location visited | State or Prefecture | measures used | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Snowfences | Tunnels | Bomb trams | Artillery locations | Heli bombing | Hand deployment |
| 03/2000 | Alyeska Resort | AK | 0 | 0 | 4 | 1 | Yes | Yes |
| 12/2001 | DOT | AK | 0 | 0 | 0 | 5 | Yes | Yes |
| 12/2003 | Alpental Ski Area | WA | 0 | 0 | 13 | 3 | Yes | Yes |
| 10/2002 | DOT | WA | 0 | 0 | 17 | 3 | Yes | Yes |
| wtr. 2003 | Azumi Mura | Nagano | 77 | 1 | 0 | 0 | No | No |

Alyeska Resort in Girdwood is located at the western edge of the Chugach Range, mostly in Class A avalanche terrain and receives as much as 1,000 inches of snow at 1,000 meters elevation. Ski area is between elevations of 50 and approximately 1,000 meters above sea level, and the area has an avalanche control program with a 50+-year history. The resort is privately owned and budgetary restraints are a concern. Initial ski area development and ongoing expansion have kept practioners busy to provide adequate protection, and keep costs down. The resort has a Howitzer Rifle, 4 bomb trams and an extensive system of established bombing routes from which dynamite or similar products are hand-deployed. Since the Resort is a smaller, more contained site it is more suited to bomb tram use than the transportation operations.

The AK DOT Girdwood Station is responsible for the 125 km (72 mi.) section of roadway from South Anchorage to the community of Moose Pass. Seward Highway operations along the Turnagain Arm (part of the Pacific Ocean) has a large budget and is funded and operated jointly with the Alaska Railroad whose tracks run parallel to the highway and cross numerous avalanche paths. The transportation corridors are of huge consequence to the economy, and no expense is spared in their protection. Slide paths reach nearly 2,000 meters above sea level. Remote sensing equipment for forecasting, helicopter bombing by private providers and exploding projectiles shot from stationary mountaintop apparatus as seen in Figure 9 and trailer-mounted mobile military guns are commonly used in protection of the road and railroad.

### 5.2. Washington active control situation

The Snoqualmie Pass off of Interstate-90 is home four ski areas, one of which is Alpental Ski Area, as well as the WA DOT avalanche control programs. Located just 50 minutes from Seattle suburbs by car, the area sees extensive traffic and commerce. The highway, Interstate-90 is the major east-west transportation route between the ports and industry, and population of the northern United States. The pass averages 450 inches a year of typically wet snow.

The pass is home also to numerous permanent artillery mounts, mobile guns, hand-thrown avalanche explosive programs and 30 bomb trams between the WA DOT and Alpental. In particular, the publicly funded DOT bomb trams are exemplary and described below. Here too there is great cooperation between public agencies and the private sector; an extensive network is used in the gathering and exchange of weather and snow forecasting related information in connection with active control applications.

### 5.3. Bomb tram development and use as possible loophole in Japan regulations

Bomb trams are used quite extensively in the Western US and effectuate aerial deployment of explosive charges by way of delivery by light-duty cableway as described above. The role of an avalanche charge is to affect a weak spot in the snowpack to effectuate a slide. At the same time, charges buried in the snow or placed at the snow surface have only a limited reach, because the explosive force attenuates within the snowpack with distance from the charge center. The effect of the charge is often depleted or absorbed before it reaches a weak spot which might otherwise allow fracture propagation, culminating in a non-result. Since this is an incomplete test, and could only be otherwise tested with multiple shots even on an isolated slide path, the idea arose to expand the reach of the initial charge by elevating it above the snowpack.

Elevation of charges above the snowpack was historically done by affixing the charge to a bamboo pole stuck in the snow at the desired location. Dynamite is currently said to still be used in this manner at Arai Ski Area in Japan. Of course this meant the avalanche worker is required to enter the dangerous avalanche areas, so other means of remote delivery, including bomb trams have come to be developed.

The need for trams or other systems of aerial deployment became evident in places where placement was difficult or dangerous due to access problems, or it was assessed that aerial deployment of medium

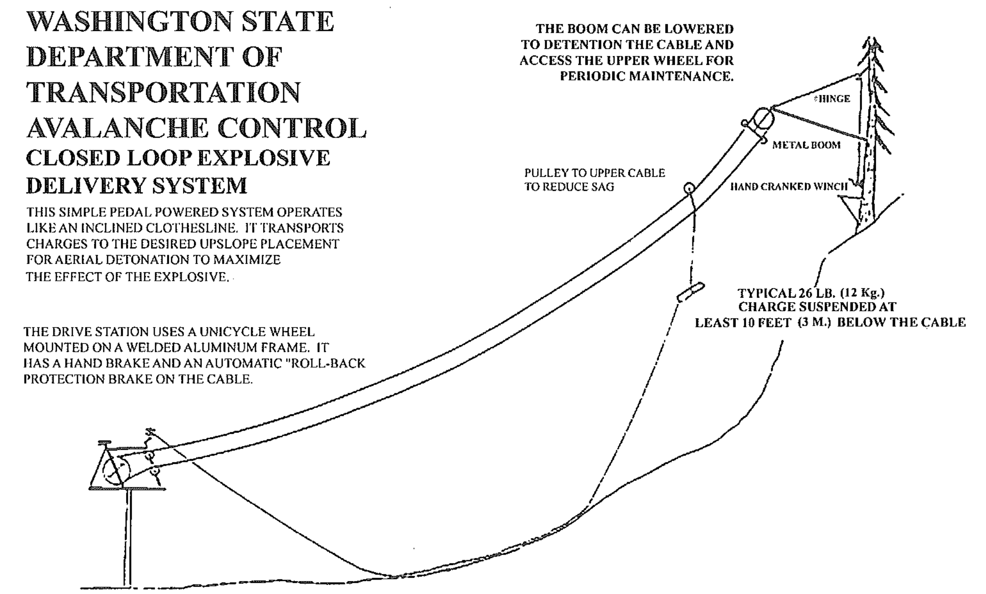


Figure 9 Raising type bomb tram
Image courtesy of Washington State Department of Transportation

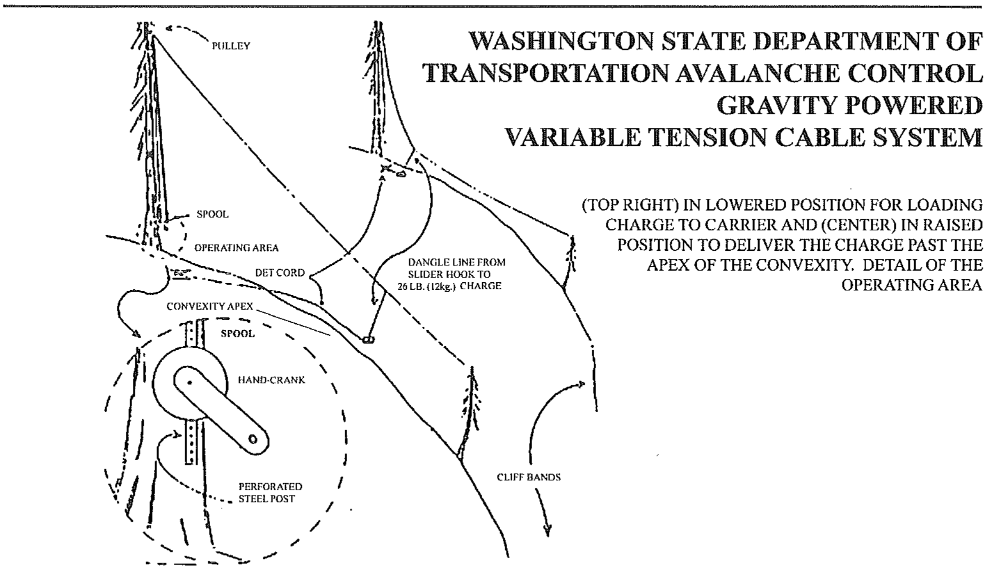


Figure 10 Lowering type bomb tram
Image courtesy of Washington State Department of Transportation

to large size charges has a wider reaching effect is therefore more reliable and cost effective than surface deployment in certain snow types or locations (see Figure 9-11). Due to the fixed nature of the bomb trams, placement accuracy is high. Bomb trams are discussed here because they could serve to circumnavigate difficulties in delivery of explosives to avalanche prone slopes in Japan while maintaining accordance with current explosives regulation.

### 5.4. Inner workings of bomb trams

At this time there are basically 2 primary types of bomb tram : Raising type and Lowering type. The Raising type requires has a human powered drive station at the base. Using manpower and a modified mountain bike as the drive station, the possibility of mechanical failure and unnecessary electrical current generation is reduced. The lowering Type is essentially gravity powered, variable tension tram. Either can be built with 5mm galvanized steel cable and are shown in the images and figures 10.

Trams are suited to most mid-range placement situations, offer a high degree of safety for the operator, can effectuate exact placement, and will trigger more snow than charges placed on the snow surface. Either bomb tram type requires access to a station at either the top or bottom of the slide area and both are of simple design requiring minimal setup.

### 5.5. Bomb tram application potential in Azumi

The Forest Road has accessible locations from which trams could be operated to protect the roadway. The raising type is probably best suited to the Azumi situation due to location of the road below the slide paths, and existence of safe zones at either end of the road corridor for placement of apparatus. Tram apparatus could be strung from points along the road outside of the avalanche paths and utilized to deliver explosive charges to the problem slopes above. The likely selection for charge size and make up would be 10 kg charges of ANFO with some kind of primer. Also, although cost totals for tram or alternate measures were not calculated as part of this study, it is assumed that tram use when coupled with ANFO (Ammonium Nitrate Fuel-Oil Explosive) at JPY1.820 (approx. 2 USD) would be a cost effective solution when compared to the cost of permanent structures either already built (Figure 5) or now in the planning stages. For possible tram locations in the case study area see Figure 11.

### 5.6. Hand throwing of charges-current options in Japan

At all operations visited in the US, dynamite or its equivalent is hand thrown into pockets of isolated instability. On the other hand, at this time in Japan such hand-deployed use of dynamite or similar substances is not an allowable activity. However, recently ACE (Avalanche Control Explosive) are being allowed to be hand deployed. ACE in the current or perhaps a modified form might be suitable to for use from a set bombing route or routes taken on foot in above the Forest Road to access avalanche prone

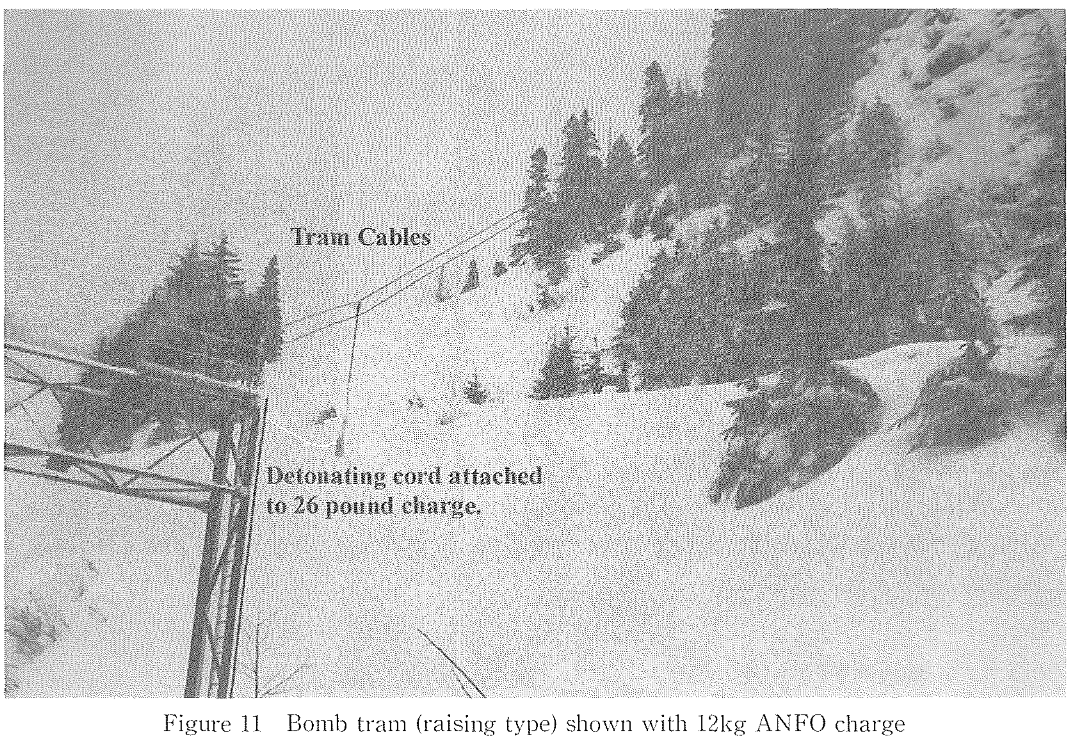


Figure 11 Bomb tram (raising type) shown with 12kg ANFO charge
Photo courtesy of Washington State Department of Transportation
Snoqualmie, Washington, USA

slopes. (see Fig. 12). However an arduous task, it would requires carrying backpacks full of charges uphill, though the snow to established locations from which to throw the shots.

## 6. ACE (Avalanche Control Explosive) testing

### 6.1. Classification history

Because ACE, categorically falls under the Pyrotechnical Devices (fireworks) classification, according to recent regulation interpretation. ACE are thereby legally "throwable". The product, after limited development in Hakuba, lobbying of the regulation authorities, and patenting, ACE have been classified in the same manner as such items like small "cherry bombs" which are used to ward of bears and other wildlife and a "fish bomb" which are used both as fireworks displays and to scare of marine mammals that occasionally interfere with commercial fishing operations. ACE are currently in initial use phases of avalanche work (utilizing hand deployment techniques) at 8 ski areas on Honshu, the main island of Japan.

### 6.2. Need for further investigation

Although to some degree availability of ACE charges has spawned a rush to try out the new technology, there is still only limited availability of information or effectiveness data is from which to judge ACE potential. To better understand and realize the utility of ACE in applications like those hypothesized in connection with bombing from set routes taken on foot in Azumi general research and elementary effectiveness experimentation were undertaken as part of this study.

### 6.3. Product make up

ACE consists of a 0.25kg (250 gm) single shot black powder charge tightly hand-wrapped in 13 layers of special paper with a match-strike type igniter. Black powder is a slow speed explosive. Slow speed explosives are argued to be suited to the purpose of dislodging cornices and other large formations of dense snow. On the other hand due to problem associated with moisture, duds and dud disposal, internationally the use of black powder and match-strike igniters has largely been abandoned for avalanche work. For similar reasons, pyrotechnician literature recommend against using the fireworks version of ACE during rainy periods.

### 6.4. Development background

In the development of ACE, the underlying idea was not to reinvent the wheel, but rather to utilize an existing authorized technology in an allowable form. To invent a large, all new, more powerful device, developer Koshihara explains, would only give rise to scrutiny by regulatory authorities such as the police forces that issue permits for each individual explosives application operation. The choice to use black powder stems solely from government allowance for hand deployment of the product. Powder volume also, was decided on the basis of what was already being allowed for rather than on the basis of what might be most suited to snow safety applications.

### 6.5. Developer testing

The extent of currently available test data is from when explosives testing facility KayaTech Inc. to test sound characteristics of ACE explosion as one would test a firework. Tests were performed side-by-side with the non-snow-use firework equivalent of ACE. Samples were exploded at the surface and at a height of 1.5, and readings were taken from a distance of 10 and 30 meters using a highly receptive, low frequency sound wave meter. The device measured A-weighted sound pressure level, and Sound Pressure Level (SPL) measured in decibels (dB). The only real conclusion that could be made from the research with respect to ACE use in avalanche work was that sound travels well through the air confirming that aerial

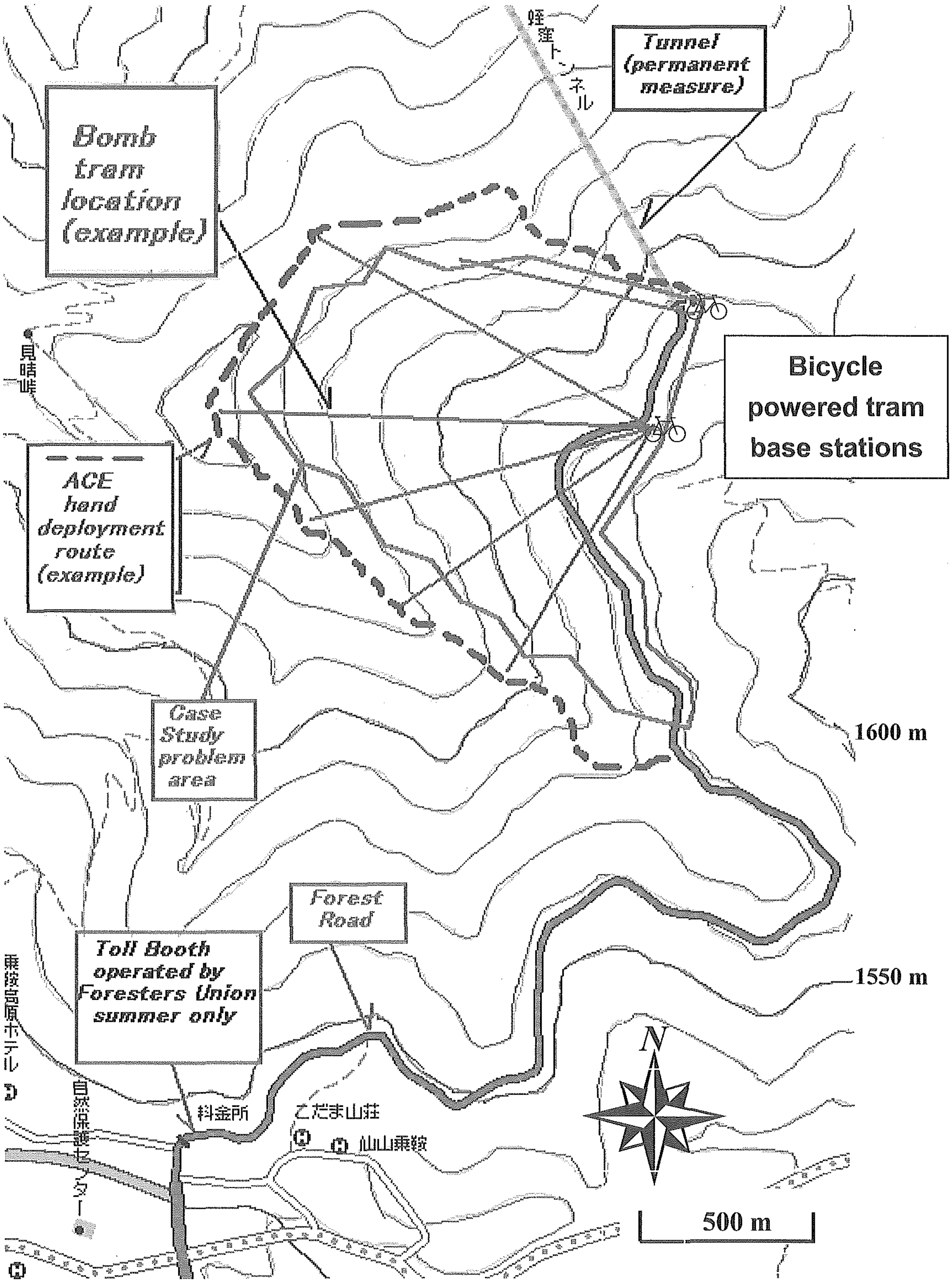


Figure 12 Azumi avalanche active control solutions map
Example of a system of bomb trams strung from the Forest Road situated below and ACE hand deployment footpath (bombing route).

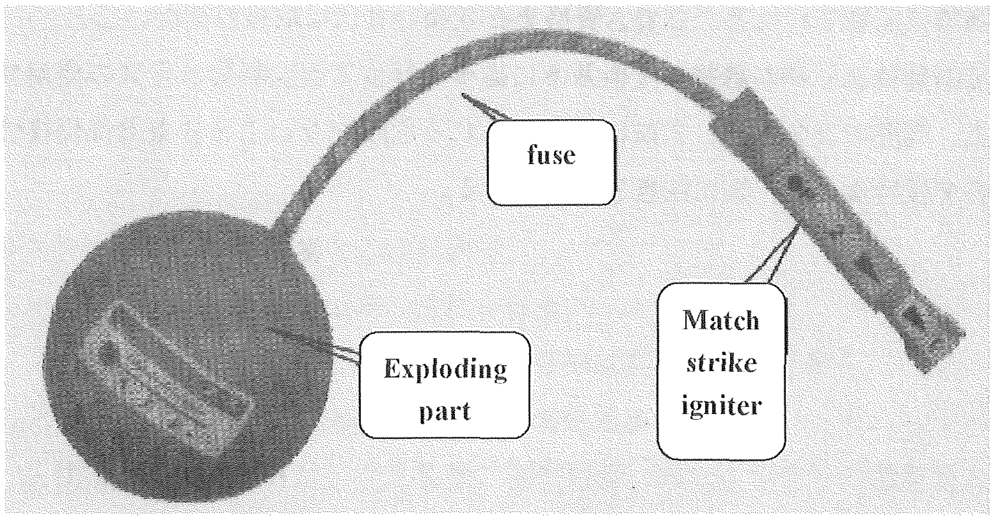


Figure 13 ACE body

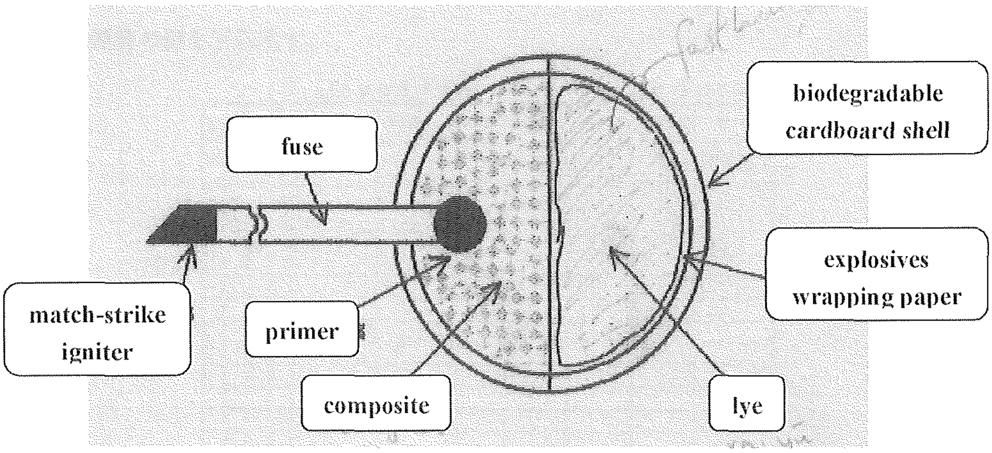


Figure 14 ACE Charge make up

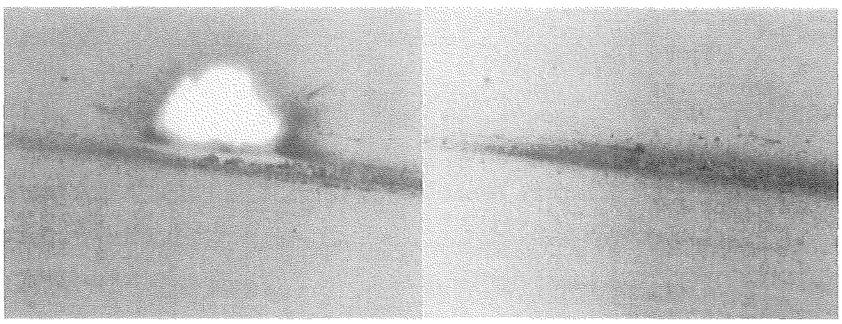

Figure 15 ACE explosion on hard snow at snow surface

deployment can probably affect a larger area than buried charges. Consequently, the reason buried charges sound muffled is because the shock is absorbed by the snow.

### 6.6. Swiss charge size comparison

Statistics on charge size from Switzerland, show no charge as small as ACE to be I use whatsoever. ACE may not carry the explosive power necessary for the job of artificial release. Charges of both high and low-detonation velocity deployed by various means in Switzerland average consistently nearly 7-16 times greater in mass than ACE. Charges as small as the standard ACE are never utilized, and in situations

Table 8 Charge size comparison

| data source | means | method | charge size | charge min/max |
|---|---|---|---|---|
| Switzerland (all types) | by hand | thrown | 1.70kg | 1.5-5.0kg |
| | tower | suspended | 2.00kg | 1.5-5.0kg |
| | swing arm | suspended | 2.00kg | 1.5-5.0kg |
| | cableway | dropping | 2.40kg | 1.5-5.0kg |
| | bomb tram | suspended | 3.30kg | 1.5-5.0kg |
| | helicopter | dropped | 4.00kg | 1.5-5.0kg |
| Japan (ACE) | by hand | thrown | 0.25kg | 1.5-5.0kg |

where wind might affect trajectory of launched or dropped charges, charge size average reaches 4 kg. Comparison shown in Table 8. Analysis of these values lend to the theory that ACE are not powerful enough for use in slope stability testing or slide size and timing mitigation.

## 6.7. ACE on-snow test details

Table 9 ACE test details

| | test # | date | time | aspect | slope | weak layer | charge height |
|---|---|---|---|---|---|---|---|
| Inclined slope | Control 1 | 02/18.03 | 06 : 30 | W | N/A | N/A | N/A |
| | 1 | 02/18.03 | 06 : 50 | W | 32 | Y | -30 |
| | 2 | 02/18.03 | 07 : 10 | W | 32 | Y | 0 |
| | 3 | 02/18.03 | 07 : 30 | W | 32 | Y | +100 |
| | 4 | 02/18.03 | 07 : 50 | W | 32 | Y | +200 |
| Inclined slope | Control 2 | 02/21/03 | 06 : 30 | E | N/A | N/A | N/A |
| | 4 | 02/21/03 | 06 : 50 | E | 25 | Y | -30 |
| | 5 | 02/21/03 | 07 : 10 | E | 25 | Y | 0 |
| | 6 | 02/21/03 | 07 : 30 | E | 25 | Y | +100 |
| | 7 | 02/21/03 | 07 : 50 | E | 25 | Y | +200 |
| Inclined slope | Control 3 | 02/24/03 | 06 : 30 | W | N/A | N/A | N/A |
| | 8 | 02/24/03 | 06 : 50 | W | 32 | Y | -30 |
| | 9 | 02/24/03 | 07 : 10 | W | 32 | Y | 0 |
| | 10 | 02/24/03 | 07 : 30 | W | 32 | Y | +100 |
| | 11 | 02/24/03 | 07 : 50 | W | 32 | Y | +200 |
| Inclined slope | Control 4 | 02/25/03 | 06 : 30 | E | N/A | N/A | N/A |
| | 12 | 02/25/03 | 06 : 50 | E | 28 | N | -30 |
| | 13 | 02/25/03 | 07 : 10 | E | 28 | N | 0 |
| | 14 | 02/25/03 | 07 : 30 | E | 28 | N | +100 |
| | 15 | 02/25/03 | 07 : 50 | E | 28 | N | +200 |
| | 16 | 03/07/03 | 08 : 10 | E | 28 | N/A | N/A |
| | 17 | 03/07/03 | 08 : 30 | E | 28 | N/A | N/A |
| No slope | Control 5 | 03/07/03 | 06 : 30 | E | N/A | N/A | N/A |
| | 18 | 03/07/03 | 06 : 50 | E | 0 | Y | -30 |
| | 19 | 03/07/03 | 07 : 10 | E | 0 | Y | 0 |
| | 20 | 03/07/03 | 07 : 30 | E | 0 | Y | +100 |
| | 21 | 03/07/03 | 07 : 10 | E | 0 | Y | 0 |
| | 22 | 03/07/03 | 07 : 30 | E | 0 | Y | +100 |
| | 23 | 03/07/03 | 07 : 50 | E | 0 | Y | +200 |

### 6.8. Testing location

Norikura Ski Area is on leased and private lands immediately adjacent to the lands above the Forest Road. Two ACE test sites plots were used, located on the North and south sides of ToriOne ("Bird Ridge") within the ski area boundaries, one site sloped and one not.

### 6.9. Test preparation, authorization and demonstration

Permission to test ACE was required from local authorities including prefecture and local police and fire departments as well as the Ministry of the Environment. Due to the uniqueness of the experiments, there were media requests for coverage, spectators were not allowed due to the early morning timing, weather dependency of experiments, difficulty of access, and lack of staff necessary for supervision of

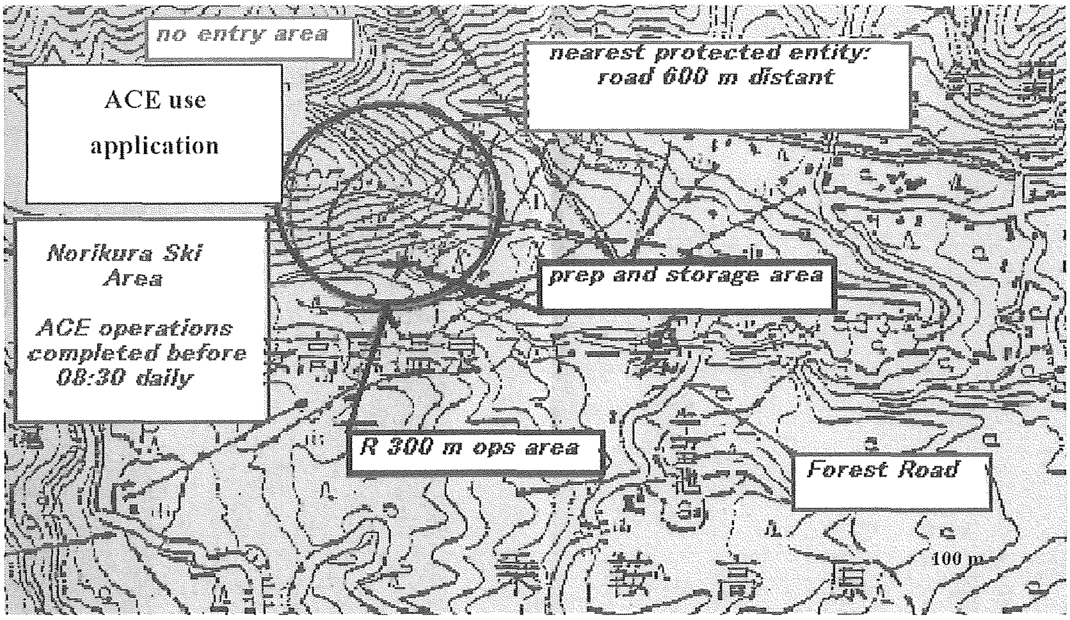


Figure 16 ACE Testing permission application map

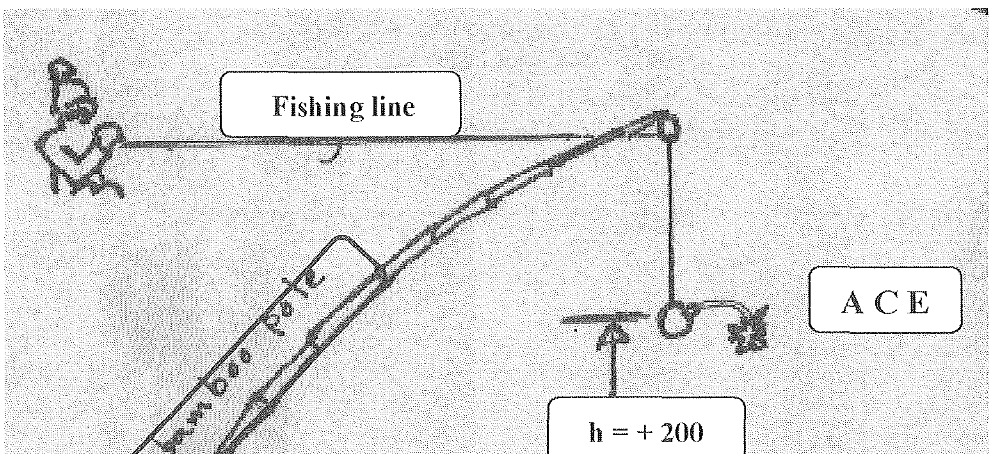


Figure 17 Improvised ACE aerial detonation technique

spectators.

### 6.10. Test materials, methods, equipment and tools

Common ski and snowboarding, snow sampling, communications, equipment and ACE were utilized. Transportation to testing locations was by ski lift, snowmobile and tracked ski slope grooming equipment. Avalanche rescue equipment was available at all times.

Charges were initially set on the snow surface in areas of probable slide activity. Despite weakness found in the snowpack, results after numerous attempts to release slides were all negative. For purposes of aerial detonation of ACE charges, an approximately 7m bamboo pole and common fishing line was used. Video images were recorded using a Mini DV camera.

Later, using an improvised aerial detonation technique, further testing was conducted at both flat and inclined locations in various snow and snowpack conditions. For this purpose and to evaluate the range and effect of ACE charges, they were suspended above the snow before detonation. Snow density, readings taken pre- and post-detonation and later interpreted. Charges were buried at -30cm or placed at heights oft 0m, 1m, and 2m heights above the snow's surface.

## 7. Test results

Exploding ACE below, at, or within 200cm of the snow surface causes deformation resulting in a depression or crater, however little evidence of slide release was evident even on inclines of 35 degrees.

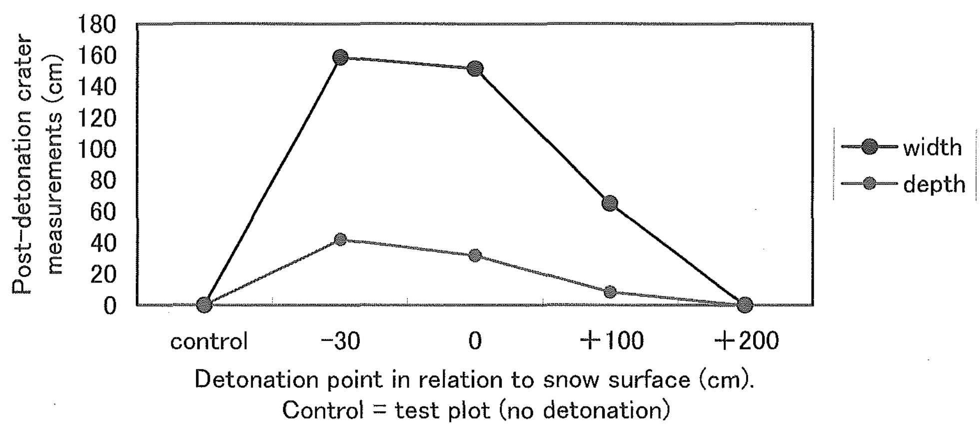


Figure 18 Crater size in relation to ACE detonation height
(Craters range from 0-160 in width and up to 50 cm in depth)

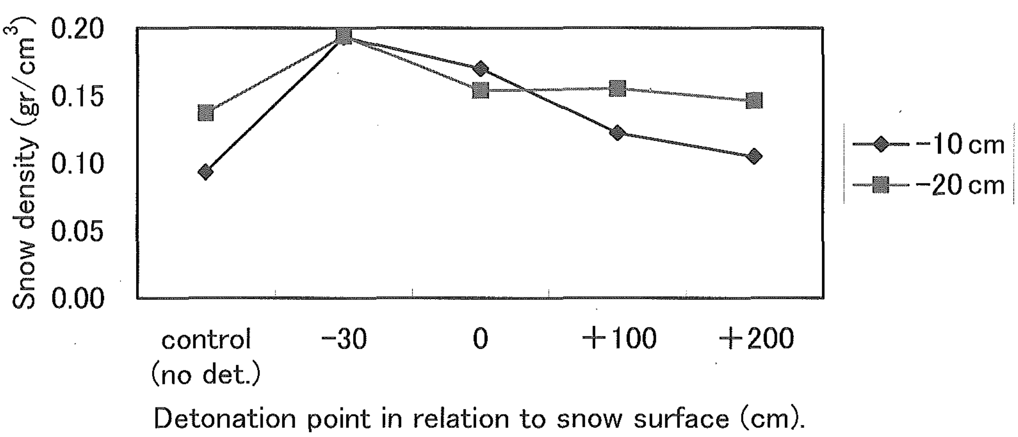


Figure 19 ACE post-detonation density change
(in snow surrounding crater)

Mixed results were seen with charges deployed at heights of greater than +100 cm showing little evidence of explosion the snow surface in most snow types (Figure 18). Only when detonating at the surface or buried charges in soft snow conditions were depressions of a maximum width of +150 cm were created.

Values for snow density change as a result of ACE explosion were taken at -10 cm and -20 cm depths and then are compared to control pit values (Figure 19, 20). Highest compaction was after explosion of buried charges, perhaps due to the lack of open space for the explosive force to dissipate into.

Under all snow conditions within charge-affected areas relatively small post-explosion increases in snow density occurred. In the following graph it is somewhat easier to compare density change at different explosion height with the control pit density readings (Figure 21).

## 8. ACE test discussion

### 8.1. ACE main tendencies and interpretation

Crater width and depth values were greatest at detonation height of -30 cm from the snow surface, at a detonation height of +100 cm are much less than that of at 0 cm, and at a detonation height of +200 cm are near 0. Fracture propagation failed to occur on slopes even when a weak layer was identified near the surface. Density change values were generally higher than the control site at detonation height of +100 cm, were negligible at detonation heights of +200 cm, and were negligible at a distance greater than +

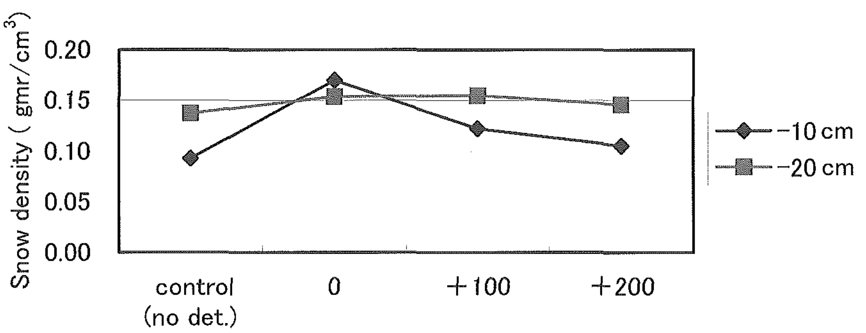


Figure 20 ACE post-detonation density change
(in snow surrounding crater)

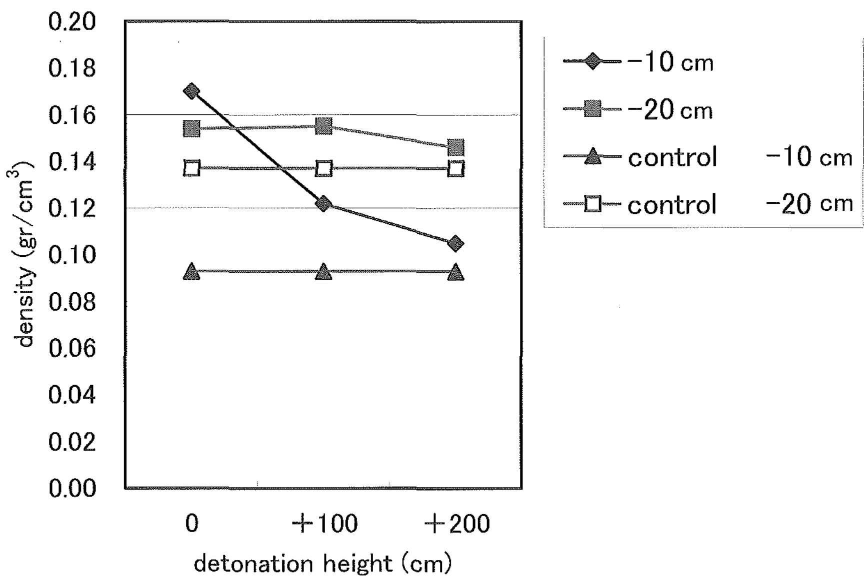


Figure 21 Comparison of density change averages

200 cm from the detonation point.

The difference between crater depth and width values between aerial detonation heights of -30 cm and 0 cm are not significantly different. Although the deepest readings were taken when charges were detonated below the surface, the greatest change in depth occurred when detonating charges at the snow surface. This is perhaps due to the requirement for more deeply buried charges (-30 cm) to first displace snow above the charge (and expend energy) before excavating any additional snow. Crater width and depth values at a detonation height of +100 cm are so much less than that of at 0 cm, it is concluded that the effective range of ACE is around +100 cm in all directions.

Depth and width values between aerial detonation heights of 0 cm and +100 cm are considerable. Based on the fact that little to no effect on the snow surface is evident at a detonation height of +200 cm, and no effect was seen at distances greater than +200 cm from the point of detonation, it is assumed that ACE use results in no fracture propagation effect in excess of this distance. Hence, as all results indicate the power of ACE to reach far within or across the snowpack to propagate fractures within weaker layers is very limited, even if pinpoint accuracy were achieved in ACE placement, due to the limited reach of effect, it would be foolhardy to assume that negative results (no snow movement) is an accurate test of snow stability. Furthermore, if the ACE product is in fact an ineffective tool, to ask avalanche workers to explode volatile fireworks in the harsh mountain environment is in effect needlessly assuming unnecessary risk. Unless ACE use is producing consistent positive results ACE use may be considered potentially unsafe and to thereby demonstrate low cost performance.

Table 10　Effective radius of charges used in Switzerland and ACE
(　　) = estimated value

| | detonation height | charge size | radius that will remain stable under 400 pa of pressure (nat'l snowfall trigger) |
|---|---|---|---|
| Switzerland (nationwide) | +3-3.5m | 4.0-5.0kg | 120-130m |
| | +1.5-2.5m | 1.5-2.5kg | 80-90m |
| | approx.+1m | 4.0-5.0kg | 80-90m |
| | approx.+1m | 1.5-2.5kg | 60-70m |
| | - - | 4.0-5.0kg | 50-60m |
| | - - | 1.5-2.5kg | 35-40m |
| | approx.-0.2m | 4.0-5.0kg | 40m |
| | approx.-0.2m | 1.5-2.5kg | 25m |
| | -0.7m | 1.5-5.0kg | 10m |
| | 0m | 3.0kg | 40m |
| | 0m | 0.7kg | 20-25m |
| | 0m | 0.6kg | 15-20m |
| | | | |
| ACE (AZUMI) | +2m | 0.25kg | (≦2m) |
| | +1m | 0.25kg | (≦2m) |
| | 0m | 0.25kg | (≦2m) |
| | -0.2m | 0.25kg | (≦2m) |

### 8.2. Effective radius data comparison by size

Also of note are the values found below in Figure 10. The figure compares commonly used Swiss explosive size to ACE. Charge size and use methods seen in the chart may be considered representative of international standard. Judging from the extreme difference I charge size, it can be hypothesized that the effective radius of ACE charges size is roughly 1/5 of the smallest charge size in use in Switzerland.

## 9. Conclusion

### 9.1. Bomb tram & ACE technology comparison

Research of both bomb tram and ACE technology and their comparison lend to valuable insight of the new Japan product and probable solutions for Azumi. Generally speaking, either system after some modification could be a viable low cost highly effective alternative for use at the Forest Road. A program using either technology would relatively simple in design and low cost making either a suitable choice for situations like that found in Azumi. However, due to the extreme difference in delivery capacity of a tram vs. the pre-determined and currently limited size of ACE and the resultant total explosive energy and results seen with use of either product, results of hand deployable ACE use are incomparable to that of charges potentially delivered by cableway.

### 9.2. Recommendations

The problem of avalanche risk reduction on these two road corridors, however much more complex than the author envisions, is thought to possibly be resolved at a lesser cost to the environment and taxpayers than typical permanent or measures. Action should be taken to enhance winter road security until a more comprehensive study can prove the feasibility of additional expensive permanent structures. Or in cases where permanent measures are not possible in the timeframe required, or have proven to not meet the desired level of risk reduction, at a minimum strengthening of the existing program is recommended, including active control where possible.

To increase safety and attain the best balance between time open and reduction of avalanche hazard risk, the function of road closure timing, should be left up a dedicated staff member skilled in avalanche forecasting using a recognized system of snow stability assessment. As necessary, an alternating, one-way traffic pattern without pilot car (like the automatic signals found at Japanese road construction sites) could also be utilized in problem zones to reduce localized congestion and increase traffic speeds as a means to reduce the time vehicles and persons are exposed to avalanche risk in the problem area.

Work on the Forest Road should include no new construction of permanent avalanche protection measures with the exception of upgrades to existing snowfence structures, artificial reforestation. Upgrades to existing fences could be made by covering the uphill side with netting or other material to create a smaller mesh over the effective area of the works, such as attachment of vertically lashed bamboo stalks or other environmentally friendly material some centimeters apart across the face of each structure, installation of nets between trees, and trees and snowfences to this same end.

Other measure improvements could include the incorporation hazard mitigation through the utilization of either of the two active control as technologies discussed in this paper. In case ACE were selected for use through hand-deployment or use with other means of placement like trams, it is recommended that the total explosive power be increased to the effectuate desired results in the use area, and that more weather resistant type of igniters be considered as an alternative. In case bomb trams were selected for use, the apparatus design should based on existing light duty, low maintenance foreign models. All the above measures would need be administered by specialists in conjunction with standard snow plowing techniques.

The nature of a winter road hazard mitigation scheme using active control is simply an expansion on a maintenance-type scheme of snow plowing, and has a re-occurring seasonal cost. Generally, the cost for a program of active control over 10 years is often lower than the cost to the taxpayer and environment than that of permanent improvements, which in case of the Forest Road could be easily funded through a slight increase in summer year-round road tolls at the existing booth used by the Foresters Union.

The combined result of these recommendations in conjunction with the effect of existing permanent measures would decease the avalanche hazard on the Forest Road to near zero, and not create any huge amount of waste such as steel and concrete structures do when they reach the end of their lifespan.

### 9.3. Forest policy issues affecting prefecture road planning

In conclusion, it is thought that bigger than the problem of which technology to choose, is the process by which technology is selected. In order for either of the options presented in this paper are able to be brought to the table during the planning process, other policy issues will have to be addressed. Government, in this case Nagano Prefecture must not just be of a mind to simply allow for the offer of such measures, it must actively seek them out and strive to include them in the selection process. To this end, adjustments to policy or procedural requirements are required so that new or alternate technology is able to be reviewed during public works planning processes. Without improvement of the establishment system of funds appropriation, participation by specialist companies with new technology, approach or ideas may be thwarted and best results not achieved. In case of avalanche measures, without such change in policy, government agencies are likely to see only offers of repeat performances limited mainly to establishment overpriced construction of permanent measures. In times of over-budget government, this is a dire problem.

## 10. Limitations of this study

The research project was a success in learning how to conduct experiments, and served as an introduction to forest policy for recreation areas. Numerous difficulties were encountered. In ascertaining the extent of effect of ACE detonation, the relatively small explosive force of ACE proved troublesome. Although it was assumed and ascertained that the effect of the explosion on the snow would be that of compaction, and higher density value in the affected area, it was difficult to gauge the range of the effect of the explosion on the snowpack beyond this point in the absence of successful artificial release. The expense involved in exploding ACE JPY 3,000 each also proved problematic. Since not many could be sacrificed on a small budget, ACE was not tested in a wide range of snow conditions, leaving the possibility that there are some snow conditions more suited to ACE use than those occurring at the time of testing.

## 11. Ongoing developments

In the summer of 2003, eleven additional fences nearly identical to those previously constructed were added to complement an initial 77 that were already in place in 2003 for a grand total of 88. Despite the continuing reoccurrence of avalanches along the Forest Road, their ability to prevent all types of snow movement is under scrutiny, the project received emergency funding. Also planned is increased reforestation either side of the Hirukubo tunnel entrance located at the Forest Road mountain pass, as well as areas in between existing snowfences.

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Figure 22 Additional permanent measures installed 2003
Yoshikage Ito Photo

Sameth at Alpental and Lee Reddin and Craig Wilbour at the WA DOT.

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## 冬季道路の安全性―長野県安曇村の事例研究―

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**Japanese Summary**

キーワード：雪崩対策，人工雪崩，花火，森林政策

本研究は，長野県安曇村の上高地乗鞍スーパー林道の冬季の雪崩に対する安全性について検討したものである。この林道は同村白骨温泉の唯一の冬季アクセス道であり，多額の雪崩対策が実施されてきた

にもかかわらず，必ずしも危険の低減に成功していないことが，2003年1月に22台の車両と乗客を巻き込んだ雪崩事故として露呈した。

米国ワシントン州やアラスカ州での雪崩管理システムと対比すると，日本では恒久的な土木施設による対策に重点をおく一方，雪崩の予報予知といったソフト対策に乏しい。例えば，この林道では2003年3月までの過去23年間において雪崩防止柵88基に約15億円をかけたにもかかわらず，積雪雪崩観測装置・雪崩予知システムの構築には投資をせず，スーパー林道の開閉も近年，降雪量のみを考慮して実施してきた。

ここで，欧米で一般的な積極的道路管理，すなわち大雪の予報，道路閉鎖，人工雪崩，道路除雪，道路閉鎖解除，といった一連のシステムのうち，人工雪崩のスーパー林道への適用可能性，安全性，合法性などについて検討してみた。まず，米国の道路管理局とスキー場で用いられている人工雪崩専用の簡易索道について，資料を収集するとともに現地調査を行った。さらに，日本で最近合法的な手投げ式雪崩火薬弾として開発されたACEという花火玉について，雪崩を効果的に起こし得るか否かを安曇村でテストした。この他，県や村の雪崩対策関係者と接触し，積極的道路管理への行政的対応について何が問題点であるかを探った。

これらから，人工雪崩用索道とACEとは安曇村で効果的に使用できる可能性はあるものの，索道火薬種類の変更やACE爆発力の増加など更なる技術的改良と同時に，こういった新しい防災システムを導入できる行政的環境の創出が不可欠であることが判明した。