DESIGN AND CONSTRUCTION OF SNOW SUPPORTING STRUCTURES FOR THE MILEPOST 151 AVALANCHE, JACKSON, WYOMING

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ABSTRACT: Reduction and management of avalanche threats to motorists on roads and highways threatened by avalanches can be accomplished by use of constructed defence structures (snow bridges or rakes) in the avalanches' starting zones. The United States (US) has, as a general practice, relied on forecasting and artificial avalanche release to manage risk. Due to increased traffic volumes on rural, mountainous roads, including interstate highways, the probability of interaction of avalanches with motorists increased. Consequently, US engineers and transportation officials have now begun to consider "other options" for avalanche hazard reduction, and these include constructed, or "passive" protective measures in the avalanche starting zones and run-out paths.

The Wyoming Department of Transportation (WYDOT) has evaluated options for constructed defence for the Milepost 151 Avalanche which threatens US Hwy 89/191 south of the community of Jackson. In 2006 a project was initiated to develop designs that reflect US domestic design methodologies and materials specifications for snow supporting structures (SSS) to be constructed in the 151 Avalanche starting zone. A US domestic design capacity, building on decades of European experience, has been established for the design and implementation of snow supporting structures (SSS) for the reduction of avalanche hazards in transportation applications.

The absences of SSS technology in the US is not due to a lack of avalanches. This absence can be attributed to two factors; the success of US avalanche forecasting and active control methodologies, and the unsightly appearance of SSS in alpine settings with high quality scenic attributes. The value of scenic attributes to be found on Federal or public lands is subject to the decision analysis process of the National Environmental Policy Act (NEPA) i.e. Environmental Impact Statements (EIS) and Environmental Assessments (EA). The NEPA decision criteria with respect to scenic visual attributes is known as "visual retention" and requires the visual attributes of the construction site and resulting facility be the same after construction as it was before. Collaboration between stakeholders on the 151 Avalanche lead to a SSS deployment configuration in the 151 Avalanche starting zone that mimics visual elements of the natural landscape. This organic configuration of SSS, coupled with botanical restoration, has successfully addressed NEPA visual retention requirements for the 151 Avalanche.

KEYWORDS: Avalanche, Hazard, Transportation, Snow Structure, NEPA, Visual Retention

INTRODUCTION

Reduction and management of avalanche threats to motorists on roads and highways threatened by avalanches can be accomplished with constructed defense structures (snow bridges or rakes) in the avalanches' starting zones. This has been common practice for highway and rail corridors in Europe's mountainous regions for many decades. In contrast, the United States (US) has relied on forecasting avalanche propensity at meteorological time scales, and then artificially release the threatening avalanche with a delivered shock source while the transportation corridor is temporally closed. Due to increased traffic volumes on US mountain roads, including interstate highways, the probability of interaction of avalanches with motorists increased. Moreover the direct and indirect costs-of-delay for road closures to conduct "avalanche control" as well as any resulting clean-up of debris has become large. On the order of US$ Millions/hour for delay for critical interstate highways. Consequently, US engineers and transportation officials have now begun to consider other options for avalanche hazard reduction, and these include constructed, or passive protective measures in the avalanche starting zones and run-out paths.

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BACKGROUND

The 151 Avalanche is located above US Highway 89/191 at Milepost 151 in Jackson, Wyoming. US 89/191 is four lanes and carries an

estimated 8,000 vehicles per day in the winter months. It is a well-known hazard and avalanches have struck vehicles, resulting in crashes, traffic delays, rescues, and attendant avalanche debris clean-up. It's a nasty little avalanche, see Figure 1.

Figure 1. The 151 Avalanche, Jackson, Wyoming (photo: NRippen).

The 151 Avalanche is not amenable to traditional avalanche forecasting and active control measures, though the WYDOT has an on-going regional program in this vein. The 151 Avalanche is adjacent a densely populated portion of the Jackson Hole valley floor where explosive shock sources would be a noise nuisance, and the attendant run-out zone of any resulting avalanches would spill onto private land, as well. The 151 Avalanche's starting zone is also designated critical big game (elk) winter habitat, and the use of explosive shock for avalanche control is incompatible with use of the same site for wintering big game.

Constructed or passive avalanche starting zone defense facilities have been systematically evaluated for applicability on the 151 Avalanche. These include the trial implementation of snowpack disrupting wind eddy generators, known domestically as "snow sails". This is European technology known, at least in German, as Kolktalfen. These efforts have been reported previously (Yount). More recently and in response to unacceptably high residual avalanche risk on the 151 Avalanche, even with snow sails, WYDOT implement research leading to a 65% design and engineering cost estimate for snow supporting structures (SSS) in the 151 Avalanche starting zone (Hewes, WYDOT). This was followed by installation of this design during the 2012 summer construction season.

US DOMESTIC SNOW STRUCTURE DESIGN

In the last decade, WYDOT has evaluated options for constructed defense for the 151 Avalanche. This is the first modern, domestic installation of this SSS technology in North America. The installation of 87 SSS in the 151 Avalanche starting zone utilized a traditional state department of transportation (DOT) procurement cycle, which involved private sector engineering design services, a separate construction contractor for installation, and DOT and US Department of Agriculture Forest Service (USDA FS) environmental oversight.

The US experience in the design and implementation of SSS for reduction of avalanche hazard in transportation applications is historically limited. Guidance for the design of snow bridges or rakes do not exist in the US. The pre-eminent document on the implementation of SSS for avalanche hazard reduction is the Defense Structures in Avalanche Starting Zones: Technical Guideline as an Aid to Enforcement, known as the Swiss Guideline (Swiss Guideline). It is a fully mature and comprehensive design guideline, but it does not prescribe all aspects of design of SSS, and in the case of the 151 Avalanche, snow bridges specifically. Furthermore, it references European design and material specifications that are similar, but not applicable for use by US transportation agencies and constructors. The Swiss Guideline serves as an invaluable starting point for the development of the methodologies and specifications for the design of SSS in the US.

In the design of the 151 Avalanche's SSS, the work of the authors took into account or integrated US domestic design practices for steel structures and micro-pile foundations from guidance and/or requirements of the American Institute of Steel Construction (AISC), the American Concrete Institute (ACI), the Highway Design Manual of the American Association of State Highway and Transportation Officials (AASHTO), and the Federal Rail Administra-

tion's (FRA) micropile foundation design guide. What result is the unit design for the 151 Avalanche SSS that is shown in figure 1.

Figure 2. Typical Snow Supporting Structures, 151 Avalanche, Jackson, Wyoming (photo: RDecker).

The results of these efforts is a US domestic design capacity for SSS has been established. The resulting 151 Avalanche SSS look, as one would expect, nearly the same as its modern European counterparts.

VISUAL RETENTION, NEPA AND SNOW STRUCTURES AS LANDSCAPE ELEMENTS

The absences of SSS technology in the US is not due to a lack of avalanches. This absence can be attributed to two factors; the success of US avalanche forecasting and active control methodologies, and the unsightly appearance of SSS in alpine settings with high quality scenic attributes. The value of scenic attributes to be found on Federal Land is one of a large set of assets that are managed by organizations like the US Department of Agriculture's Forest Service (USDA FS). The list management assets also includes water, wildlife, flora/timber, range/grazing, recreation, and cultural (religious and historic/archaeology), amongst others. The issue of Federal or public lands is two-fold. Most avalanches in the US come from public lands that are managed by the USDA FS. That is one reason many early avalanche technicians in the US, for both ski areas and highways, were Forest Service employees. Their job title was Snow Rangers (LaChapelle)! The 151 Avalanche starting zone is on USDA FS managed public lands. In this modern era and for the 151 Avalanche SSS specifically, the FS role is focused on implementing the decision analysis process of the National Environmental Policy Act (NEPA). NEPA is a decision making arena that relies almost entirely on the famous Environmental Impact Statements (EIS) and Environmental Assessments (EA) processes. The NEPA decision criteria with respect to scenic visual attributes is known as "visual retention". This is the onerous NEPA requirement that the visual attributes of a construction site, and the resulting facility, are the same after construction as they were before construction. The pre-construction scenic attributes are "visually retain" through post-construction. The distinction is subtle. If the visual quality of the site is, pre-construction, low; then construction impacts and resulting facilities do not have to result in any better visual retention after construction than low. However, many (and for some people nearly all) mountain areas have high quality scenic attributes, a priori. Hence, for SSS for avalanche hazard management to be used on public lands in the US, the post-construction scenic attributes must be the same as before construction was started.

So, along with doing work by supporting the snowpack to prevent avalanches, the 151 Avalanche SSS also need to be landscape elements that preserve and/or provide for visual retention.

Collaboration between USDA Forest Service landscape architects, DOT environmental consults and agronomists, and the design team's environmental consultant allowed for replication of landscape elements, using the deployment configuration of the SSS themselves, while also meeting the effective working distances needed between adjacent structures for sufficient snowpack load carrying capacity. The SSS themselves, or more accurately "organic" clusters of them, along with attendant restoration plantings, become landscape features that mimic the visual elements of the natural landscape. The primarily natural pattern in the landscape of the 151 Avalanche starting zone are triangles and diamonds of small conifer and mountain brushes (Dustin). The visual attributes in the 151 Avalanche starting zone change with aspect, as well. North facing aspects, with higher attendant soil moisture, hold these sparse conifer and brush stands, while the drier southerly and westerly aspects are entirely range grass prairie.

Figures 3a through 3c show digitally manipulated base photos of the 151 Avalanche with a typical, orderly deployment of SSS in the starting zone. Then with an organically configured deployment of SSS whose visual attributes are further developed with botanical planting/restoration. And, the SSS deployment prior to maturation of the botanical restoration. Note the placement of SSS in diamonds and triangles that mimic the landscape, at the same visual scale, as the conifer and brush stands in the foreground ridge and the one in the background, as well.

Botanical restoration is not re-forestation as it is often practiced in Europe, where forest stands of sufficient density may eventually take-over the snow supporting role of the SSS that protected them as saplings. Botanical restoration on the 151 Avalanche is part of an "engineered" landscape that utilizes the SSS themselves to assure that the high quality scenic attributes of the 151 Avalanche site are still high, post-construction. They are different, changed, but still retaining their valuable visual and scenic quality. The planting of ~400 locally harvested conifer whips and brushes around the 87 SSS of the 151 Avalanche serve to visually break-up the angular corners of the SSS, and to further mimic the same plant palate as seen on the foreground and background ridges. The mature conifer and brush stands of the foreground and background ridges are at their natural densities. At these densities, they cannot participate in supporting the snowpack and reducing avalanches, as many re-forested sites in Europe successfully do. The botanical restoration is a landscape attribute, but is not expected to provide avalanche protection.

Figure 3a. Virtual SSS in the 151 Avalanche, Jackson, Wyoming in a typical orderly deployment configuration (photo: RDecker).

Figure 3b. Virtual SSS in the 151 Avalanche, Jackson, Wyoming as landscape elements with botanical restoration (photo: RDecker).

Figure 3c. Virtual SSS in the 151 Avalanche, Jackson, Wyoming as landscape elements without botanical restoration (photo: RDecker).

CONCLUSIONS

A US domestic design methodology for SSS has been established that utilizes the venerable Swiss Guideline as an under-pinning, and not surprisingly, results in SSS that are typical in appearance (Swiss Guide). Nevertheless, domestic transportation agencies and constructors will seek SSS designs that utilize US engineering methodologies, specifications and material properties.

One obstacle to the use of constructed avalanche defense in the US has been addressed at the 151 Avalanche. NEPA visual retention has been successfully addressed utilizing and deploying the SSS in the 151 Avalanche starting zone as landscape elements themselves. The SSS are configured in organic clusters of diamonds and triangles that mimic conifer and brush stands in the natural landscape. Visual retention on the 151 Avalanche is further developed with botanical restoration through replanting of ~400 conifers and brushes. This botanical restoration develops visual qualities, but does not mature at sufficient densities to help resist the onset of avalanches from the 151 Avalanche.

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