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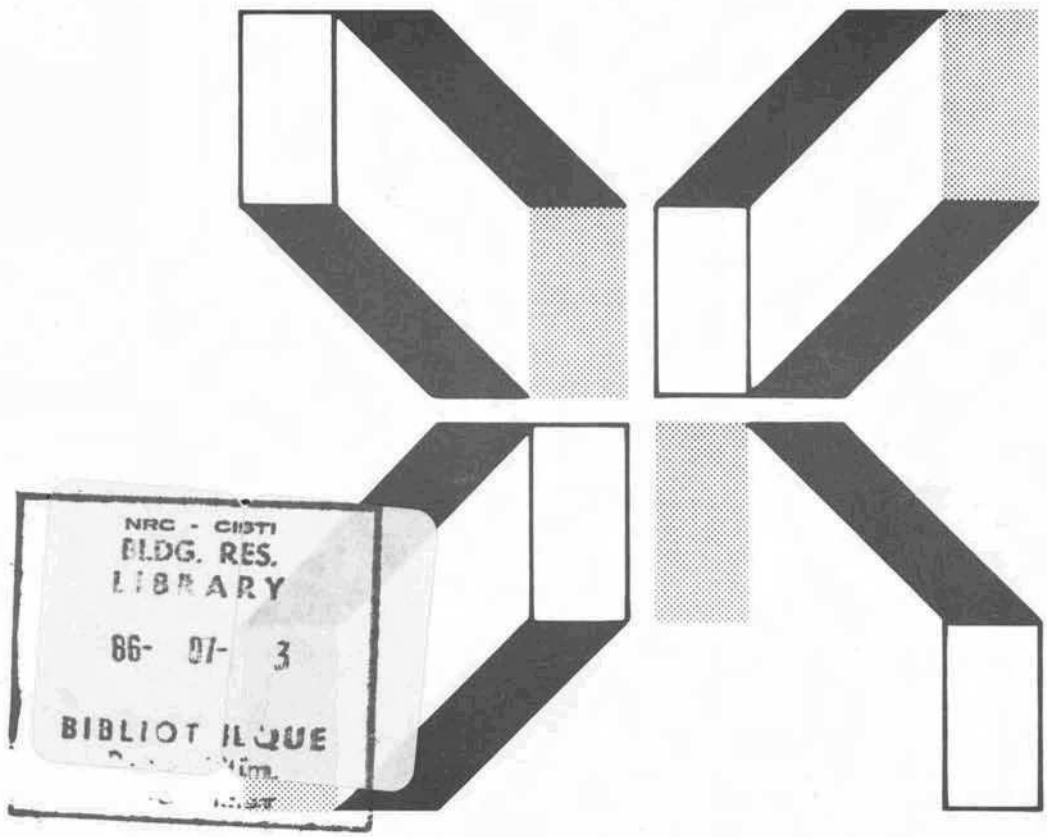

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MOISTURE CONTENT AND DIMENSIONAL STABILITY MEASUREMENTS OF THE INSULATION ON A PROTECTED MEMBRANE ROOF

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ABSTRACT

In a field study carried out on a protected membrane roof insulated with a bead polystyrene, moisture contents of the insulation were sampled, using a coring device, over a period of about six years. The results showed wide variation in moisture content at different parts of the roof as well as an increase in moisture content with time. Final moisture content ranged from about 0.3 to 21.7% by volume and averaged 11.0% by volume.

Measurement of the lengths of six 1.2-m-long specimens did not reveal a significant change over a four-year-period.

RÉSUMÉ

Dans le cadre d'une étude in situ portant sur une couverture à étanchéité protégée isolée au polystyrène moulé, on a évalué, sur une période d'environ six ans, la teneur en humidité de l'isolant au moyen d'une carotteuse. Les résultats ont révélé que la teneur en humidité variait considérablement selon l'emplacement des prélèvements et qu'elle s'accroissait avec le temps. À la fin de la période considérée, la teneur en humidité variait entre 0,3 et 21,7% et s'établissait en moyenne à 11% par volume.

On a aussi mesuré, sur une période de quatre ans, six spécimens de 1,2 m de longueur; celle-ci n'a pas varié de façon importante.

INTRODUCTION

In 1977 staff of the Institute for Research in Construction at the Prairie Regional Station in Saskatoon undertook to monitor the performance of insulation located on a protected membrane roof. The insulation was a bead polystyrene approximately 50 mm thick, in boards 610 mm wide and 1220 mm long. Its dry density was about 28 kg/m^3.

Two kinds of measurements were made:

1) Moisture content measurements were made at fourteen locations at intervals of about six months (spring and fall) over a period of several years.
2) Length measurements were made on six of the insulation boards at the beginning of the program. These were repeated four years later.

The roof consisted of five areas located on four levels. Figure 1 is a sketch of the roof showing the locations at which moisture content was determined.

MEASUREMENT TECHNIQUES

Moisture measurements were made by taking 25-mm-diameter cores of the insulation, sealing them in individual sample bottles and gravimetrically determining their moisture contents in the laboratory. Weighing of entire insulation boards might have given more reliable results, however, this was impracticable since they were bonded to the membrane. The specimens were placed in a vacuum oven at about 60°C until no further weight loss occurred. This required about forty-eight hours. The moisture contents were then calculated on a volumetric basis. The specimen volume was estimated from its dry weight and the dry density for the material (28 kg/m^3).

Holes formed by sample coring were filled with polystyrene plugs and sealed with mastic. Subsequent samples were taken within about 15 cm of earlier ones at each of the fourteen sites.

Sampling sites were selected so as to measure insulation performance under roof conditions both favorable and unfavorable to the insulation. Measurements were made at several sites where the insulation would be subjected to severe moisture attack, (three beneath pavers which rested on the insulation (PS), one at a low point (LP) and one near a drain (DR)) and nine at more favorable sites, e.g., at higher points in the roof where moisture drainage would be better. Unfavorable locations are identified in Table 1 (PS, LP, DR).

RESULTS

Average moisture contents for the fourteen sites are given in Table 1 and Figure 2. These are too few to provide an accurate average for the roof. They do, however, show the trend in the moisture content, which increased throughout the test period. Further, the results in Table 1 show wide variations in moisture content in successive measurements at individual sites and from one site to another. The reason for the former is not apparent. It may have been partly due to local variations in conditions, in quality of the insulation, and in the weather to which the insulation was exposed between tests.

The average moisture content over the period of observation was at or below 2% for five of the fourteen sites and below 6% for seven of them. Insulation at the five unfavorable sites ranged from 2.0 to 17.1% moisture content. At the time of the final measurement, one site had a moisture content below 2%, four had moisture contents below 6% and the moisture content at five unfavorable sites ranged from 2.9 to 21.7%. It is not known whether the increase in moisture content shown in Figure 2 for the two-year period between the last two samplings was due to a fluctuation or to a continuing trend.

Total precipitation (mm) for the periods two weeks, one month and two months prior to each measurement is given in Table 2. No close correlation appears between these precipitations and the moisture contents. For example, heavy precipitation preceded the September 1980 and July 1981 measurements, but the moisture

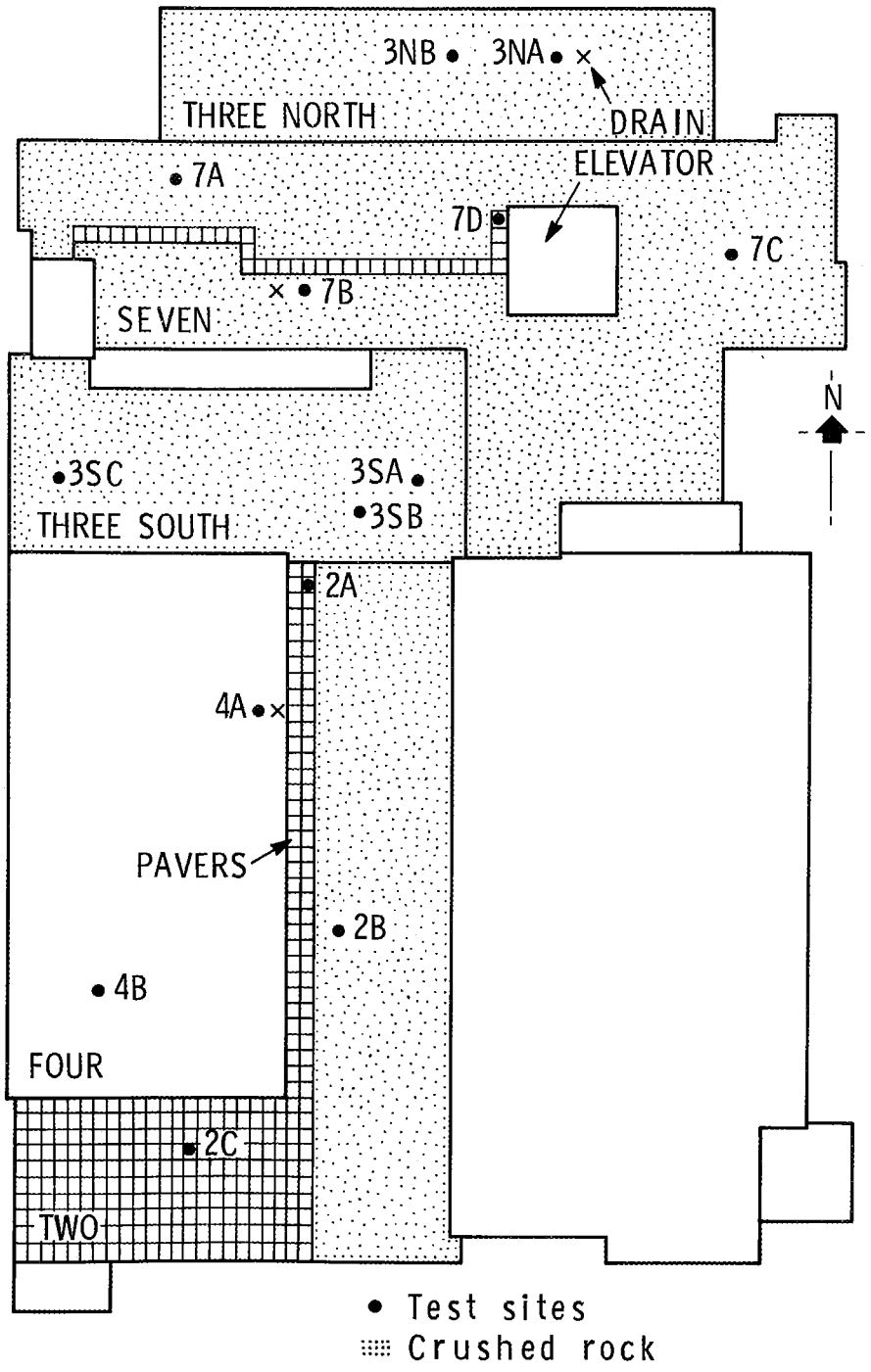

Figure 1. Roof areas. Areas not covered with pavers are covered with crushed rock.

Table 1 Moisture content of insulation specimens taken from a flat roof in Edmonton (% by volume)

	Dates of Measurements									
Specimen	10/26/77	05/02/78	10/18/78	05/09/79	10/29/79	05/14/80	09/25/80	07/22/81	06/15/83	Average
2A (PS)	4.5	10.0	10.4	4.3	8.9	4.6	5.3	16.1	10.7	7.9
2B	0.6	1.1	0.2	5.5	0.2	15.7	7.9	9.4	13.9	5.6
2C (PS)		22.2	13.5	13.2	9.3	15.0	17.0	17.4	18.6	15.7
3SA	0.2	1.5	0.2	0.2	0.3	0.1	0.2	0.1	2.5	0.5
3SB	0.2	0.1	0.5	0.2	0.9	0.1	0.2	0.1	0.3	0.3
3SC	0.6	0.3	2.9	7.2	9.3	10.0	11.6	8.8	14.2	7.5
3NA (DR)	4.0	5.8	22.5	7.8	10.4	20.5	15.6	16.7	15.6	13.9
3NB	1.4	5.5	6.0	12.2	11.9	10.2	7.9	12.0	13.9	9.1
4A	0.2	0.3	5.8	0.3	3.0	6.0	8.6	1.2	21.7	5.3
4B	0.2	0.1	0.4	0.4	7.8	0.2	4.3	9.5	9.2	3.2
7A	0.3	0.5	4.5	2.7	0.3	0.0	2.0	0.1	5.0	1.5
7B (LP)	12.9	11.4	22.0	24.6	16.7	15.9	18.3	14.4	18.5	17.1
7C	0.2	0.6	4.3	0.3	1.2	0.1	2.9	0.1	7.4	1.7
7D (PS)	0.0	0.0	0.4	0.3	0.2	7.1	1.6	0.1	2.9	2.0
Averages	1.8	4.2	6.9	5.7	5.7	7.53	7.4	7.6	11.0	6.5

(PS)–under paving stones, all others under gravel
(DR)–near a drain
(LP)–low point

contents for those dates (Fig. 2) did not differ significantly from the trend line values. Further, the highest moisture content, in June 1983, was preceded by two months of very dry weather.

Table 2 Total precipitation for 2 weeks, 1 month and 2 months prior to the measurements

Prior precipitation	Dates of Measurements								
(mm)	10/26/77	05/02/78	10/18/78	05/09/79	10/29/79	05/14/80	09/25/80	07/22/81	06/15/83
2 weeks	–	13	12	10	2	5	38	65	3
1 month	5	19	18	40	13	5	100	113	9
2 months	78	23	180	48	63	24	210	180	20

The effect of the increased moisture content on thermal resistance can be estimated. The increase in heat loss in cold weather is likely to be 3-4% for each 1% moisture content, i.e., 15–20% at 5% moisture content, 30–40% at 10% moisture content and 45–60% at 15% moisture content (1).

Any insulation on a protected membrane roof will gain some moisture; the amount depends on the moisture-absorbing properties of the insulation in the conditions to which it is exposed. The most moisture resistant insulations will commonly have an equilibrium moisture content of 2 or 3% and under unfavorable conditions may have a higher content than that.

The lengths of six of the insulation boards were measured in October 1977 and remeasured in July 1981. The lengths are given in Table 3.

There is no evidence of a dimensional change within the accuracy of measurement. The temperature was not measured but meteorological records indicate that the average for the October and July days on which the measurements were made was 6.0 and 16.2°C, respectively–a difference of 10°C. Assuming a coefficient of linear expansion of 7×10^{-5}/°C, a 10°C difference in temperature would produce a length difference of about 1 mm. However, the deck temperature is fairly stable, therefore the mean temperature of the insulation

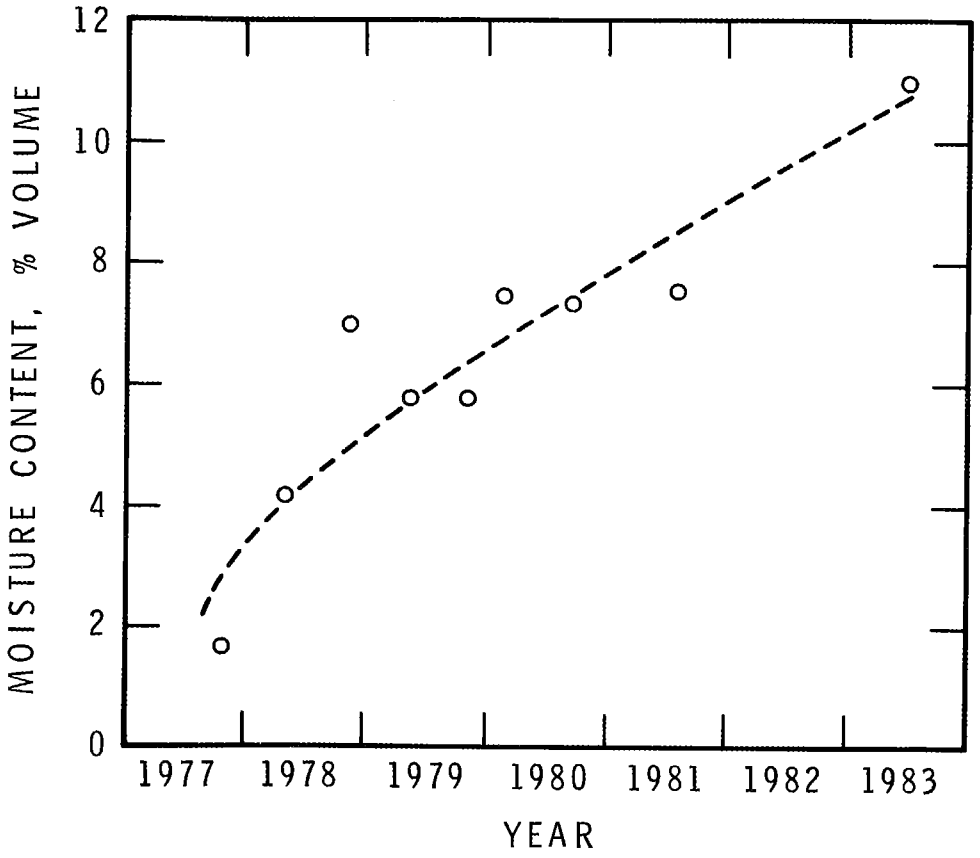

Figure 2. Average moisture contents for fourteen sampling sites. This does not represent the average moisture content for the roof. It is used here only to show the trend in the change in moisture content.

Table 3 Lengths of six specimens measured at two different times (mm)

Specimen	October 77	July 81
2B	1216	1214
3SA	1216	1216
3SC	1216	1214
3NB	1214	1213
4B	1214	1213
7A	1213	1214

will fluctuate less than the air temperature and the error due to difference in the insulation temperature is probably less than the 1 mm estimated above.

No strength measurements were made. These might have indicated whether the moisture is causing deterioration of the structure of the insulation.

SUMMARY

1) A field study was carried out on the performance of bead polystyrene insulation in a protected membrane roof. Moisture contents were sampled at fourteen locations on five roof areas of the same building. The lengths of six insulation boards were measured about four years apart.

2) Moisture contents were obtained by taking core specimens and gravimetrically determining the amount of water they contained. Moisture contents after five and one-half years of service ranged from 0.3 to 21.7% and averaged 11.0% by volume.

3) Measurements were made at low points in the roof, near drains and where the insulation was covered by paving stones. The average moisture content in six such locations was 14.7%. These above average values are probably due to the relatively unfavorable conditions at these locations.

4) Based on known knowledge, the thermal resistance would have decreased. Experimental results suggest that heat loss in the heating season would increase by about 3–4% for each 1% increase in moisture content.

5) The lengths of the insulation specimens did not change significantly over a four-year period.

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