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TEMPERATURE OF BITUMINOUS ROOFING MEMBRANE AND ITS RELATION TO AMBIENT CONDITIONS

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ABSTRACT

Temperature measurements were made on a bituminous built-up roofing membrane on a building roof at Ottawa. Thermocouples were installed at the top and middle of the membrane and one inch (25.4 mm) below it. Temperatures were measured from the middle of winter to the middle of summer. Depth of snow cover was determined at intervals on the roof and daily on nearby ground. The results show that when snow cover is shallow and temperatures are low a roof membrane may undergo many freeze-thaw cycles each winter. Because of uneven snow distribution on a roof, different thermal regimes exist in the membrane resulting in non-uniform stresses.[3]

INTRODUCTION

It is generally assumed that a snow-covered bituminous BUR membrane on a heated building does not freeze. With its temperature thus moderated by an insulating blanket of snow, the membrane would be protected from the hazards of temperature cycling. Other research indicates that freeze-thaw cycling may reduce membrane strength.[1] Minimum membrane surface temperature can fall as much as 14°F (10°C) below minimum air temperature[2], and maximum surface temperature can rise 20°F to 30°F (12°C to 17°C) above air temperature in bright sunshine. The chief cause of membrane splitting is the daily temperature cycling, according to one theory.[3]

Against this background, our research program was undertaken to measure membrane temperatures, freeze-thaw cycles, and the temperature effects of snow cover.

CONCLUSIONS

Field temperature measurements of an actual roof in Ottawa during part of the winter and summer of 1976 contradict the assumption that snow cover, irrespective of depth, prevents freeze-thaw cycling in the membrane. Under light snow cover, membranes in cold climate may experience many freeze-thaw cycles each winter.

Also emerging from the test program are the following conclusions:

- Snow cover of only 1 ft. does produce an essentially constant roof temperature at the freezing level.
- Snow depth can vary widely, between 2 and 38 in. (5 to 96 cm) at the same time. Because of variations in density, the effect of snow cover over an entire roof cannot be readily calculated.
- A membrane can be subjected not only to extreme daily temperatures in winter; it can also be frozen where moisture accumulates in the felts.
- In winter months, with no snow cover, membrane temperature parallels air temperature very closely, with repeated freeze-thaw cycles.
- In summer, the membrane temperature exceeds the maximum daytime air temperature by as much as 45°F (25°C), remaining slightly above the low air temperature during the night. (This conclusion is consistent with others' observations.)

EXPERIMENTAL

The roof of the main laboratory of the Division of Building Research (building M-20) was used for this study (see Figure 1). Thermocouples were located in two areas, A and B, 3 ft. (91.5 cm) apart and each about 1 yard square (0.84 m^2). (Figure 2 shows the location of the thermocouples). One area was cleared of snow; the normal accumulation was left on the other. Snow depth was measured over most of the roof. Air temperature was measured by two thermocouples located about 39 in. (1 m) above the roof surface.

Temperatures were recorded continuously with a strip chart recorder. Values, extracted at 06:00, 12:00, 18:00, and 24:00, were used to determine maximum and minimum temperatures during each 24 hrs., from February 5 to July 4, 1976. Air temperature was measured with a "bare" thermocouple subject to radiation effects.

RESULTS AND DISCUSSION

On February 21, 1976, snow depths varied from a minimum of 2 in. (5 cm) in the middle of some roof areas to a maximum of 38 in. (96 cm) next to the parapet. On that same day snow depth on the ground was about 28 in. (71 cm). In area B, where snow was left over the thermocouples, the snow depth was about 1 ft. (30.5 cm) at the beginning of tests and a maximum of about 2 ft. (61.0 cm) before melting began at the end of March.

Maximum and minimum air temperatures measured by the thermocouples located 39 in. (1 m) from the roof are presented in Figures 3 to 6. A comparison of these temperatures with corresponding temperatures obtained at a nearby meteorological station manned by DBR staff showed that they differed randomly by 1 to 2°F (0.5 to 1°C). These ambient temperature values are therefore adequate to assess the temperature differences experienced by the membrane in the snow-covered and snow-cleared areas of the roof.

In the snow-covered test area, membrane surface temperature remained constant (just above the freezing point) for the duration of the snow-covered period, even though the minimum air temperature dropped repeatedly to around 0°F (– 18°C) (see Figure 3). The temperature in the middle of the membrane was essentially the same as at the surface.

The temperature 1 in. (2.54 cm) inside the insulation, during periods of snow cover, remained at about 40°F (5°C), as shown in Figure 4, except for a short period in mid-March when the temperature dropped to near freezing. There is no obvious explanation for this behavior.

For the roof section cleared of snow, membrane surface temperature responded to the air temperature, as shown in Figure 5, cycling between a high of 55°F (13°C) to a low of about 0°F (– 18°C). It thus experienced repeated cycles of freezing and thawing. Exceptions to freeze-thaw cycles occured on days 24 to 29, when membrane temperature remained constant at the freezing point, presumably because freshly fallen snow had not been removed. Even the temperature 1 in. (2.54 cm) deep in the insulation showed values considerably below freezing during the period when the air temperature dropped to about 0°F (– 18°C) (Figure 6).

In the months following the melting of rooftop snow, temperatures were found to be as expected and as reported by other workers (Figures 3 to 6). Surface temperature and membrane temperature exceeded the maximum air temperature during the day by as much as 45°F (25°C); minimum was about equal to the minimum air temperature during the night.

Snow depth and its distribution on roofs depends on many design variables such as slope of the roof, non-uniformity due to gables and hips, arched and curved roofs, drifting of snow, influence of penthouses, chimneys, parapet walls and adjacent roofs [4,5]. Membrane temperature is clearly dependent on snow depth, and since this is variable so will the temperature difference be variable.

In summary, our results indicate that the conventionally assumed insulating effects of snow are undependable. A minimum depth of 12 in. is apparently required in a climate like Ottawa's to assure essentially constant temperature.

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REFERENCES

1. Laaly, H. O., *"The Effect of Moisture and Freeze-Thaw Cycles on the Strength of Bituminous Built-Up Roofing Membrane."* Presented at Symposium on Roofing Technology, Nat. Bur. Stand., September 1977.
2. Handegord, G. O. *"Problems in Flat Roofs – A Review of Research."* Nat. Res. Council Canada, Division of Building Research, Tech. Paper 182, Ottawa, June 1964.
3. Solvason, K. R. and Handegord, G. O., *"Ridging, Shrinkage and Splitting of Built-Up Roofing Membranes."* Nat. Res. Council Canada, Division of Building Research, Building Research Note 112, Ottawa, June 1976.
4. Lutes, D. A., *"Snowloads for the Design of Roofs in Canada,"* Proc. Western Snow Conference, Victoria, B.C. April 1970. p. 61-67 (NRCC 11911).
5. *"Snow Loads."* Commentary H in Commentaries on Part 4 of the National Building Code of Canada 1975. Nat. Res. Council Canada, Associate Committee on the National Building Code, Ottawa. P. 119-130 (NRCC 13989).

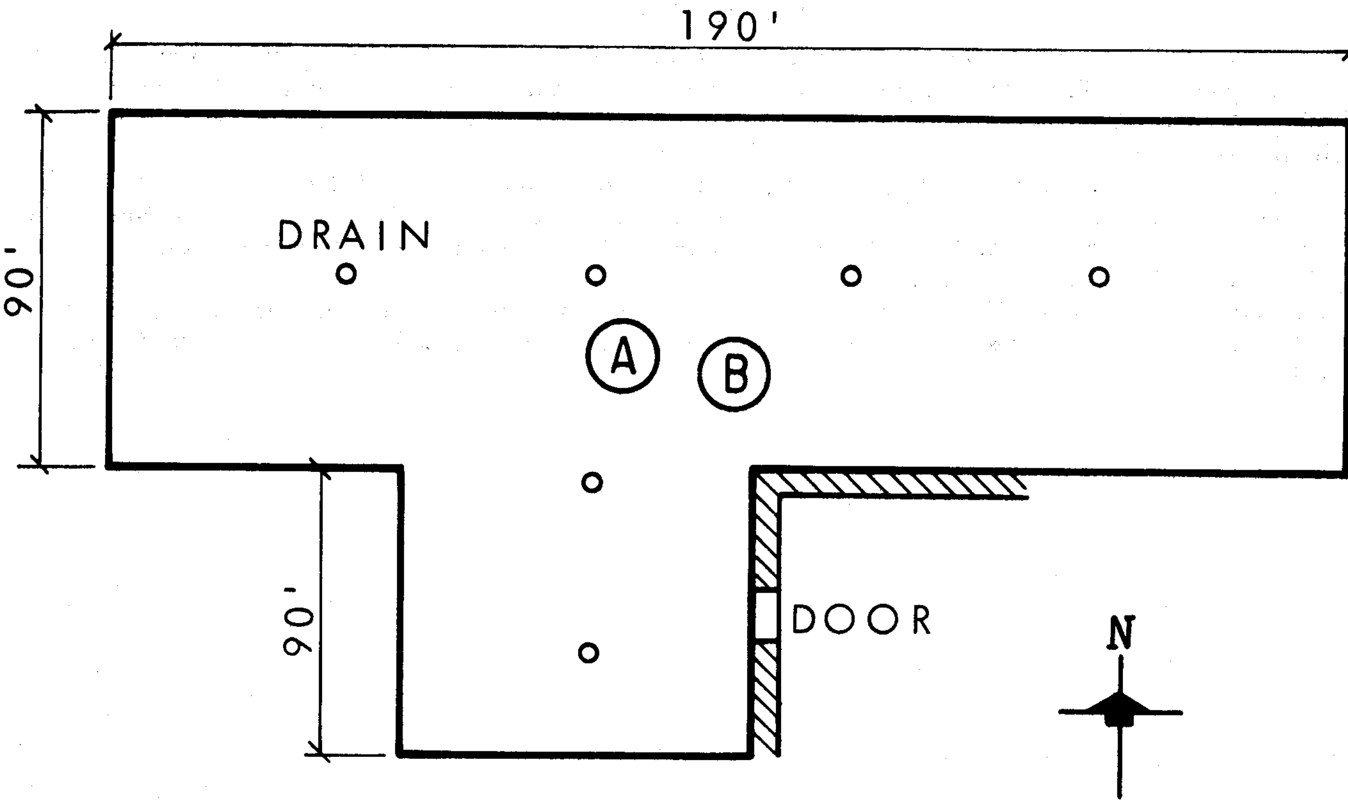

FIGURE 1-DESIGNATED AREAS A AND B ON THE ROOF OF BUILDING M-20, NRC SITE, OTTAWA

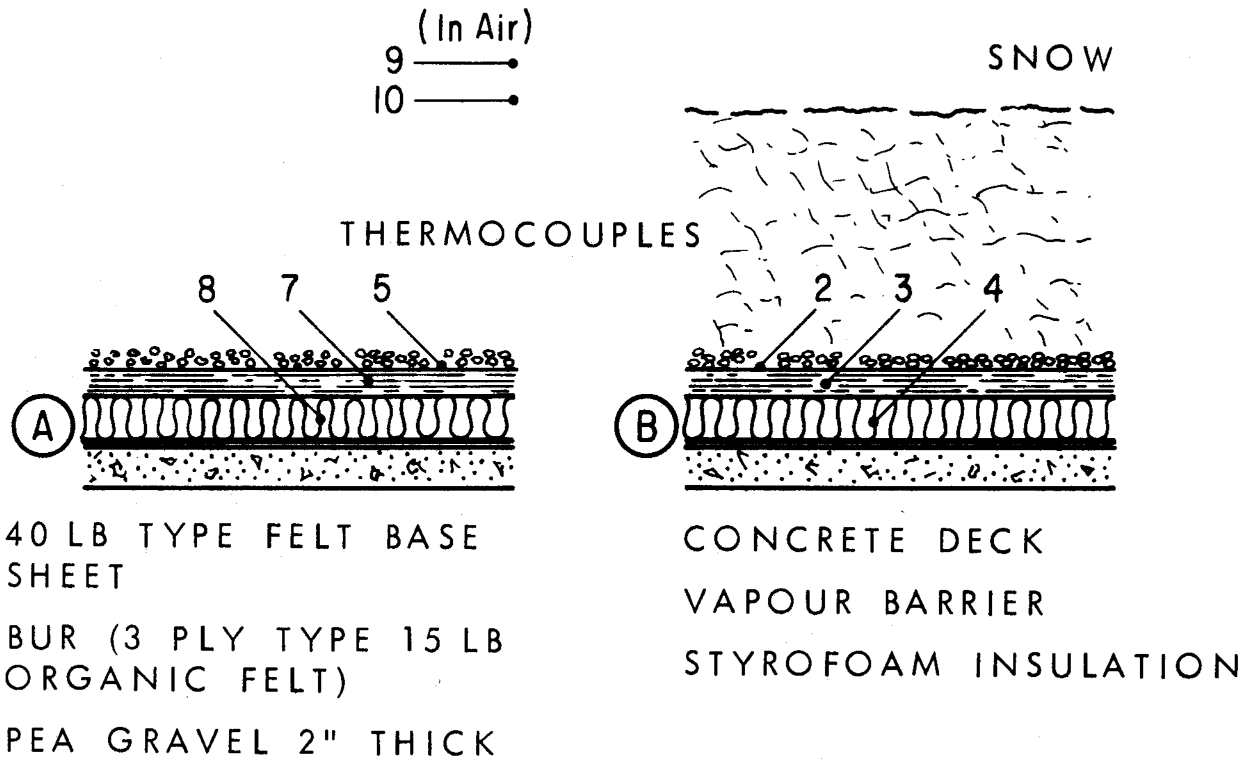

FIGURE 2-THERMOCOUPLE LOCATIONS AND CODES FOR AREA A (SNOW REMOVED) AND AREA B (SNOW COVERED)

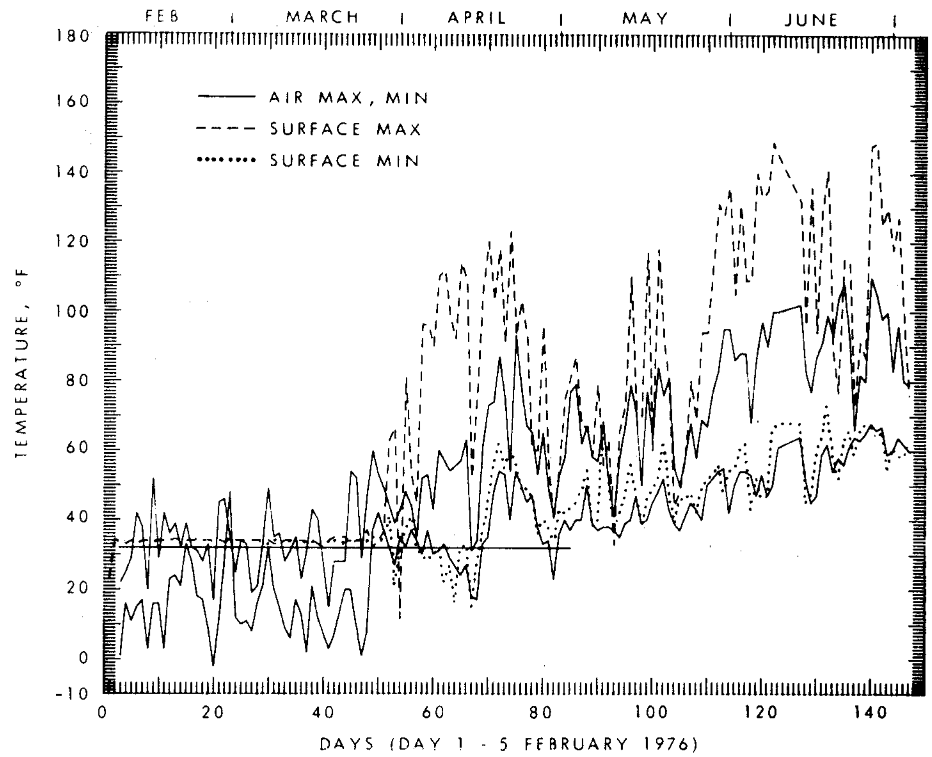

FIGURE 3-ROOF SURFACE TEMPERATURES AND DAILY AIR EXTREMES (1976), SNOW COVERED

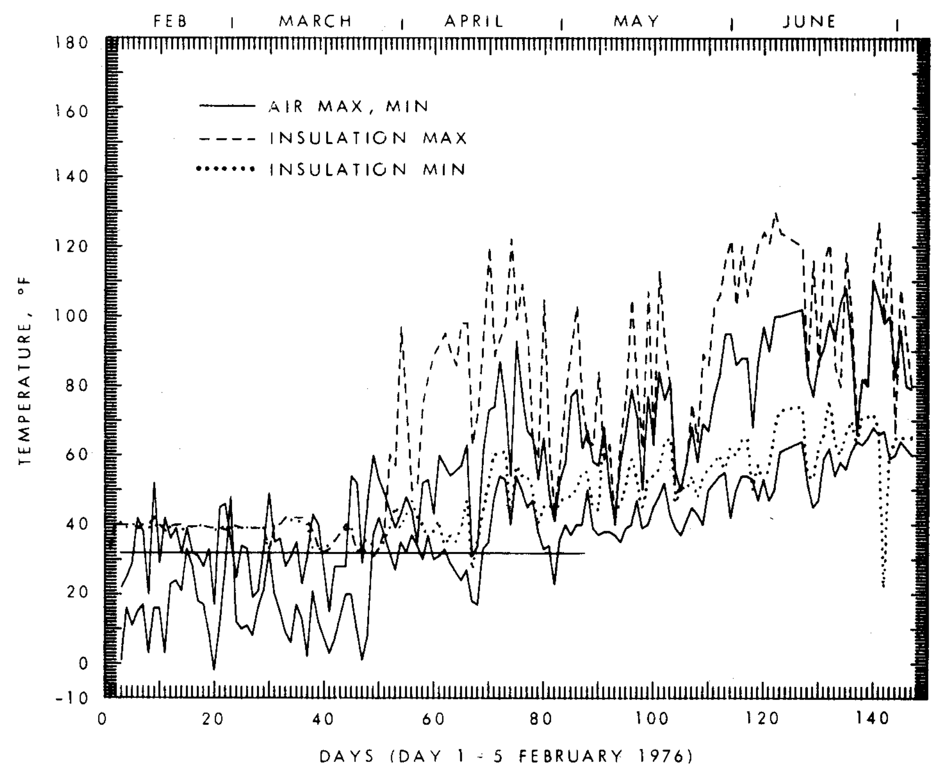

FIGURE 4-INSULATION TEMPERATURES (1 INCH DEEP) AND DAILY AIR EXTREMES (1976), SNOW COVERED

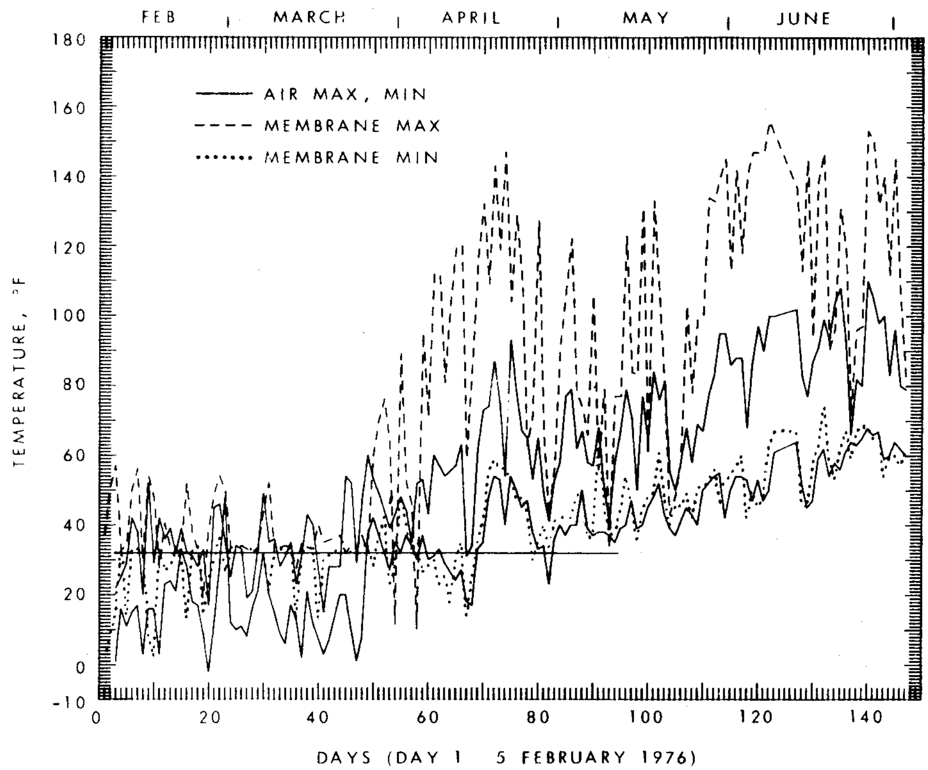

FIGURE 5-MEMBRANE TEMPERATURES AND DAILY AIR EXTREMES (1976), SNOW REMOVED

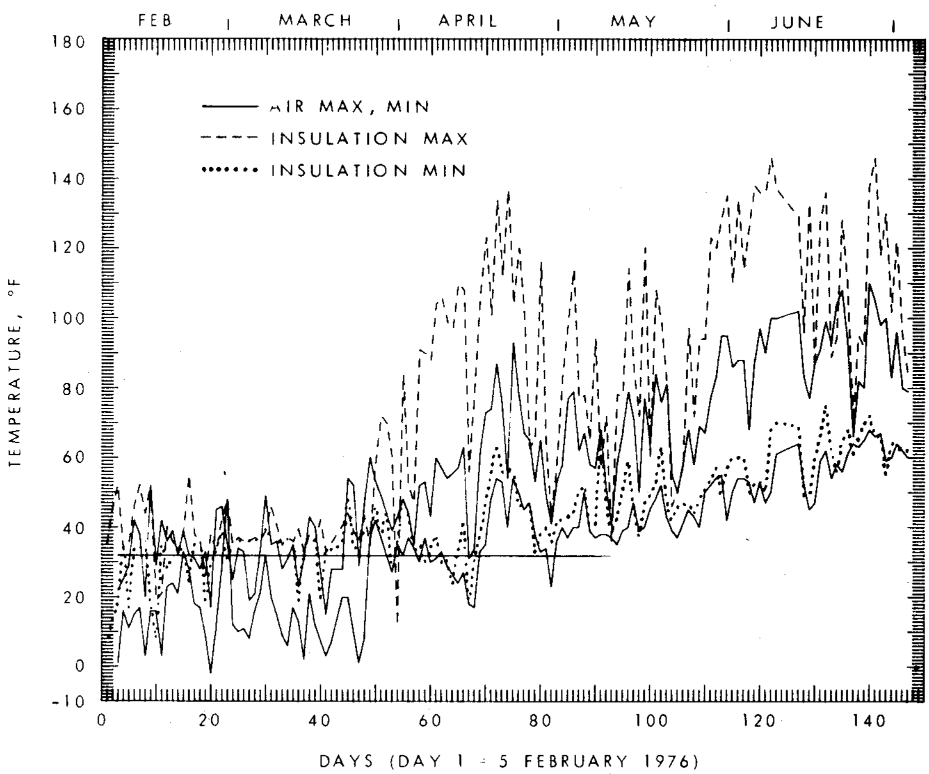

FIGURE 6-INSULATION TEMPERATURES (1 INCH DEEP) AND DAILY AIR EXTREMES (1976), SNOW REMOVED