INSTALLATION REPORT - PREPARED BY D.P.W.

Laid M. 237.2 - Dempster Highway
Henderwood Industries Ltd.
"Permabed" Test Section

PUBLIC WORKS
CANADA

PACIFIC REGION
WHITEHORSE, YUKON TERRITORY

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Background

The installation of a polyurethane foam insulation test section in the Dempster Highway was sponsored by the Department of Indian Affairs and Northern Development. The site selected for the test was Mile 237.2 of the Dempster Highway, in the Eagle River Valley. This places the test site in the zone of continuous permafrost, in a low area with fairly poor drainage characteristics.

Selection of the test area was based on several factors. Of prime importance was the fact that this section of the Dempster Highway is under construction. This area may be described as being in a natural thermal balance, unaffected by the presence of any influencing man-made disruptions, execpt the roadway, which at the time of installation would have had a negligeable influence. A 1000 foot stretch of roadway was selected which was known to be ice rich. It was believed that due to the poor drainage of the area this site, with normal construction techniques, would suffer from differential settlement and heaving.

The site of the test lies within the meander belt of the Eagle River and vegetation may be characterized by the hummocks and stunted spruce growth.

Construction over the test site was conducted during the fall of 1976. Clearing of the trees was accomplished by hand, and a 3 foot pad of a dry shale material was placed. The actual urethane installation was done during the middle of March 1977 to coincide with the period of minumum active layer thickness.

The test site is to be monitored by the National Research Council in order to determine the effectiveness of polyurethane foam insulation in embankment construction.

Henderwood Industries Ltd. placed the polyurethane foam sheeting by the use of a machine they have designed and constructed. The suppliers of the polyurethane foam was Permabed, a chemical manufacturer.

Preparation

Prior to the installation of the urethane insulation it was necessary to remove the existing roadway pad to within one foot of the original ground. Only 500 feet of the 1000 foot test section was excavated for the application of the insulation, the remaining 500 feet being left as a control section.

The area which was excavated was from station 1020+00 to 1025+00 while station 1015+00 to 1020+00 was left as the control section. The stations referred to correspond to the survey on the present Kluane Construction Limited construction.

Excavation of the test site was accomplished with the use of Kluane's equipment on the site. A bypass road was constructed around the excavation site on the north side of the highway. This bypass was constucted using mostly snow in the vicinity to preclude the introduction of drainage obstructions.

The excavation of the test site required 2 days, commencing on March 5, 1977. After excavation of the existing pad was completed the test site was given a final blading with a grader on March 7, 1977. This preparation was requested by Henderwood Industries Ltd. to ensure proper operation of their equipment.

On March 8, 1977 a Department of Public Works soils crew began drilling holes in the test section for the installation of the monitoring system and also to gather some core samples from the subsurface soils.

Hank Johnston and Joe Plunkit, both from the National Research Council, supervised the drilling operation and installed the thermistors for the monitoring system. Nine holes were drilled for the installation of the thermistor cables. The location of these holes were at stations: 1017+00, 1019+00, 1021+00, and 1023+00, along centre-line of the highway and at a 13 foot offset right of centre-line. The ninth thermistor cable was installed at station 1021+00 and about 60 feet right of centre-line, as a Datum cable in undisturbed ground. As a further means of monitoring the test site a deep bench mark was installed at station 1020+00 to a depth of 40 feet. All drilled holes were backfilled with a dry sand.

On March 22, 1977 the monitoring system installation was complete except for the four thermistors which were to be installed on the top surface of the insulation and the placement of the eight settlement plates to be positioned just prior to backfilling.

Installation

Transport of the materials and the machine from Calgary to the test location were to be completed by March 14, 1977. This was delayed until March 15, 1977.

The machine arrived at the Eagle River at 7:00 P.M. on March 15,1977. It was then off-loaded with the help of the Army, on site building the Eagle River Bridge. Because of the one day delay the Henderwood people decided to off-load and assemble the machine the same evening.

With the aid of the Army personnel, a crane and a forklift, they accomplished the assembly by 11:30 P.M. Final adjustment of the machine was done the following day.

The machine itself weighs 37,000 pounds and carries 600 gallons, of the chemicals used to produce the foam. The machine is a prototype and is still in the development stage. Henderwood hopes to increase the carrying capacity of the machine by installing belly tanks capable of carrying 5,000 gallons.

A diesel generator supplies power to five electric motors which drive the five separate hydraulic systems that operate the entire machine. Hydraulic motors in each of the large front wheels provide the propulsion while the small rear wheels provide steering. The entire inner components are encased in a box-like structure of urethane foam sheeting to insulate the area used for the production of the foam.

The production of the foam sheeting takes place entirely within the machine. The chemicals used to produce the foam are heated to 54° C. and mixed within the spray nozzle which travels across the sheet. The liquid chemicals are sprayed between two sheets of polyethelene vapor barrier. As the foam rises it is restricted by two banks of rollers, above and below, which give it a uniform 2 inch thickness. This sandwich of urethane foam and polyethelene travels through the rollers to the rear of the machine where it is layed on the ground.

In this manner the width of the sheet is controlled by the travel of the spray nozzle, while the length of the sheet is only restricted by the length of vapor barrier or the quantity of raw chemicals. The machine is capable of varying the width up to 12 feet which is the width of the rollers.

Because of the manner in which the foam is layed, the forward speed of the machine must match the rate of production of the sheeting. The desirable rate at which Henderwood suggested they operate the equipment produces 10 feet of sheeting per minute. In this manner they hoped to lay 4 strips 10 feet wide and 500 feet long in about 5 hours. This was not acheived due to several difficulties which will be discussed later.

Production of the foam sheeting commenced at 5:00 P.M. March 16, 1977 and was completed at 2:00 P.M. March 19, 1977. A small scale back-filling exercise was conducted over a 16 foot by 30 foot area of foam sheeting on March 17, 1977. The backfilling was accomplished with a D-8 cat pushing a 2 foot pad over the sheeting. The material used as backfill was the same shale material which was originally excavated from the test section. This small scale backfill operation was conducted for the benefit of the observers who were leaving the same day. They wished to see how the foam and the urethane withstood the action of material being placed on top of it. After backfilling two spots were randomly selected and dug out by hand. It was found in both cases that the vapor barrier had been torn by tension resulting from bridging over gaps or cracks in the urethane itself.

The total production of foam sheeting covered an area of 400 x 30 feet.

Upon completion of production the machine was disassembled and reloaded in four and a half hours again with the use of the Army's crane and forklift.

The backfill of the foam section was done on March 21st and March 22nd with the use of Kluane's equipment. Just prior to the backfill operation the remaining thermistors and settlement plates were installed in their respective locations.

Problems and Difficulties

Several problems were encountered in the application of the polyurethane foam. These problems and difficulties concerned both the equipment and the materials used.

a) Equipment

Of a major concern was the need for both a crane and a forklift in the off-loading and assembly of the machine. This equipment was easily available at the site however it is unlikely to be present at most highway construction sites. It is possible that other equipment could have been used for the assembly and disassembly of the machine however since a good portion of this must be carried out from above the machine it would require some careful setup.

In the construction of the machine Henderwood was unable to obtain the proper sized tires, at the present time, for the large front wheels. This resulted in problems in the application of the foam sheeting. Theoretically the rate of foam production must match exactly the rate of forward movement of the machine. In this manner the foam would be laid exactly in place as it was produced. The front drive wheels being too large did not allow the matching of the speed of production with forward motion resulting in the foam sheeting being dragged along the ground.

This difficulty was adapted to by using a steady production speed and driving the machine in a start and stop fashion. Ideally as the foam hits the ground from the rear of the machine it is still warm and flexible, cooling and becoming less flexible once it is in place. With the start and stop placement method the foam tended to cool before it was in its final site giving it a wavey surface that did not lay flat on the ground. It is possible that upon backfilling this could result in fracturing of the foam due to tension along the bottom surface.

The rear steering wheels of the machine was an adapted front end of a tractor. The tires use on these wheels were not capable of handling the weight or turning capabilities of the machine. Two flat tires hampered the test, one during application of the foam and the other immediately following completion of the test run. Since only one spare was carried the machine was on-loaded at the test location.

The carrying capacity of this prototype is 600 gallons of foam producing chemicals, which would ideally produce 12,000 square feet of 2" thick foam sheeting. It was the intension of Henderwood to lay a 10' width at 10 feet per minute which would mean refilling every two hours. Future modification to the machine would include a 5000 gallon belly tank which would increase operating time to almost 17 hours.

Base preparation for the laying of the foam was fairly extensive. The machine being a rubber tired vehicle requires a fairly smooth surface to work from. The operation of the machine on steep grades was not part of the test run. In moving the machine from its off-loading site to the test site it was driven down a 6% grade without difficulty, but as far as production on steep grades was not done, this aspect cannot be evaluated.

During production the only serious problem encountered with the machine was a difficulty with the roller chain drive. While the sheeting is being formed it is run through two banks of chain driven rollers. The problem occurred when the drive chain slipped off several times. With lack of the drive chain the sheeting would stop whereas the spraying of the foam liquid would not. This resulted in the foam rising excessively and jamming the rollers. The rollers also had a tendency to force gaps in the foam between the polyethelene.

Both the problems, jamming and gaps were apparently solved by the introduction of belts between the rollers and the foam in the first bank of rollers where the rising of the foam takes place. Once this filed modification was implemented the quality of the foam was improved.

Materials

The liquid foam material was shipped to the site in 45 gallon drums loaded on an insulated semi-trailer. It was the original intension of Henderwood to manufacture sheeting 10 feet in width with a 3 pcf density of foam. The manufacturer of the foam material could not specify the density to which the foam would rise. The foam which was produced had a density of 5 pcf with a compressive strength of 110 psi instead of the intended 45 psi. Because of the increased density it was not possible to produce the intended 10 foot width as the foam would not rise sufficiently. Instead a 6 - 7 foot width was the maximum which could be obtained.

The barrelled foam liquid was stored in the semi-trailer, which was to be heated by a Herman-Nelson heater. Due to an oversight the doors to the trailer were closed resulting in the heater being extinguished. The liquids can only be pumped when warm so the cold liquids presented a few hours delay in the start of the test run.

The other raw materials required were the rolls of polyethelene. At the time Henderwood was unable to obtain rolls 12 feet wide so they used in its place 3 rolls of 5 foot width on each of the top and bottom surfaces. Henderwood did state that they would be using a 12 foot width but that it would not be available until later in the year. Because of the necessity of using 3 rolls instead of a single roll the seams on the lower surface had to be temporarily fastened to prevent the spray from blowing between the seams. This joining of the rolls was accomplished with a teflon tape. The hot foam tended to make the seal quite stable. This taping was only done on the lower surface and its purpose was only a temporary seal until the sheet was completed.

The polyethelene was not only intended as a form for the urethane, but also as a vapour-barrier since urethane is apt to absorb water, reducing its insulative properties. As a vapour barrier it was found that it tended to be weak in the lengitudinal direction and was subject to tearing. This was observed in the backfilling exercise carried out. Tension cracks were observed at both sections which were excavated after backfilling. It was also found that rocks in the backfill material could puncture the polyethelene reducing its efficiency. For this reason Henderwood suggested the backfill material be of 1" minus material to reduce the possibility of puncturing the polyethelene.

Since as the foam rises it has no edge restriction the edges tend to be of irregular shape. The sheets cannot be butted together without the introduction of gaps varying in widths up to 1½'. For this reason it was often necessary to overlap adjacent sheets. The machine could not accomplish this so the sheets were produced and then shifted into place by hand. This was quite awkward as the size of the sheets, 6 feet wide and varying from 200 - 400 feet long were fairly unmanageable.

During the test run it had been snowing and thus the foam sheeting was layed over a thin layer of snow. It was found that the polyethelene when cold would slide around very easily. This greatly hampered the small scale backfill test. As the three short strips were being back-filled it is estimated they moved approximately 10 feet. To reduce the possibility of a reocurrence with the final backfilling of the main portion of the urethane foam, the sheeting was nailed down with 8" spikes and wood scraps. This apparently solved the problem as no serious movement of the sheets was noted upon backfilling.

These problems and difficulties account for the delays in the completion of the test run from a single day to four days.

Chronological Sequence of Events

March 5/77	-	started excavation of stations 1020 to 1025 using Kluane's equipment
	-	DPW mobile drill arrives at site
March 6/77	-	excavation of the test section completed
March 7/77	-	H. Johnston and J. Plunkit of NRC arrive 5 soils people from DPW arrive
March 8/77	-	soils crew drilling in test section
March 9/77	-	drilling being done in test section
March 10/77	-	drilling carrying on
	-	thermistor cables being installed
March 11/77	-	drilling completed
	-	thermistor cables being installed
March 12/77	-	thermistor installation complete
	-	H. Johnston and J. Plunkit left
March 13/77	-	Peter Kayne, manager with Henderwood arrived with R. Heleama, left again to pick up Henderwood people in Dawson
March 14/77	-	Observers arrive:

J. Hudson	DPW
C. Amos	DIAND
M. Cheung	DPW
P. Gerabek	DPW
E. Gibson	DPW
E. Powell	Arctic Gas
N. Hernadie	R. M. Hardy

Henderwood crew arrives:

S. Henderson	President
P. Kayne	Manager
R. Heleama	Technician
B. Oneil	
R. Broad	
D. Hazzer	
S. McKenzie - Greeve	

- Materials arrive via White Pass Trucking

March 15/77	-	machine arrives at Eagle River at 7:00 p.m.
	-	assemble machine until 11:30 p.m.
March 16/77	-	moved machine to test location at 2:30 p.m.
	-	loaded 600 gallons on machine
	-	started run at 5:00 p.m. produced 125' x 7' to 8' of foam. Machine down with chain drive problem.

March 17/77 - produced 400' x 6' of foam
- conducted backfill test
- observers J. Hudson
M. Cheung
P. Gerabek
and E. Gibson depart.

March 18/77 - production of foam sheeting continuing and completed
- C. Amos, S. Henderson, N. Hernadie and E. Powell left

March 19/77 - loading equipment from 2:30 p.m. to 6:00 p.m.
- Henderwood Crew left with machine

March 20/77 - tacked down foam sheets
- installed final thermistors and settlement plates

March 21/77 - started backfilling foam sheeting

March 22/77 - completed backfilling of test section.

Summary of Costs

Kluane's Equipment: Excavation and Backfill	$ 18,102.00
Urethane in place @ \$0.80 to \$1.10/ft^2	$ 9,600.00 to $ 13,200.00
Transport Drill	$ 2,282.00
Compressor Rental	$ 2,000.00
Room & Board for Observers & Crews 94 mandays	$ 2,350.00
DPW Vehicle Rental	$ 392.00

Other costs unknown:

Transport of machine and materials from Calgary
Unloading and loading machine
Transport of observers
Two rental vehicles for Henderwood crew
Monitoring system
Salaries of all personnel involved in test.

1. The insulation test section from Station 1021+00 looking east. The snow has been bladed off the surface in preparation for excavation.

2. D/8 cat ripping Station 1020+00 to 1025+00 in preparation for removal of pad to within one foot of original ground.

3. Excavation of test section using Cat 631-C scrapers. Photo taken looking west with the by-pass road, around the site, in the right foreground. The excavated material was stockpiled at the east end of the test section prior to backfilling.

4. Test section after final blading in preparation for the foam sheeting. The sheeting was laid on the snow which had fallen after the blading.

5. The D.P.W. drill crew taking a core sample at Station 1023+00.

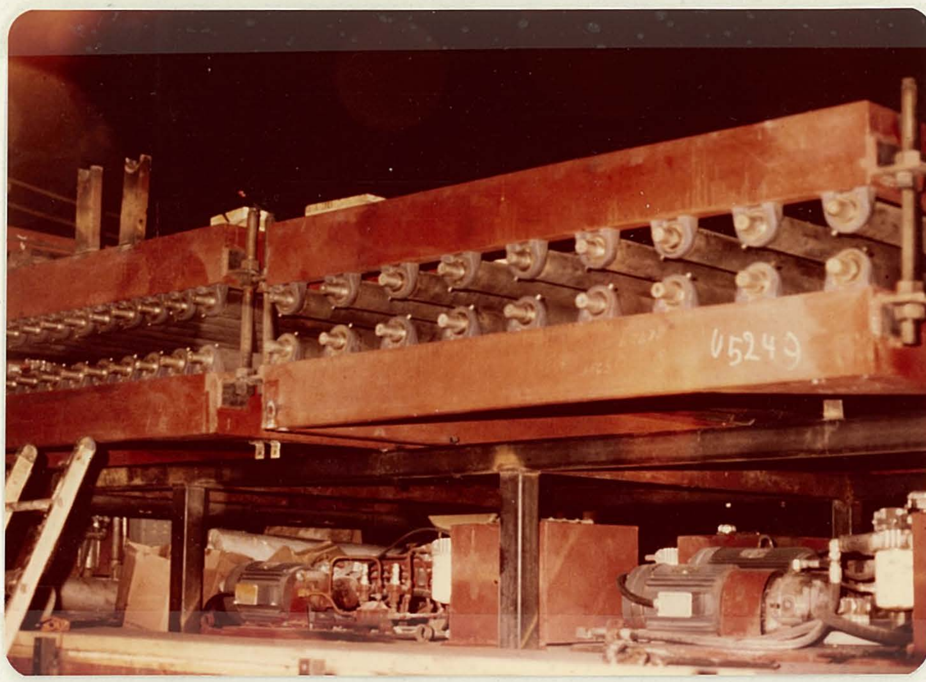
6. The core sample from Station 1023+00. The ground surface is at the left of the photo. It can be seen that the sample contains a high organic and ice content.

7. The ice lenses are clearly visible in the core sample at 1023+00.

8. The installation of the monitoring system by NRC. The thermistor cables reach to a depth of about eleven (11) feet with thermistors at one to two foot intervals.

9. The thermistor cables were buried by hand to prevent damage. The top thermistor can be seen at the ground surface where it would rest at the bottom surface of the foam sheeting. The cable holes were back-filled with a dry sand.

10. The foam producing machine being off-loaded from the transporting flatbed. The machine was being assembled as it was off-loaded.



11. The interior of the machine. The two banks of rollers, that restrict the rising foam and form the sheet, can be seen. Beneath the rollers are the hydraulic systems which operate the entire machine.

12. The assembled machine encased in urethane sheeting and plywood. Inside the final bank of rollers can be seen; beneath them are the hydraulic fluid reserves.

13. Pumping the foam producing liquids from 45 gallon drums to the machine. The liquids were not warm and so presented difficulty pumping.

14. The polyethelene sheeting in place in preparation for production. The truck was positioned to prevent the sheeting from being dragged along as the foam was produced.

15. The first foam produced. Some difficulty was encountered in placing the foam as it was produced and this is discussed in the text. For this reason it was necessary to initially pull the sheeting from the machine.

16. The non-uniformity of the first sheeting produced can be seen. The sheeting tended to have gaps at the edges where the foam had not risen sufficiently. This was later corrected.

17. The porosity of the foam and the heat bonding of the polyethelene is seen in this cut off section of sheeting.

18. In the intial production of sheeting the foam was applied to produce a 3 pcf density. The foam when applied at this rate would not rise sufficiently to produce a uniform sheet. In this photo the travel of the spray nozzle is easily distinguishable in the sheet. The problem of the gaps in the foam was remedied by increasing the application rate to give a 5 pcf density.

19. Even with the 5 pcf density a few gaps in the foam are present. These gaps in the foam are weak spots which could result in tearing or puncturing of the vapour barrier.

20. This is a tear in the vapour barrier created within the machine itself. It occurred at a gap in the foam and was torn by the rollers of the machine.

21. A typical sheet of the foam insulation, approximately 6 feet wide. The pattern impressed in the surface is from the belting over the rollers which was added during the test run. The roughness of the edges of the sheet made it necessary to overlap adjacent sheets.

22. The test run is complete and most of the sheets are in their final location. Some minor shifting of the foam was done to reduce the gaps between adjacent sheets. The rippled appearance of the sheets is a result of the stop and start method of production used in making the sheets.

23. The insulation just prior to backfilling. The sheets have been attached together and also to the ground, with wood scraps and 8 inch spikes. This was a precaution taken to prevent movement of the sheets during backfilling.

24. A small-scale backfill test was conducted for the benefit of the observers who had to leave. During this test it was noted that the sheets moved approximately 10 feet and so the main portion was tacked down before final backfilling.

25. After the backfilling exercise two spots were randomly selected and excavated by hand to see if the vapour barrier had been punctured.

26. Both locations showed tension cracks in the polyethelene. One of these areas was completely removed by sawing through the foam into

27. the underlying foam. When it was removed it showed that the foam itself had cracked.

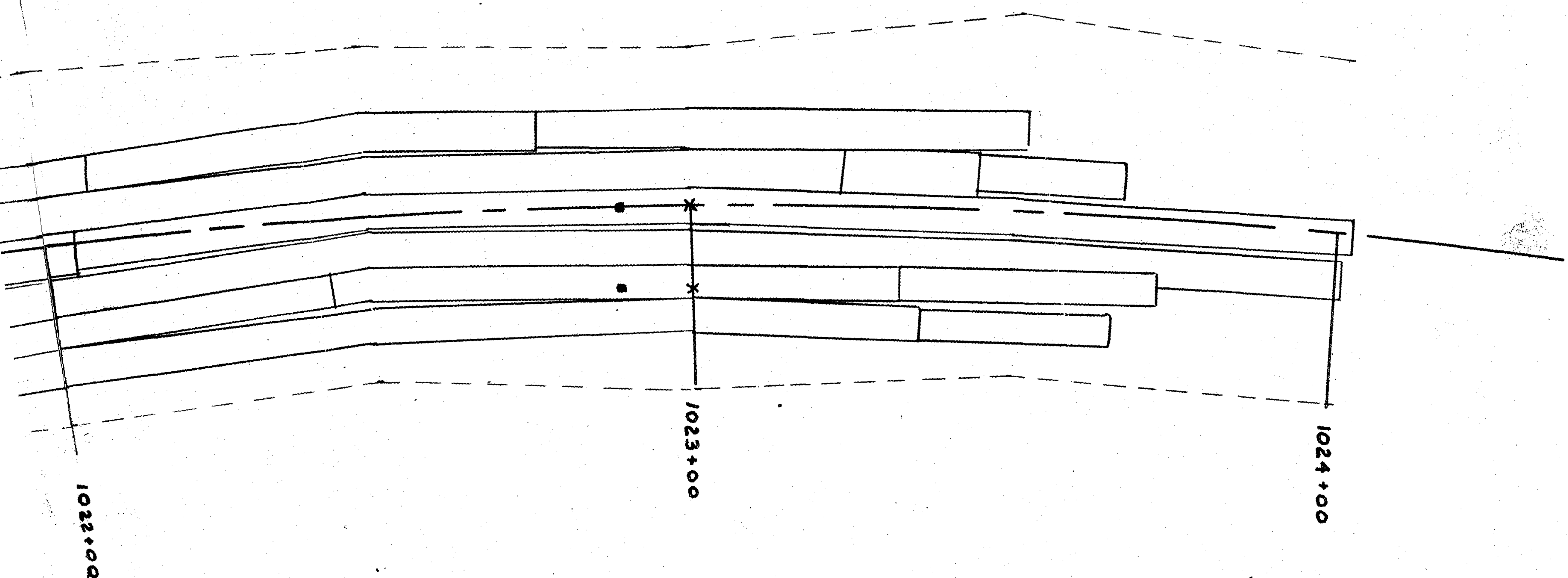
28. The final backfilling of the insulation was accomplished by pushing a two foot pad over the sheeting. The sheeting did not move during backfilling so it is believed that the tacking of the sheets was successful.

29. The loading of the machine was done at the test site with the aid of the Army's crane.

Insulation Test Section

Mile 237.2 Dempster Hwy.

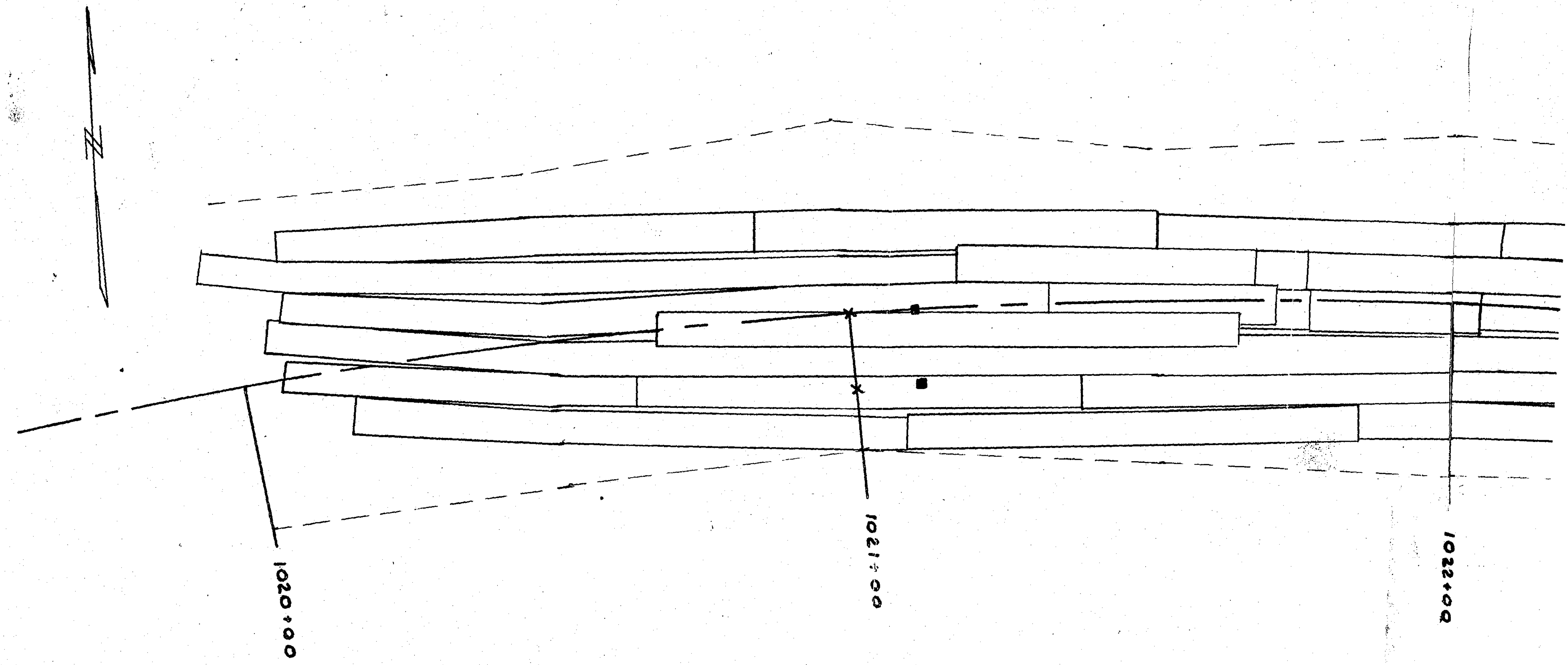
Sheet Layout



× Thermistors

■ Settlement Plates

1 in. = 20 ft.


1020+00
1021+00
1022+00