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TUNNEL LINING STUDIES II

by

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SUBLIMATION CONTROL MEASURES OF THE PERMAFROST IN THE CRREL TUNNEL

INTRODUCTION

In the CRREL tunnel (Fig. B1,B2), sublimation is extremely apparent, but because of the tunnels limited usage it poses no significant problems. However, in an operating mine with forced air ventilation and continuously operating machinery, the problems associated with sublimation may no longer be insignificant. The dust released by the evaporating ice poses not only the obvious respiratory threat, but an additional safety threat, as fine silt suspended in the air reduces visibility, and removal or suppression of the dust will be of importance

THE SUBLIMATION PROCESS

An understanding of sublimation and its causes is needed before one can develop methods of handling sublimation. First, sublimation is simply the process of ice evaporating directly into vapor without passing through the liquid phase. In order for this to occur there must be enough "room" between air molecules to allow the water molecules to enter. In other words, the relative humidity must be below 100%.

The air in an enclosed area , such as the CRREL tunnel, will in time accept all the water it has room for. After that point it may exchange water with the surfaces it comes in contact with but it cannot accept any greater amount. Saturation has occurred and sublimation must stop. However, if the sublimation does not stop, either the air is losing moisture somehow or it is being exchanged with unsaturated air.

During the winter months when the outdoor temperature is below that of the tunnel, the tunnel exits are opened to allow the cold winter air to enter and cool the tunnel's permafrost surface. The effect of this winter cooling plus summertime refrigeration act together to keep the permafrost frozen yearround. The outside air has a very low relative humidity and therefore picks up moisture quite readily as it passes through the tunnel. Between the process of sublimation and the process of air exchange the wintertime relative humidity balances out around 64%. In the summer months when the tunnel portal and ventilation shaft are closed the relative humidity inside the tunnel should rise to 100%; however, it actually drops to around 55%. This unexpected relative humidity lead to an examination of the tunnel's refrigeration system. It was found that during the summer months the refrigeration system removed between 8 and 12 gallons of water daily. This figure when applied with the tunnel's estimated volume of 84,600 cubic feet, air temperature of 26 degrees and average soil water content 74% + or - 20% yields a calculated sublimation rate of around 0.025

inches per month. This calculated sublimation rate varies little with an observed sublimation rate of around 0.023 inches per month (Wellen 1979).

Under working conditions the heat liberated by machinery, personnel, and ventilation would require a larger refrigeration output. This increase in refrigeration would in turn increase the rate of sublimation, making its control all the more important.

SUBLIMATION CONTROL

Ideas for two approaches of handling sublimation have been considered. The first approach applies to areas where the particles comprising the permafrost are coarse enough not to become suspended in the atmosphere, or in areas where sublimation occurs at a relatively slow rate. The method is merely a periodic cleaning of the tunnel surface. This can be done with a device such as a vacuum cleaner. In the event that erosion due to sublimation occurs extensively enough to warrant repair, areas can be filled in with a concrete-like frozen soil mixture called permacrete.

The second approach consists of actually retarding the sublimation process. This can be done by two different methods, first, by raising the relative humidity of the air, and second, by inhibiting the moisture in the soil from interacting with the air.

The possibility of raising the relative humidity artificially was tested by setting up a humidifier of the wet cloth type in the tunnel. As the air passed through the unit its humidity rose from around 60% to nearly 100%. While this method proved to raise the humidity its feasibility is questionable, as the refrigeration system will either remove this additional moisture or it will become so iced over that it will essentially cease to function.

An alternate method of achieving a higher relative humidity would be to alter the refrigeration system so that it condenses less moisture. Alterations might include larger cooling coils that opperate at higher temperatures, and thermostat control adjustments which promote shorter but more frequent operating cycles. In any event, no more refrigeration should be supplied than is necessary to prevent excessive soil creep.

TEST INSTALLATIONS

Various materials were used as membranes to test the possibility of stopping or at least significantly inhibiting any interaction between the air and the moisture in the soil. Membranes studied were wood, plastic film, foam insulation, grease, and water. These were observed for a 145-day period, starting on May 4, 1979 and continuing until September 25,1979.

Sites for the testing of these various membranes were selected in the tunnel mainly on the basis of soil grain size. Two stations were erected, one on each side of the adit in an area were the soil was comprised mostly of silt-size particles. The water content varied from 67% to 120%, and some organic materials were present. All loose material was removed from the wall to allow the various membranes to be applied to as fresh a surface as possible.

The wood lining consisted of three boards measuring 1 x 6 x 20 inches (Fig. B3). The boards were nailed directly onto the permafrost surface to cover an 18 x 20 inch area. Irregularities in the permafrost surface would not allow the wood to fit flat against the surface over the entire area. Along the perimeter the gaps were filled with fiberglass insulation. At the end of the observation period the boards were carefully removed. Several measurements of the thickness of the dust layer behind them were made and averaged. This value was then compared to the average thickness of the dust layer on the unprotected surface surrounding the area covered by the boards. Both surfaces were cleaned of all loose material prior to the application of the wood. The wood lining proved to be about 46% effective (Fig. A1) in checking sublimation

Polyethylene was used as the test material for the plastic film experiment. Thin boards were laid on the perameter of the polythylene and nailed to the permafrost surface, thus making what resembled a picture frame with the polythylene stretched behind (Fig. B4). Fiberglass insulation was tucked in between the boards and the polyethylene to fill the gaps created by the tunnel walls' uneven surface. The finished covered area measured 12 x 15 inches. At the end of the observation period one corner of the polyethylene was cut loose and rolled back. It was immediately apparent that there was a definite color difference between the covered and uncovered portions of the permafrost surface (Fig. B5). The area that had been covered was much darker than the surrounding area. Its appearance was close to that of a freshly cut surface. Also noted were small ice crystals (approx. 0.5mm in diameter) thinly distributed along the back side of the polythylene. Sublimation measurements were made on the area in the same manner as described for the wood lining. The polyethylene lining proved to be around 90% effective (Fig. A1) in checking sublimation.

No actual installation was performed for the foam insulation test. Instead, an existing installation of urethane foam installed by CRREL in 1967 was used. This was done to hopefully get an idea as to the effects of long term membrane coverage. The CRREL installation consists of a small room lined with urethane foam insulation. The room was originally lined for the purpose of testing the possibility of heating portions of the tunnel. The room was supposedly never heated enough to melt the surrounding permafrost. A portion of the foam lining was removed from the wall to observe the conditions of the permafrost surface. A layer of nicely formed ice crystals measuring an average of

0.5 inches thick were adhered to the back of the foam lining (Fig. B6). Immediately behind the ice crystals was a 0.5-inch layer of relatively ice-free silt (Fig. B7). Beyond that the permafrost appeared intact. The layer of sublimated material in the areas adjacent to the lined room measured around 4 inches thick.

Two materials were used in testing grease as a liner, Chevron* automotive grease (Fig. B8) and Vaseline* petroleum jelly. The greases were rubbed onto cleaned portions of the tunnel wall. Within a few days the Chevron product would readily wipe off the wall, and the material directly under the automotive grease became soft and appeared wet. This was apparently due to an additive in the grease which lowers the melting point of water, as when a drop of water was applied to the grease it remained liquid, when a drop was applied to the vaseline it froze. The higher viscosity of the vaseline at the tunnel's temperature served to make the vaseline much more resistant to abrasion than the grease. Diffusion into the surrounding soil was a characteristic of both the grease (Fig. B9) and the vaseline. However,

(*The brand names of Chevron and Vaseline are used only to describe the materials involved in this project. Their use in no way reflects any quality of either the product or its manufacturer.)

the vaseline diffused much less than the grease. The vaseline expanded its boundary by a maximum of 0.5 inches. Sublimation measurements of these two linings were made by inserting a dissecting needle into the surface until it met some resistance (Fig. B10). These measurements were compared again to those of the surrounding area, yielding an effectiveness of 56% for the grease and 88% for vaseline (Fig. A2).

Water was by far the easiest membrane to install. It was simply sprayed onto the wall in light enough amounts to limit running and allowed to freeze before next application (Fig. B8). This spray and freeze process was repeated until a coat of 1 to 2 mm was obtained. The clear coating provided by the water added an optical quality to the wall that revealed a great amount of detail in the permafrost (Fig. B11). Such things as taber ice and folding of the silt strata became very visible. The water layer sublimates just as the ice in the soil sublimates (Fig. B12), therefore it requires periodic renewal. For the length of the observation period the surface was recoated three times. At the end of the observation period a series of holes were chipped through the layer to observe any happenings behind it. In most places this probing revealed solid material as expected, but on occasion a layer of relatively ice-free silt was found. For the most part this layer was barely detectable, (ie. less than 0.02-inches thick) but on one instance a thickness of 0.05-inches was found. The thicknesses of this ice-free layer were used to evaluate the effectiveness of the water layer. The result was around 94% (Fig. A3).

CONCLUSION

Overall comparison of the tested membranes shows that the best results occurred with polyethylene, water (ice). and petroleum jelly. The effectiveness of these membranes seems to be due to their ability to actually inhibit moisture migration, rather than simply block air flow. However, even with the impermeable quality of these membranes some sublimation occurred behind them. This is probably due to the air being maintained at a temperature below the natural temperature of the permafrost. The moisture in the wall migrates in molecular form from the warmer region to the colder region. This same process is considered responsible for the formation of lens ice. The formation of ice crystals behind both the polyethylene and the urethane foam offer support to this conclusion.

As for actual use the water (ice) layer is the most promising due to its effectiveness and ease of application. The polyethylene and petroleum jelly offer slightly less effectiveness. They are considerably more difficult to install but require less long-term maintenance than the water, as the water gradually thins due to sublimation.

REFERENCES

Wellen, Earl W. (1979) Sublimation of Ice in Permafrost Silt at The CRREL Tunnel (Unpublished M.S. Thesis. University of Alaska).

APPENDIX A
SUMMARY OF DATA

The tables listed in this appendix contain the data used in calculating the effectivness value of each of the membranes. The effectiveness value was calculated by subtracting the value of the average depth of sublimation inside the covered region from the average depth outside the covered region and dividing this value by the average depth outside the region. The headings "IN" and "OUT" used in the tables indicate wheather the measurement was made inside or outside the region covered by the membrane.

FIGURE A1

TYPE OF COVERING	WOOD		POLYETHENE	
MEASURMENT LOCATION	IN	OUT	IN	OUT
MEASUREMENTS OF SUBLIMATION AFTER A 145 DAY PERIOD (INCHES)	.15	.20	<.02	.25
	.15	.25	<.02	.20
	.10	.25	<.02	.25
	.15	.20	<.02	.25
	.10	.20	<.02	.20
	.15	.25	<.02	.20
	.10	.30	<.02	.15
	.15	.25	<.02	.15
	.10	.30	<.02	.15
	.15	.30	<.02	.20
TOTAL	1.35	2.50	<.20	2.0
MEAN	.135	.250	<.02	.20
STANDARD DIEVIATION	.3488	.379	---	.463
EFFECTIVENESS	~46 %		~90 %	

FIGURE A2

TYPE OF COVERING	GREASE		VASELINE	
MEASURMENT LOCATION	IN	OUT	IN	OUT
MEASUREMENTS OF SUBLIMATION AFTER A 145 DAY PERIOD (INCHES)	.05	.15	<.02	.20
	.10	.15	<.02	.15
	.10	.20	<.02	.20
	.10	.15	<.02	.15
	.05	.15	<.02	.15
	.05	.15	<.02	.20
	.10	.20	<.02	.20
	.10	.20	<.02	.15
	.05	.20	<.02	.10
	.05	.15	<.02	.15
TOTAL	0.75	1.70	<.20	1.65
MEAN	.075	.170	<.02	.165
STANDARD DEVIATION	.0264	.0258	---	.0337
EFFECTIVENESS	~56 %		~88 %	

FIGURE A3

TYPE OF COVERING	WATER 1		WATER 2	
MEASURMENT LOCATION	IN	OUT	IN	OUT
MEASUREMENTS OF SUBLIMATION AFTER A 145 DAY PERIOD (INCHES)	.02	.10	.00	.15
	<.02	.10	.00	.15
	<.02	.05	<.02	.10
	.04	.05	.00	.10
	.00	.15	.00	.10
	<.02	.15	<.02	.10
	.00	.15	.00	.10
	.00	.10	.00	.15
	<.02	.10	.00	.10
	.00	.10	.00	.10
TOTAL	<.14	1.05	.04	1.15
MEAN	<.014	.105	.004	.115
STANDARD DIEVIATION	----	.034	.0084	.0242
EFFECTIVENESS	~90 %		~97 %	
MEAN EFFECTIVENESS		~94 %		