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Cold Regions Research &  
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## *Examination of a blistered built-up roof: O'Neill Building, Hanscom Air Force Base*

C. Korhonen and A. Greaiores

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PREFACE

This report was prepared by Charles Korhonen, Research Civil Engineer, and Alan Greatorex, Civil Engineering Technician, of the Civil Engineering Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory.

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CONVERSION FACTORS: U.S. CUSTOMARY TO METRIC (SI) UNITS  
OF MEASUREMENT

These conversion factors include all the significant digits given in the conversion tables in the ASTM Metric Practice Guide (E 380), which has been approved for use by the Department of Defense. Converted values should be rounded to have the same precision as the original (see E 380).

<u>Multiply</u>	<u>By</u>	<u>To get</u>
Feet	0.3048*	Metres
Inches	0.0254*	Metres

\*Exact

EXAMINATION OF A BLISTERED BUILT-UP ROOF: O'NEILL BUILDING,  
HANSCOM AIR FORCE BASE

Charles Korhonen and Alan Creatorex

INTRODUCTION

Blisters are perhaps the most common defect in built-up roofs (The Roofing Spec 1979). As part of our research on cold-regions-related roofing problems we traveled to Hanscom Air Force Base, Bedford, Massachusetts, on 4 and 5 January 1983 to examine the roof of the O'Neill Building (Fig. 1). This roof was constructed late in the fall of 1980 but was not accepted by the owner until December 1981. During construction of this roof it was noted that edge venting was not being provided. Consequently 27 two-way insulation breather vents (Fig. 2) were retrofitted into all but the West Penthouse portion of the roof. That roof portion was constructed with edge vents. By August 1982, four months before its one-year warranty expired, the roof began to show signs of severe blistering. To determine the cause of this blistering we conducted visual examinations and infrared surveys, took 2-in.-diameter core samples of the membrane and

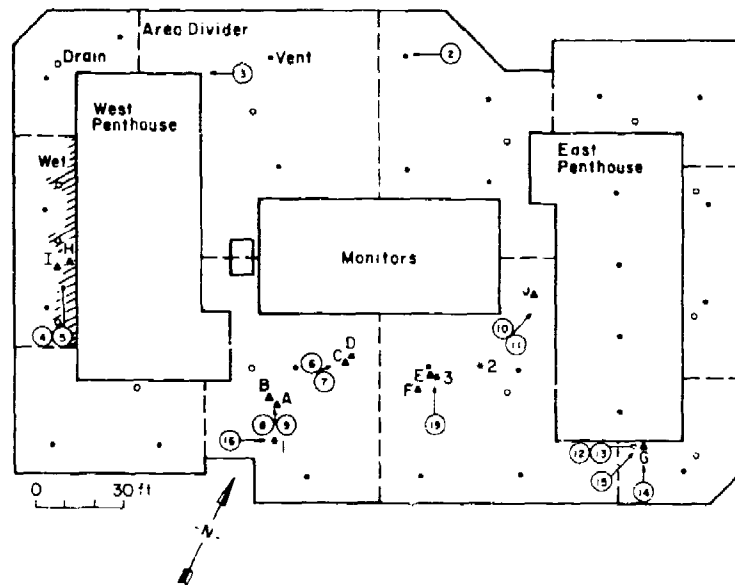


Figure 1. Plan view of O'Neill Building roof. Numbered arrows indicate the viewing direction of figures in this report. Numbers indicate blister cut locations. Letters indicate sample locations.

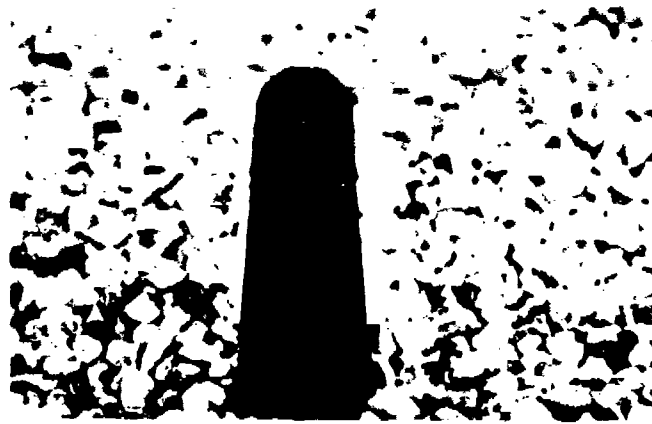


Figure 2. Two-way vent retrofitted into the roof. The vent is a rain-shielded stack that allows air to either enter or exhaust from a roof.

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the insulation, and photographed the inside of three blisters. The techniques for conducting infrared surveys were discussed in detail by Toblasson (1982).

#### VISUAL EXAMINATION

We examined all but the penthouse and monitor roofs (Fig. 1). The roof consists of a structural concrete deck, a two-ply organic felt and asphalt vapor retarder, a layer of 2-1/4-in.-thick felt-faced urethane board insulation, and a four-ply organic felt and asphalt built-up membrane with a protective gravel covering.

Blisters are the most visible problem on this roof. Although we did not examine the penthouse roofs, we understand that they are also blistered. Most of the blisters on this roof are small, low-profile humps, but some have grown to several feet long and 1 to 1-1/2 in. high. More blisters are evident in the southern portion of this roof than in the northern portion. In the south side 14 blisters were counted in a roof area 50 ft square; there were 4 blisters in the same size area in the north side. We were told that blisters are more evident and more numerous on warm, sunny days. Since the sun apparently enhances the growth of blisters, the paucity of blisters on the north side can be explained by the fact that this side is shaded by the penthouses much of the time, while the south side receives full sun.

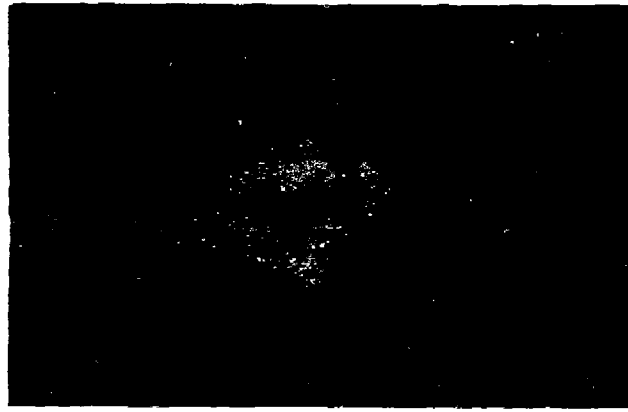


Figure 3. Flashing defect. At least seven flashing locations suspected of being potential moisture entry points were outlined with white spray paint.

For the most part the flashings on this roof appeared to be in excellent condition. At least seven defects were noted and marked with white spray paint (Fig. 3). Although our infrared survey shows that these defects are currently watertight, we suggest that they be repaired as warranty work.

Near the end of our examination it began to rain, producing numerous small ponds across the roof. This is not desirable, as ponding can magnify the effect of even the slightest flaw in a membrane. If a roof sheds water, it can survive some flaws without leaking. As shown in Figure 1, area dividers separate this roof into several small, independently drained segments. According to construction drawings each segment was designed to slope from 1/8 to 1/3 in./ft, depending on the distance to a roof drain. The most severe ponding occurred in areas that had a design slope of less than 1/4 in./ft. This reinforces the importance of the roofing industry standard minimum slope of 1/4 in./ft.

#### INFRARED SURVEY

During the evening of 4 January we surveyed this roof with an ACA Thermovision 750 infrared scanner in search of hot spots. Those hot spots that were suspected of being wet insulation were outlined with white spray paint and thermogrammed. (A thermogram is a photograph of the infrared scanner's display screen.) The following day we took several 2-in.-diameter core samples to verify our infrared findings. The cores revealed





Figure 4. Thermogram of a thermal anomaly along the flashings at the base of the west wall of the west penthouse. The arrows point to roof drains.

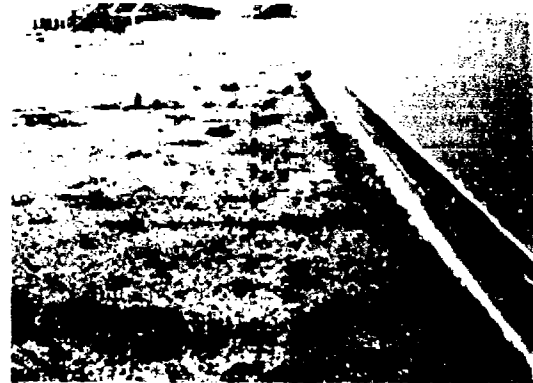


Figure 5. Sample area H and I. The dotted line approximates the damp insulation boundary. The arrows point to the roof drains seen in Figure 4.

that only one hot spot was related to a roof leak; the rest of the hot spots resulted from thickness variations in the built-up membrane.

As shown in Figures 4 and 5 and as verified by sample H, a strip of damp insulation parallels the west side of the west penthouse. The fact that this wet insulation is near the penthouse flashings suggests that a leak has occurred there. However, since our visual examination did not uncover any obvious flaws in this area, it is possible either that the leak occurred during construction before the flashings were watertight, or that spring meltwater from snow drifts gets behind the flashings and into the roof. We are uncertain exactly how water has entered this area, but we do suggest that a qualified roofer examine this area in more detail than we could during our brief overview.

Core samples A and C, taken from thermally bright and blister-free roof areas, revealed slight traces of moisture that we believe are unrelated to leaks. Both areas were thermally bright because the membrane in each area was extra thick. A thick membrane can store more solar heat and remain warmer longer than a thin membrane.

Sample C was taken from one of numerous small hot spots that dotted the roof surface (Figs. 6 and 7). Although sample C was slightly wetter

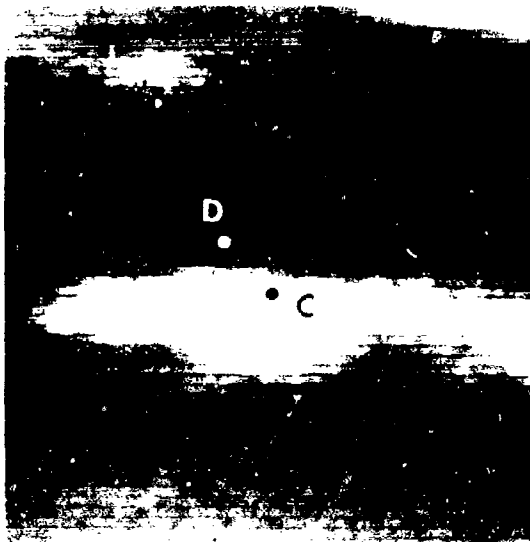


Figure 6. Thermogram of a hot spot (bright spot) that occurred in a visually uniform area of roof.



Figure 7. White spray paint outlines the hot spot shown in Figure 6. The letters and dots signify core sample locations.

Table 1. Core sample results.

Sample	Membrane thickness (in.)	Moisture content (% by weight)	Thermal value (% of original)
A	3/4	8	97
B*	3/8	4	99
C	1/2	9	97
D	3/8	2	99
E*	3/8	3	99
F	3/8	2	99
G	3/8	3	99
H	1/2	17	94
I	3/8	5	98
J*	3/8	2	99

\* Insulation not adhered to roof deck.

than sample D (taken from outside the bright area), its membrane was 1/8 in. thicker than sample D (Table 1). This moisture is not believed to be indicative of leaks, but rather is believed to have been built into the roof. Perhaps the insulation got wet during storage or was rained on during installation. The extra membrane thickness was due to an abnormally heavy interply mopping.



Figure 8. Thermogram of a 2-ft-wide thermal anomaly extending from the roof edge to the monitor. The arrow points to a roof drain.



Figure 9. Sample area A and B. The arrow points to the same roof drain as in Figure 8.

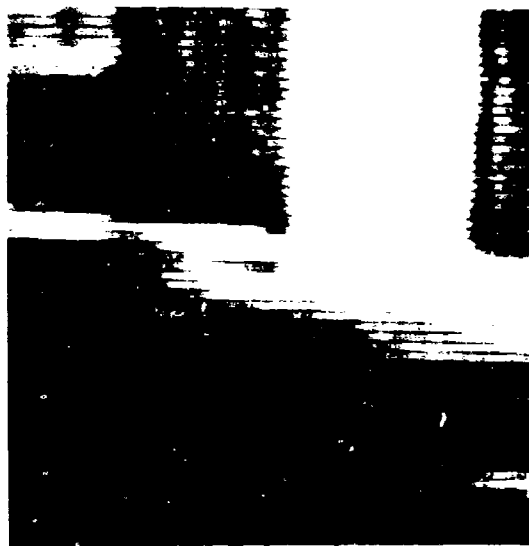


Figure 10. Thermogram of a hot spot near the double doors of the east penthouse.

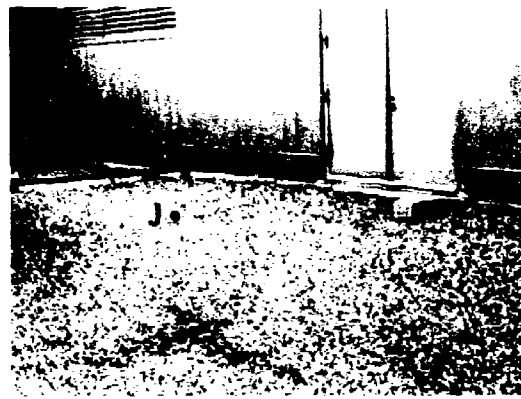


Figure 11. Roof area near the double doors shown in Figure 10.



Figure 12. Thermogram of a bright area along the penthouse flashing.

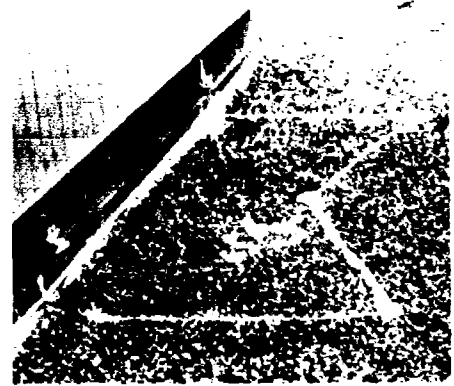


Figure 13. Spray-painted lines mark the boundary of the bright area in Figure 12.

Sample A was taken from a 2-ft-wide bright band that extended from the south parapet wall to the monitors at the center of the roof. A portion of that bright band is shown in Figures 8 and 9. The membrane in this area was  $3/8$  in. thicker than the surrounding roof because extra plies were used there to splice one day's work into another. The thermally bright area to the left of the bright band in Figure 8 is thought to result from extra heavy interply moppings associated with work near the roof drain.

Another prominent hot spot occurred near the double doors of the east penthouse (Figs. 10 and 11). Since sample J, taken from that area, contained only 2% moisture and the membrane there was not extra thick, we believe that the apparently hot door seen in Figure 10 was the cause of this hot spot.

On the south side of this penthouse a small hot spot was detected along the flashings (Figs. 12 and 13). The presence of caulking directly above this area (Fig. 14) suggested a leak. However, sample G showed this area to be dry. During the spudding operation for sample G we discovered that this area had been punctured and patched (Fig. 15). The patch, which amounted to an extra thick flood coat, explains why this area appeared brighter to the infrared scanner.

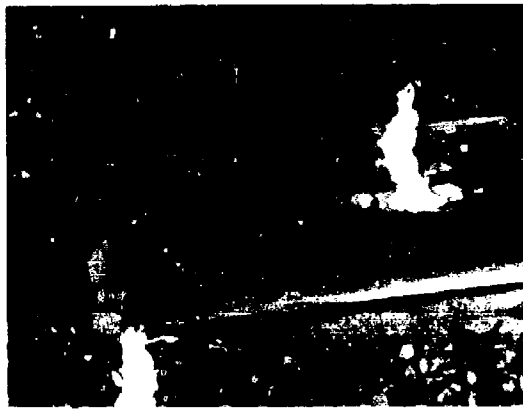


Figure 14. This caulking may indicate past defects.

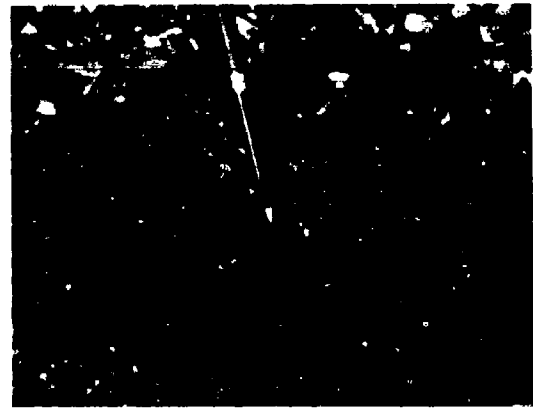


Figure 15. Membrane puncture near sample G. No moisture had entered this area.

Samples E and F showed that a bright area surrounding one breather vent corresponded to a mound of gravel and not wet insulation.

Although the majority of the hot spots detected on this roof were not moisture related, the results of core samples taken from these areas strengthened our blister findings.

#### BLISTER FINDINGS

Three blisters were cut open and examined. Each blister had formed because of voids that had been constructed into the built-up membrane. No indication of water or ice was evident within the blisters.

The first blister (Fig. 16) was actually a number of small blisters that had coalesced into a larger one. This group of blisters formed within the asphalt mopping between the insulation and the built-up membrane. We believe that they were built into the roof, as the mop string and the uneven interply moppings (Fig. 16) certainly indicate application problems. If asphalt is allowed to cool too much, it will not flow uniformly when applied. Thick, uneven moppings can result in poor adhesion and blisters. The excessive and nonuniform thickness of bitumen shown in Figures 16 and 17 and recorded in Table 1 strongly suggests that the asphalt was too cold at application. Cold application can cause poor adherence; three of ten insulation samples on this roof were not well adhered to the roof deck (Table 1). Poor adherence between roof components could make the membrane susceptible to thermal splitting and blowoff.

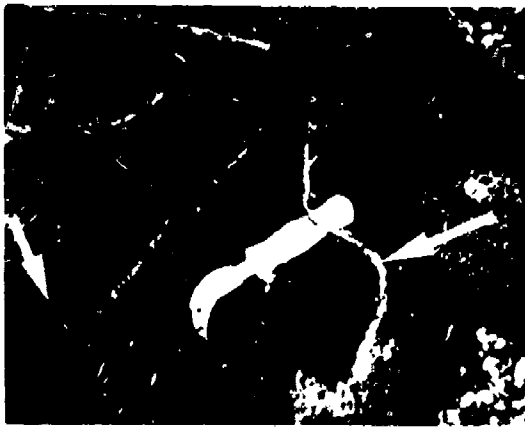


Figure 16. Inside of blister number 1. The arrows point to a mop string and a mound of asphalt.

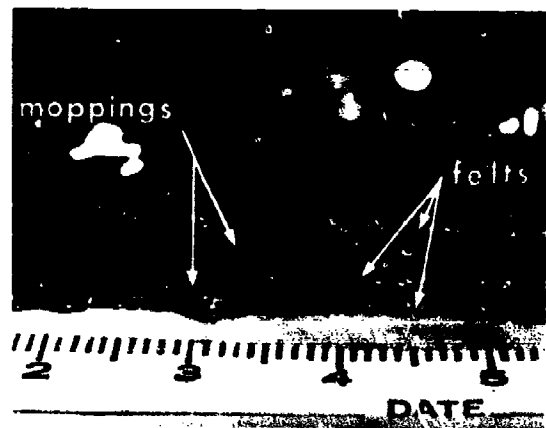


Figure 17. Cross section of built-up membrane. Note the tremendous difference between interply moppings.

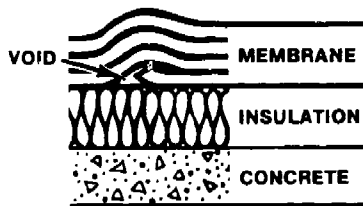


Figure 18. A curled felt edge created blister number 2.



Figure 19. Dry spot on the underside of a felt that led to blister number 3.

Organic felts must be broomed to achieve complete adhesion between the felts and the insulation. Blister number 2 was created by a curled felt edge (Fig. 18), probably because it was not properly broomed in during construction.

Unlike the first two blisters, which had formed at the insulation-membrane interface, blister number 3 had formed between the bottom and the top three plies of the membrane. Figure 19 shows a dry spot on the underside of a felt that we believe was the void that led to this blister. This lack of asphalt-to-felt adhesion also indicates improper brooming.

The three cuts show that the blisters could be due to a combination of cold asphalt and poor workmanship. Since this roof was constructed late in the fall, we suspect that cold weather was an important factor.

#### CORE SAMPLE AND BLISTER PATCHES

The weather was very cold when we patched the cored areas and blister cuts. This could affect the performance of the patches, so they should be considered to be only temporary.

Next summer an additional 5 in. of gravel should be spudded from around each patch. They were not graveled in so they should be easy to locate by referring to Figure 1. The membrane should then be cleaned with a wire brush and a new layer of roofing cement added, followed by a felt 3 in. larger than the old patch. Then the area should be covered with more roofing cement and graveled. Spray paint should be used to mark each patch to assist future maintenance in those areas.

#### SUMMARY AND CONCLUSIONS

The two-year-old roof of the O'Neil Building at Hanscom Air Force Base is seriously blistered. The blisters on this roof are caused by voids that were built into the membrane during construction. The majority of the voids apparently resulted from inadequate brooming and from uneven asphalt moppings, likely due to cool asphalt.

An infrared survey, verified by core samples, indicates that a slight amount of moisture unrelated to the blisters is nonuniformly spread throughout the insulation in this roof. Although undesirable, it does not pose any major problems at its current level. Table 1 shows that the moisture detected in this roof does not seriously reduce the roof's insulating ability. Most of this moisture was probably built into the roof. The infrared survey also uncovered a strip of wet insulation along the flashings on the west penthouse. It is not certain whether this moisture entered the roof before or after construction, but this area should be examined in detail. The remainder of this roof is believed to be watertight.

We saw at least seven flashing flaws. They were marked with spray paint and should be repaired by the contractor under terms of the roof warranty. A cold process consisting of roofing cement and reinforcing mesh is probably adequate.

Of the ten insulation samples we took, three were not adhered to the deck. Poor adhesion could subject the roof membrane to increased thermal stresses and the likelihood of splits and wind blowoff.

#### RECOMMENDATIONS

The flashing flaws marked with white spray paint should be repaired with roofing cement and reinforcing mesh as a warranty service by the contractor. The flashings on the western side of the west penthouse should be examined for flaws and patched if necessary. In addition they should be examined to determine if meltwater could enter this roof from above the flashings. If so, the flashing should be patched or reconfigured to prevent leaks.

There are several alternatives available for dealing with the blisters on this roof. They are:

- 1) Replace the entire built-up membrane and insulation.
- 2) Replace just the membrane and the wet and unadhered insulation.
- 3) Repair the blisters.
- 4) Leave the membrane alone but conduct periodic visual and infrared examinations, repairing any defects noted.

Alternative 1 assumes that the membrane and the insulation need to be replaced. Although the outlook for this blistered, poorly attached membrane is not good, there are probably many years left in it and the insulation is still in good condition. Thus, it seems wrong to remove and replace everything.

Alternative 2 assumes that the membrane needs to be replaced but the insulation is in good condition. We recommend against this alternative until the membrane deteriorates beyond repair. Currently the membrane, although imperfect and aesthetically unappealing, still waterproofs the building.

Alternative 3 is very difficult to achieve when the size and number of blisters are as great as on this roof. Blister formation takes time, and it is likely that blisters will continue to grow for several more years. Cutting and patching many blisters may cause more harm than good to a roof because of the increased roof traffic that would occur. This alternative should also be rejected.

Alternative 4 acknowledges that numerous blisters will shorten a membrane's service life because blisters puncture easily and deteriorate.



Currently this roof membrane is essentially watertight. Because of this, it should be maintained rather than torn off or patched. To keep it watertight, all traffic should be kept to a minimum and detailed visual examinations and necessary repairs should be made at least twice a year. In addition, infrared moisture surveys are recommended on a three-year cycle to catch problems as they develop. Once the membrane begins to leak, alternative 2 should be used. At that time any dry, unadhered insulation should be rebonded to the deck, and all wet insulation should be replaced. Then a new membrane can be added.

All of these alternatives have certain technical appeal. However, we feel that alternative 4 will produce many more years of economical, serviceable life from this blistered roof. If this roof is neglected, it will soon fail, creating problems for both the occupants and the base civil engineer. Maintenance is the key to achieving reasonable performance from this imperfect roof.

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