TRAM IMPROVEMENTS ON SNOQUALMIE PASS

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ABSTRACT: Locally constructed explosive trams have proven safe and effective for delivering large elevated charges to inaccessible locations. There are 24 explosives trams in the Snoqualmie Pass area. Most of these have been in place for some time. Some of these trams have been damaged in various ways. Many have been improved by partially re-designing and rebuilding them.

The WSDOT avalanche crew has sixteen explosives trams, Alpental ski resort has seven. The Central Cross Country Center has one. We are dependent on the proper function of these trams. We have found we can reduce the number of problems we have with our explosives trams by use of extra care in the design and construction of more robust trams. We can reduce operational problems if we keep the tram design and operation as simple and standardized as possible. The more reliable a tram is the safer it is.

KEYWORDS: tram, carrier, cable, belay

1. INTRODUCTION

Any one tram can be called low maintenance. We have found with a fleet of trams that we are dependent on trained operators, a fair amount of maintenance, and a program of continuous improvement. We have established a tram log. The log describes all parts of each tram, when maintenance is preformed, upgrades, and problems with each tram. We have looked at problems we have had with each tram. We try to come up with ways to eliminate the problems.

Improvements in explosives tram design, construction, and operation techniques will be discussed that make our trams last longer, that make them more reliable, and that make them easier to use.

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2. TRAM TYPES

The trams on Snoqualmie Pass are built on three basic designs. 1. Variable tension single cable trams that use a slider link and det cord belay. Nothing needs to be retrieved after the charge goes off. 2. Variable tension trams that use a carrier and a separate carrier belay line. The carrier must be retrieved for the next operation. 3. Closed loop powered moving cable trams. These tram types are described (*Redden 1988*) and (*Gibson et al 2000*).

1. The variable tension single wire trams use gravity. We have access to the upper terminal of these trams. Det cord is used to belay the charge down into position and detonate it. These use a light duty steel carabineer we call “slider link” that is not retrieved. The slider link snaps on to the main cable and slides down the main cable. Open sided sliders were tried. Occasionally cable ice would force these to jump off the cable. The charge is suspended 2m below the cable and slider on the dangle line which is a piece of synthetic cord. These sliders with attached dangle line accumulate at the stopper. The slider links are only retrieved for reuse when the tram is maintained for other reasons. These trams are the simplest and most trouble free.

Long variable tension trams can be difficult to get the cable to the operator's location with out a convenience line to pull the main cable down, even with the cable slack. Gravity makes the cable pile up at the lower terminal. In this situation a convenience line is attached to the main line so that the main line can be pulled into the launch point. Further modifications have a properly tensioned convenience line that is attached to the main line and to the upper terminal tree so that when the main line is slacked the convenience line is automatically tensioned and the main line is brought to the launch location.

2. Variable tension gravity trams that have a carrier instead of a slider link are also used. These are more complex, and more things can go wrong. The extra problems occur with the carrier and the belay. Carrier design has evolved over time. The carrier must be retrieved right after the charge goes off. These trams have a carrier that is belayed as it rolls down the main tram line into position with a light cable or cord. The charge hangs below the carrier on a dangle line. The main part of these carriers is an industrial steel pulley that rolls down the main cable. Carriers are used on longer trams where a slider with a det cord belay is not practical, or to reduce det cord costs.

3. We have full loop trams. Some of these are variations such as multi charge, variable tension, hand powered trams. We have unicycle powered full loop trams. We have reduced the chance of roll ups in full loop trams with the addition of a swivel, and with careful carrier design with enough carrier weight hanging below the cables. When a full loop tram rolls up one revolution, the next 200 rolls come all too easy. This past season we had a roll up that involved hundreds of revolutions. It took 28 man hours to unroll. There have been others as bad. It is important to prevent the two cables from crossing each other. If they do, the lay in the cables appears to make them act like a den of snakes. The two cables can entwine themselves quickly.

We have found that when a single wire gravity tram has too flat an angle it is hard to get the charge to deploy if there is any cable ice. This is particularly true of multi charge single wire trams. We have replaced both of these multi charge trams with multi charge full loop hand powered trams. That way we can power the charges into position. Careful det cord belay management is particularly important in multi charge trams.

3. PROBEMS

Problems we have had with trams: Trees have fallen on trams. Ice builds up on the cables, and has broken a few trams. We have had infrequent vandalism. Snow can pack into either the drive or idler wheel of full loop tram during operation at either terminal. This can cause a derailment. The far terminal has been blown up. The far terminal tree has been killed over a period of 10 years because the charge was a little too close. Terminal trees have failed because they were not guyed. The charge was too close to the cable and broke the cable. Individual wire strands have been broken by charges that were a little too close to the cable. Charge carriers sometimes can't be retrieved by the belay line because the dangle line tangles around the main line or gets sucked into the carrier pulley.

Belay lines have been blown up. The belay line or spool needs some sort of brake in long steep trams. The belay line has been bird's nested on the spool. Cable ice has prevented a few successful operations. Trams lines have been tangled in the trees by the wind. Trams have been left with too much slack, and the belly of the mainline has been buried in the snow. The main cable cut through a nylon cord slider with in the first 10m of deployment. A factory det cord splice failed. We have run out of det cord when belaying a charge and the charge has gone ripping down the zip-line. The det cord was being spooled off of people's fingers and the spool got away and went flying down the hill. Det cord was looped back on itself in a multi charge gravity tram the explosion was "cut off" to the charge beyond the loop. Full loop trams have wound up. Off brand cable clamps have slipped and failed.

WSDOT has a small crew where every crew member has spent a fair amount of time working on trams. Alpental has a much larger crew with a wider range of experience and skills. This has led to additional tram challenges. A larger crew is handy when stringing long tram wires. Training and tram simplification has reduced many tram problems.

Some confusion has occurred when multiple people have worked on and modified the same tram. However, many people have contributed valuable effort and ideas to improving trams. It appears to work best when someone in a work group takes ownership of the maintenance and improvements of the trams.

4. SOLUTIONS

There is not a lot that can be done about trees falling on small trams other than to have plenty of spare cable, Crosby clamps, and a winch in inventory. Once we had personnel at both terminals of a tram when a large tree fell on the tram mid span. It was a scary moment, but luckily no one was hurt. Tree fall and cable ice that causes the tram line to break and vandalism have been quite infrequent.

Slack reduces damage from cable ice build up. Slack must be designed into trams. We are mindful of the sling angle and forces. The forces go up dramatically as the angle of each leg of a tram approach 90 degrees. The force at 60 degrees is double that of no angle. At 80 degrees the force is 5.8 times. Sling angle needs consideration when leaving the tram after use because of the weight of ice build up. Slack needs to be considered if the lower terminal is positioned by a bridle set up. The bridle position is adjusted with the proper amount of slack when constructing a tram with a bridle. The force is on both the tram and the anchors. There is always a balance between the proper amount of slack, and so much slack that the tram will tangle in near by trees with wind, or the belly will be buried in new snow. Our tram wire alignments are made by limbing trees when ever possible.

Ice build up can most often be removed by running the slider into the ice and pulling it back and repeating many times until the charge is fully deployed. When a belayed carrier is used on a single wire tram the burning fuse limits the amount of time there is for this. Safety in this instance must be considered. A dummy charge can be used to remove the ice. In a full loop tram, the iced cable can be powered into the top and bottom terminals before the charge is loaded. This is most often successful.

New snow buildup with just the right water content can be packed onto the drive or idler motorcycle or unicycle wheel of a full loop tram. This has caused derailments. The most recent far terminal design installed this spring includes a grove cutter bar.

We have eliminated the risk of blowing up the far anchors by the use of a stopper on single wire trams. The stopper is a connection of the main line of the tram to a separate line from the far anchor. This "stopper" can be a thimble to thimble connection of the two lines. The stopper connection replaces running the main tram wire and potentially the charge right to the far terminal. It is best if the stopper connection reaches the ground if the far terminal happens to be a tree. This facilitates construction and repair. If we were to completely replace a far terminal we would consider using one size larger cable from the far anchor to the stopper. This would almost eliminate the damage to the far anchor by ice and tree fall. The far terminal is most likely the hardest to access for repair. The stopper needs to be about 12-15m' from the far terminal tree to keep from slowly killing it with the explosive force of our standard charge. We use revolution counters on our unicycle powered full loop trams to keep the charge from being run "to block". We have added metal tags with proper revolutions for each charge on full loop multi charge trams. A hand cranked old chair lift sheave with liner makes a good drive wheel for a full loop tram where a lot of power is not necessary.

We have found that if a tram terminal tree is important then we guy it. Even if the tree is rather large it is guyed. Properly located and tensioned guy wires turn the forces on the tree or mast into a compression force. We have had a few "force on a tree over time" type tree failures. It can appear that the more important a tree is, the more likely it is to fall over.

WSDOT has standardized on one charge type for all trams. We have found that having to prepare several charge types for different trams can create unnecessary problems. WSDOT tram charges are prepared ahead of time without thought to which tram any charge might go to. The standard charge is 12.5kg ANFO in a woven poly bag (a standard flood sand bag) with a solid poly liner for strength and water resistance. This is primed with a .45kg cast booster that is inside the tightly taped bag that has a 50 grain det cord pigtail run out through the side of the bag. The cast boosters must be 50 grain det cord sensitive. The det cord used for the belay and initiation can be as small as 18 grain.

This standard charge also has 2.2m nylon or poly cord dangle line securely attached to the charge with hitches and tape. An ANFO explosion 2m below a steel tram cable does not damage the cable. A non conducting synthetic cord is always used for a dangle line between the galvanized steel cable of the tram and the charge. The booster inside the bag creates an opportunity for more complete combustion of the ANFO as opposed to the booster placement on the outside. A figure eight stopper knot in the 50 grain det cord on the back side of a booster will allow the charge to be retrieved if necessary.

Occasionally we increase the charge size, or we use an explosive with a much higher detonation velocity than ANFO, such as making the whole 13kg charge with cast boosters. When we use larger or faster charges we use .75m longer dangle line. This is to prevent blowing up our tram, or breaking individual cable strands with the added blast force.

Wind can blow the belay line into a tangle in trees, or the belay line can get blown up, or the dangle line can get tangled in the main line and prevent retrieval. Belay lie belly can be managed with commercial longline fishing "snap-on" links that are placed as the charge is belayed down the line. A long belay line can be quickly rewound with an electric drill. Belay lines are best managed on spools. Careful rewinding by holding constant tension keeps bird's nests from forming on the spool. A brake on the belay line or on the belay line spool for long steep tram can be necessary. We destroyed the brake on a Kolstrand commercial salmon hand troll spool on the first use. Bicycle caliper brakes or something as simple as a piece of leather work well.

Carrier design has evolved to reduce the dangle line tangles around the main line by the wind or the force of the blast. Carrier design also reduces the chance of the belay line being twisted around the main line after use. This is caused when the force of the blast throws the carrier up and over the main line. A piece of steel flat bar .64cm X 5cm (1/4"X2") from ½ meter to 1 meter long is attached to the block or pulley that rolls on the cable. The top of this flat bar is inside the block. The top of the flat bar must be well rounded to avoid the sharp edges acting like a sheer when the force of the explosion drives the bar up into the cable. About 1.5-2m of .825cm (5/16") chain or heavier is then attached to the bottom of the flat bar. It is best if the chain is in fire hose. The flat bar/chain length should be longer than the synthetic cord dangle line that is tied to the bottom of the chain. The blast under a carrier of this design is much less likely to tangle the dangle line around the tram main line in such a way that carrier retrieval is difficult.

We have found that a two pulley carrier is unnecessary and actually worse when the cable has ice on it. The two pulley carrier is also worse when ice freezes the cheek plates to each sheave. Icing of the sheave to the cheek plates could be reduced by putting grease fittings into each cheek plate.

The carriers have a light cable leader attached right near the bottom of the pulley. Keeping this attachment as high as possible helps reduce the amount of times the carrier belay line is blown up. Operationally it is important to hold tension on the carrier until the charge goes off. If slack is allowed, the belay line can be blown up.

A good carrier/ cable connection point for a full loop tram can use cable clamps built right into the carrier. This allows the extra cable necessary to slack the tram for repair to be stored coiled and taped to the carrier. An industrial pulley runs on the other wire. It doesn't matter whether the pulley is on the top wire or the bottom. The use of a pulley running on the other wire more than cuts the amount of cable sag caused by the charge weight in half. The load is shared between the two wires.

1/8" or 3/16" solid braid nylon cord prussic slings are handy for use on the cable to tension and de-tension it. If necessary these prussic knots grip can be reinforced with electric tape.

We have found the use of det cord spindles such as a ski pole rather than fingers is necessary for smooth reliable det cord pay out. These spindles are run through the center of the det cord spool and deep into the snow. We have placed one at every tram. Before spindles, we all laughed at the guy who let the det cord spool go flying down the hill out of his hands. This kind of preventable tram failure causes controllers to be belayed into the starting zone to retrieve the det cord end. Well, sooner or later it will happen to everyone. The det cord flying down the hill is not the fault of the guy who let it get a way, it is the fault of the design or poor planning. We also maintain positive belay control of the det cord after it has come off the spool by hand. This allows one more chance to stop the charge with the belay if the det cord is not spliced, or if the end of the spool is reached. We have had only one factory det cord splice fail in nearly 1000 spools of cord. Non-electric main line or shock tube is not strong enough to use for belaying our standard charge. The shock tube should not be stretched (*Holmberg et al 2002*)

5. SAFETY

Trams were installed to replace belaying a crew member into the avalanche starting zone with a case of dynamite taped to the top. A lot of tram construction occurs in trees and steep terrain that requires climbing gear and a well thought work safety plan. We carry a belay line, and parts, for emergency tram repair when doing control work. Over time the belay line has increased safety. WSDOT has 2 uphill trams that are unicycle powered. These are on elevated platforms 6-7.5m high. The charge is peddled up into place and the rim caliper bicycle brakes are set. A Kline grip cable roll back preventer is set. Then the fuse or non electric cap is attached to the det cord. These up hill trams should never be operated by peddling a lit fuse in a charge up from the operator's platform.

Thought should always be given to safe blasting technique. The more reliable a tram is the safer it is.

6. PIECES AND PARTS

The steel cable we use is foreign manufacture .826cm (3/16") 7X19 galvanized aircraft cable. This cable is about .17/foot from Pacific Industrial in Seattle in 1000m lots. This 7X19 lay steel cable is flexible and damage resistant. We have found that with proper dangle line length for the quantity and speed of explosives used, that tram cable life will be more than 15 years, or until a tree falls on the tram.

A non electrical conducting cord is always used for a dangle line between the galvanized steel cable of the tram and the explosive charge. Steel cable trams produce friction sparks with the slider link, and probably produce static electricity. Inexpensive poly or nylon cord with a breaking strength of more than 100 kg is used. We buy what ever is inexpensive and in stock in large quantities. The most inexpensive has been several 1220m spools of .318cm (1/8") poly twine.

The blocks or pulleys we use are steel industrial blocks with a 7.62cm (3") steel sheave and a maximum cable capacity of 1-1.25cm. The cheek plates must fit tightly to prevent an in block derailment, or to prevent any cable damage or extra rolling resistance from a partial cable pinch. Plastic sheaves will ware rather quickly when used with steel cable. The blocks we use have a becket bolt on the bottom. The becket bolt is usually not as strong as the attachment point on the top of the block.

Boat trailer winches make good tram winches. We have found that the $60 boat trailer winches are much better for tram use then the $30 models. Ice in the gears of a winch stretches the winch frame over time. A good winch on a tram that is used frequently will last about 15 years unless a tree falls on the tram line. The dog is usually the first part of the winch to break.

Small carabineers made from .826cm (3/16") steel make good sliders for variable tension trams and they cost only $.27 each. They are available in boxes of 100 from Pacific Industrial in Seattle.

Snap on commercial fishing links are available from Seattle Marine Supply.

We use large, long lag bolts at least 1.6cm X 25cm (5/8" X 10") long put into the side of the tree when possible. We use hangers made of steel flat bar or a large shackle. We do not use eye bolts or lag eyes. Eye bolts have proven too weak. Any time we wrap a tree we use wood 2X4's nailed to the tree or other similar protection under the cable wrap to protect the bark.

We have found that Crosby brand cable clamps last longer than inexpensive U bolt and saddle cable clamps. The galvanizing on the lay grabber inside part of saddle of the less expensive clamps wears off and then they slip. If we are working on a tram anyway, we are not shy about replacing cable clamps that have been in service for some time.

We have mounted a number of winches on Telspar that is mounted to the upper terminal tree. This allows the winch to be moved up as the snow gets deeper. Telspar is perforated square steel tube that is easy to mount, and easy to mount things to using the perforations.

Small motorcycle wheels work well for far terminal return or idler wheels for full loop trams. The far terminal is made as strong as possible. The far terminal of a full loop tram in most cases can be made more easily serviceable with the addition of the motorcycle wheel on a vertically pivoting boom that has a topping block arrangement and winch. In a bridle situation the same easy service/easy adjustment can be built with the use of winches and topping blocks. On closed loop systems we have had an increased amount of rolling resistance caused by 2 sheaves that were too small and were not properly aligned.

We have built operator platforms on some of our trams. These elevated platforms solve the large variation in snow level and tram geometry problems. It is useful to have a welder on the crew for a variety of tram fabrications.

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