

# SUGGESTED REPAIR SPECIFICATIONS FOR BUILT-UP ROOFS OVER WET LIGHTWEIGHT CONCRETE DECKS

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**D**uring the period from 1970 to 1980 it became apparent that some pattern of problems was emerging with built-up roofs installed over wet-fill and lightweight insulating concrete decks. The problem did not appear to be localized in any specific section of the country because incidents occurred in the Northern Midwest, Minnesota and the Dakotas for example, as well as in the Deep South, Florida and the Rio Grande area of Texas.

This escalated incidence of problems with traditional BUR membranes applied over a deck and material which had enjoyed an acceptable reputation in the construction industry for perhaps 30 years, was unexpected, particularly by roofing materials manufacturers, and many were deeply concerned. The question frequently asked was, "What went wrong with this roof that makes it different from others in the past?"

Recognition of the problem did not come easily as every roof involves many variables. Gradually, however, a pattern with one common element began to form. The lightweight insulating concrete deck had retained the major part of its mixing water years after it had been installed. This finding resulted from field examinations and laboratory testing of a large number of roofs over lightweight concrete decks. Cuts were taken from roofs which had leaked in some areas and had not leaked in other areas. Great care was used to examine the membrane and deck in areas purposely selected to be as far away from known leaks as possible. The purpose of this selective sampling was to assure, as far as possible, that test results would not contain errors introduced by water from a local leak or an imperfect membrane.

In a number of instances, existing sound roofs which had been installed over lightweight insulating concrete but had never leaked also were examined. These roofs and decks helped identify the origin of the problem, because the lightweight concrete decks under roofs which never had leaked contained substantial amounts of the original mixing water. The roof membranes over these decks were deteriorating, although they did not yet leak. The water had remained in the concrete deck since it was poured, as long as 10 years or perhaps longer in some instances. It was not unusual to find 50 to 90 percent of the original water still in the deck five to eight years after the building was constructed.

Another finding of this investigation was that lightweight insulating concrete decks which had remained wet virtually were all composed of vermiculite aggregate and portland cement. Some decks, which were composed of perlite aggregate with portland cement, appeared to be quite dry when examined. The roofs on those decks presented no problem. Few decks containing perlite aggregate were examin-

ed, either because there were few such decks constructed during the preceding years or because few roofing membrane problems had developed. Only buildings with problem roofs came to the attention of the manufacturer who had issued a roof guarantee. No decks containing lightweight concrete composed of portland cement and a foaming agent were encountered in this investigation. At the time of this study, the market for foamed concrete had not reached its full potential. In addition, foamed concrete contains only about 30 percent as much initial water as vermiculite concrete, and therefore there is less excess water to dry out.

## THE PROBLEM

Few people expected water in the lightweight concrete to remain troublesome for years. In some instances the weight of water remaining exceeded the weight or mass of the concrete itself! This resulted in a dead load on the structure which was never anticipated by the designer. The high water content reduced the thermal insulation value of the concrete to an average of 50 to 30 percent of that expected. As long as the concrete remained wet, it never reached its expected compressive strength. In virtually every wet deck tested for compressive strength, the deck had less than the 125 psi minimum specified compressive strength.

Perhaps the greatest negative contribution of water remaining in the deck was degradation of the roof membrane. Leaks in decomposing roof membranes brought this problem to national attention. Roof membranes of the period 1970 to 1980 often consisted of organic felts or asbestos felts, neither of which can withstand long exposure to high levels of moisture.

The roof membranes removed from wet decks were subjected to extensive laboratory examination. Results of laboratory analysis led to the following general conclusions:

- the membranes taken from wet decks had higher than normal moisture content;
- tensile strength of the membrane and individual constituent plies was reduced;
- organic felts and base sheets decomposed or rotted, with maximum decomposition occurring in the base sheet or felt nearest the deck;
- asbestos felts, being inorganic, did not rot but lost tensile strength.

Roofs over wet decks in the North usually exhibited splitting two to five years after they were installed. This was caused by moisture absorption and reduction of membrane tensile strength. In the South, where temperatures are moderate, the typical failure pattern consisted of rotting from the bottom up and took somewhat longer before

becoming evident. Perhaps five to seven years passed before the owner was aware of major problems.

### EXAMPLES OF DETERIORATED ROOFS

Figure 1 shows a typical four-ply organic roof consisting of a base sheet and three plies taken from a wet deck in Iowa. The deck contained 84 percent water in 1981. The roof was applied in 1970, and splits began to occur in 1976. The organic felts exhibited a combination of rotting and deterioration prior to splitting.

Figure 2 shows a coated organic base sheet and two #15 asbestos felts which were taken from a wet deck in the Rio Grande Valley of Texas. The roof was applied in 1975 and began to leak in 1978 or 1979. The sample was taken in December 1981, at which time the deck contained 50 percent moisture. The base sheet from this sample was so deteriorated that it had to be pieced back together to make the exhibit. This roof split as a result of deterioration and loss of strength. Note that the inorganic asbestos felts did not rot.

Samples in Figures 1 and 2 were made by preparing a small 3- x 5-inch sample of the membrane without gravel, and putting it in a circulating solvent bath in the laboratory. The trichlorethylene solvent dissolved all of the asphalt in the membrane samples, leaving only the felts themselves. After the solvent had completely evaporated, the felts were weighed to determine if they met the specifications for dry felt weight. They also were examined for deterioration or rotting. Severe deterioration or loss of weight as shown in Figures 1 and 2 is instantly recognizable.

Figure 3 shows a cross section of a lightweight concrete deck with a deteriorating roof membrane. Figure 4 shows the same condition where trapped moisture in the deck has broken through the asphaltic vapor barrier base sheet, penetrated the board insulation, and reached the roof membrane. Failures or problems of this magnitude have been observed in Missouri and Texas.

### DETERMINING THE CAUSE OF THE PROBLEMS

Manufacturers and roofers were unable to identify the basic source of the problem for some time because it was generally accepted that lightweight concrete decks had not caused major roofing problems before. Gradually, however, it was recognized that one major change had occurred in deck design and application. This was the change from the original fiber glass formboard or other porous supporting structure for the liquid concrete mix to a corrugated steel supporting structure.

Apparently, it was assumed that the steel corrugated supporting structure would be faster and less expensive to install, and would provide the same drying capability as the earlier porous formboard. Thus, the deck could enjoy a more competitive position and sales would increase. Steel deck sales increased, but the unperforated corrugated steel supporting structure failed to allow excess water to evaporate from the wet concrete as in the past. Originally, it was thought that side laps in the steel would provide sufficient openings for drying. Note the cross sections of the deck in Figures 3 and 4. The side laps of the corrugated steel supporting structure are so tight that no evaporation of any consequence can occur at this point. When this type of deck construction was widely used, architects, specifiers, roofing

material manufacturers and roofers believed that excess water would evaporate through the side laps within a few weeks or months. Unfortunately, the water remained for years.

### ATTEMPTS TO DEFINE AND ATTACK THE PROBLEM

At least one roofer in Kansas City, Mo., challenged the concept that adequate drying would take place through the side laps alone. Paul L. Morris, president of Sellers & Marquis Roofing Co., had experienced marginal results with this type of deck as far back as the early 1960s and, based on first-hand personal experience, doubted that side lap venting would allow the decks to dry as expected.

As co-chairman of the Technical Committee of the Midwest Roofing Contractors Association, Morris raised so many questions that at least one lightweight concrete supplier responded with additional research and information which they made available to the roofing industry at a presentation given by John L. Wright at the Midwest Roofing Contractors Convention in 1972 and again at a Roofing Technology Conference at the National Bureau of Standards in March of 1973.

Wright suggested that the metal supporting deck should have about 3 percent slotted or punched open area in its surface. His second idea proposed that drilling 1/2-inch or 1-inch diameter holes through existing, non-perforated metal deck and into the building interior would have some beneficial drying effect.

In 1970, Wright and Morris collaborated with two schools to test the efficiency of drilling holes in wet decks. The schools were Truman High School and Luff Elementary School, both in Independence, Mo. At the time the holes were drilled and schools reroofed, the moisture contents of representative samples of the decks were:

#### Truman High School 1970

- Sample 1 58% water over metal forms
- Sample 2 28% water over metal forms
- Sample 3 2.7% water over glass fiber formboard

#### Luff Elementary School 1970

- Sample 1 52% water over metal forms
- Sample 2 29% water over metal forms
- Sample 3 32% water over metal forms.

At each school 1/2-inch diameter holes on 24-inch centers were drilled from the top down through the concrete and the metal form. A new roof then was placed over the deck. The 1/2-inch holes on 24-inch centers were far less than the optimum 3 percent open area.

In 1982, the Truman School deck was sampled and found to have dried to a 3.75 percent moisture content. In 1983, the Luff School was sampled and found to have dried to a 13.4 percent moisture content. Some drying of the exposed concrete would have taken place while holes were being drilled, but the deck was covered in a matter of hours so this drying was minimal. No drying rates of wet-fill concretes over various substrates ever have been published or made available to the roofing industry. One attempt was made more than 20 years ago, but it has not been widely accepted or credited. The most recent data available was taken from a six-year-old roof in South Carolina. Wet fill measured over side vented metal was 31.8 percent water by weight. Wet fill

poured over porous structural wood fiber panels was 3.2 percent water by weight.

In the 1970s roofing manufacturers who had issued guarantees on roofs over lightweight concrete decks were suddenly faced with roofing repair costs on roofs that were only five to seven years old. Subsequent investigation showed that the problems originated in wet decks. However, no known solution for repairs generally was available. Only the few people who attended the 1972 technical meetings of MRCA and the 1973 NBS meeting had any information that drilling holes could be one step in an effective repair. Without this information, manufacturers with service contracts or bonds were at a disadvantage. Manufacturers recognized that the owner expected a major repair to stop leaks. Manufacturers also knew that putting another roof over the same wet deck would not solve the problem, only postpone it. Unless the deck could be made to dry, any repair would be wasted.

### **SPECIFYING AND CARRYING OUT A TOTAL REPAIR**

After the drilling technique became better known there was hope that some repairs could be accomplished successfully. The majority of lightweight concrete decks installed during 1970 to 1980 were installed without the 3 percent open area suggested as optimum. Consequently, the majority of roofs installed over wet fill decks did not dry and required extensive repairs. No explanation has been offered as to why the decks were installed without open areas in the steel after it had become apparent that the open area was needed.

Figures 5 and 6 show the cross section of a typical deck which has not dried, but has been drilled with  $\frac{3}{4}$ -inch diameter holes on 24-inch centers. Drilling allows moisture from the wet concrete to evaporate downward into the building. Obviously, more holes will accelerate drying, but will also cost more. Experience shows that  $\frac{3}{4}$ -inch holes on 24-inch centers costs about \$15 per square for labor. Corks costing 4.5 cents each may be put in the holes from the top to act as insulation if a new roof is to be put directly over the wet deck. Application of new board insulation directly over the wet deck is recommended. In this case, the corks can be eliminated. The owner gets the thermal value of new insulation immediately and does not have to wait years for the wet concrete to dry. This solution is depicted in Figure 6 with a smooth glass felt roof membrane, coated white, applied over the insulation.

### **THE WATER SEAL OR HIGHLY EFFECTIVE VAPOR SEAL**

Planning for repairs of wet fill decks evolved in the 1970s and early 1980s. The practicality of drying out the deck by drilling holes was less expensive and less hazardous than removing the wet concrete from an occupied building.

In some cases the concrete deck still contained as much as 80 to 100 percent retained moisture. It was anticipated that the holes would allow the deck to dry eventually to 5 or 10 percent moisture content. Because this drying takes place slowly, the new roof would be exposed to nearly the same moisture conditions as the original roof, at least for the first four to five years. A new and more reliable base sheet or water barrier was needed over the wet deck after the holes were drilled. Plastic sheets were considered. However, they were not good vapor barriers and could not withstand hot

mopped asphalt.

Glass felts were being introduced by most manufacturers during the late 1970s and early 1980s, and it was assumed that a glass base sheet would be an ideal material for the bottom ply of a roof placed over a wet lightweight concrete deck. Unfortunately, glass felts were not immune to damage.

### **DAMAGE TO GLASS FELTS FROM CONCRETE DECKS**

On Dec. 18, 1981, a major producer of lightweight concrete aggregates announced that his company could no longer issue a roofing warranty for glass felt BUR roofs applied over lightweight concrete deck systems.

The company's tests had shown that exposure of the fibrous glass felts to the alkaline environment of poured in-place lightweight concrete decreased the tensile strength of the glass felts. On Dec. 22, 1981, a leading manufacturer of glass felts confirmed this behavior by issuing a bulletin which stated that the fibrous glass felts were weakened by alkaline concrete decks and could be susceptible to splitting.

Those who were evaluating glass felts over lightweight concrete analyzed test cuts from existing installations. Figure 2A shows the results of lab testing a three-ply coated glass roof which had been exposed to a wet concrete deck for 18 months. The bottom ply of glass had degraded 50 percent. The tensile strength of this three-ply Type IV glass membrane, measured by ASTM D 2523 at 70F, was 58.3 pounds per inch. This deterioration is more rapid than that of the organic or asbestos membranes. To meet ASTM D 2178-81 a single Type IV glass felt has a minimum tensile strength of 44 pounds per inch. The strength of the three-ply glass felt roof membrane had been reduced to almost one-ply.

Tests also measured the effects of alkali on organic and asbestos felts. It was found that these felts were not significantly affected by the chemicals in the concrete.

Further tests showed that the attack on glass felts was two-fold. The moisture in the deck attacked the binder which held the glass felts together and the alkali (calcium hydroxide) from the portland cement attacked the fibers themselves. The attack of alkalies and glass fibers had been known for years, but this was the first time roofing membranes had been involved.

### **FINAL DEVELOPMENT OF THE WATER SEAL BASE SHEET**

Another attempt was made to find a water-resistant seal to place over the wet deck to protect roofing membranes. The properties of this membrane had to include:

- virtual 100 percent resistance to water vapor or liquid water transmissions;
- alkali and water resistance;
- ability to be nailed to the deck with conventional deck nails and discs, and be tough enough to stand roofing traffic;
- ability to absorb hot asphalt on the upper surface so a membrane or insulation board could be mopped to it;
- laps to be nailed but not sealed.

The basic seal was composed of 1 mil of aluminum foil laminated with heat resistant adhesive to a kraft paper. The kraft paper was to receive the hot asphalt mopping. The foil

also had to be protected by other films and plastics from the effects of alkalinity in the concrete.

Through the cooperation of two basic aluminum producers and an aluminum laminating company, three different foils with kraft paper became available for repair and reroofing. All companies cooperated in providing foil protected from alkaline attack. To date, eight buildings have been re-roofed using drilled holes and foil laminate, and results are encouraging. Figure 11 shows the foil has resisted alkali attack for two years, and the insulation above the foil is dry. The deck has dried slightly.

### THE BASIC SPECIFICATION FOR RE-ROOFING OVER WET LIGHTWEIGHT CONCRETE DECKS

1. Remove existing roof.
  2. Drill 3/4-inch holes at 24-inch centers through concrete and metal forms. For faster drying, drill more holes.
  3. Nail aluminum foil water seal over wet deck with conventional deck nails and discs. Use one hundred nails per square.
  4. Mop a #15 felt, or a glass felt, over the water seal to get temporarily in the dry. Glaze the #15 felt.
  5. Mop selected insulation boards over the temporarily glazed surface.
  6. Apply hot built-up roof over insulation.
- 1 alt.** If no insulation is to be used, put one cork into each hole before putting down foil and mop new roof directly over foil.
- 2 alt.** Use smooth surface BUR and coat white to reduce solar load as shown in Figure 6.
- 3 alt.** Apply appropriate single-ply roof over insulation or foil. Some types of single-ply roofs can be used over lightweight concrete if holes are drilled and foil is applied.

### SUMMARY

The photographs in Figures 7 through 32 show four different installations of this technique for reroofing wet decks. Other applications have been made in Texas, South Carolina, and Florida. The first application, in August 1982, was on the Riverview Elementary School in Riverview, Fla. Florida Roofing & Metal Works, Inc. of Tampa was the roofer.

A second application was made on Limona Elementary School in Brandon, Fla. by Giffen Roofing of Tampa in 1983.

The third application was on the Kingswood School in Brandon, Fla. in 1983 by NSM, Inc. of Tampa.

The fourth complete reroofing of about 1,000 squares was done on the Daniel Morgan Middle School in Winchester, Va. in 1982. In addition to the holes and foil, the school received two layers of insulation, a smooth glass roof coated white to reduce the maximum surface temperature by 40 to 50F. The School Board of Winchester, Va. reports minimum energy savings of 25 to 35 percent per year with the new roof.

Figure 11 shows a cut of the Riverview roof in 1984. Holes are on 24-inch centers. The foil is still intact, showing no alkaline attack; and the roof and 1/2-inch insulation are dry. The roof and 1/2-inch insulation are dry. The deck has lost moisture from the original 108.3 percent to 98 percent in two years.

Figures 17 through 32 show the step-by-step reroofing of the Morgan School in Winchester, Va. in 1982. The roofer on this project was Anderson Roofing & Sheet Metal of Winchester.

It should be recognized that this procedure for repairing roofs over wet lightweight concrete cannot point to a long record of success. Time alone will verify its merit or lack of merit.

It has been almost 15 years since Morris and Wright introduced their concept for relieving trapped water in wet decks. Decks at the Truman and Luff schools have dried to very low moisture contents. Currently it is believed that a final deck moisture content of 15 percent or less is acceptable. Deck manufacturers now specify how to reach that dry value by proper vent openings in the original construction. The exact time when that dry value will be reached is still not known, however.

The aluminum seal is presently the best product to separate new construction from the old wet deck. Someone may suggest a better concept in the near future. Any improvement will be welcome.

### ACKNOWLEDGMENTS

In addition to Mr. Morris and Mr. Wright and the Midwest Roofing Contractors Association and the National Bureau of Standards for their 1972 and 1973 records, we are indebted to the lightweight deck company for its warning regarding the use of glass felts over concrete and the glass company who assisted in this technology. We are also indebted to the aluminum producers and the aluminum foil coating company who put their research staffs to work on the problem of creating an alkali resistant foil.

We earnestly and sincerely hope that these efforts will not be in vain, and that in a few more years we can say, that we have found an effective way to reroof or repair roofs over wet fill decks.



Figure 1

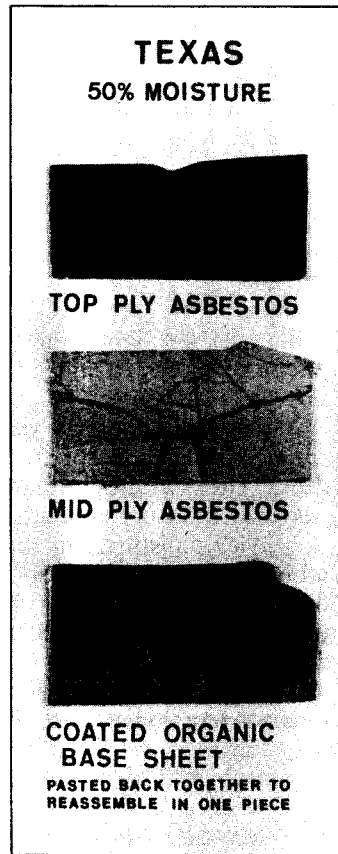


Figure 2



Figure 2a

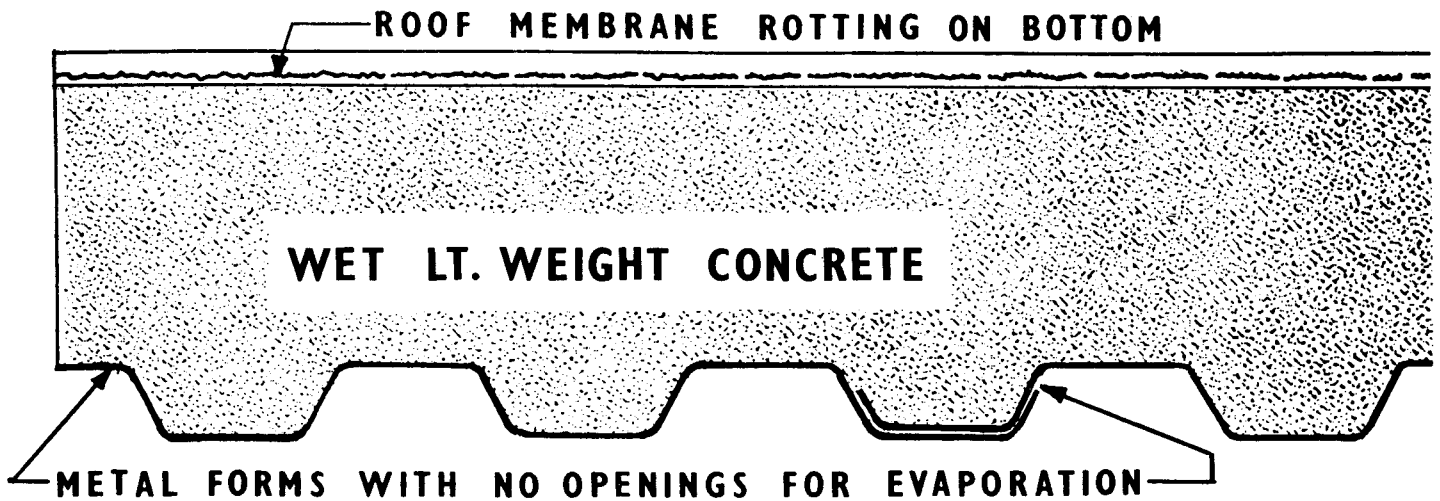
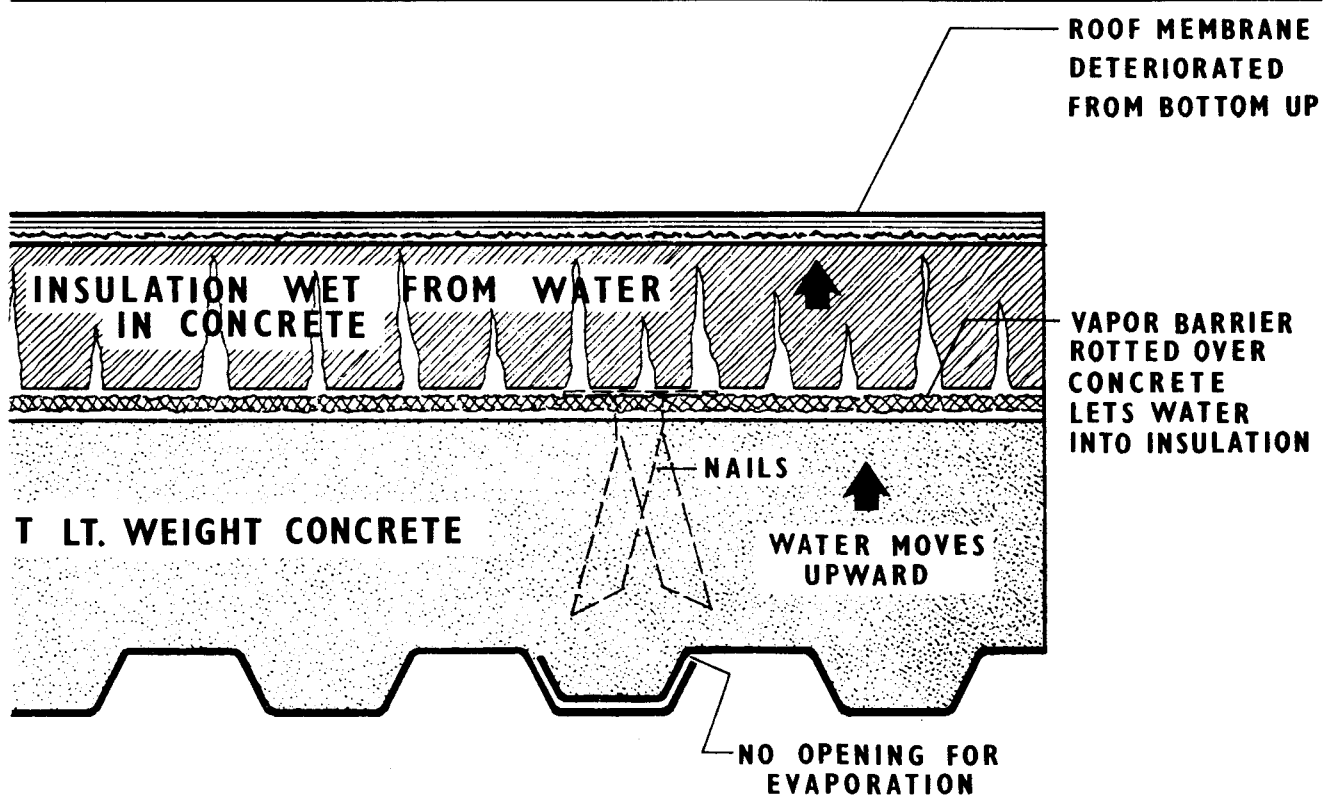
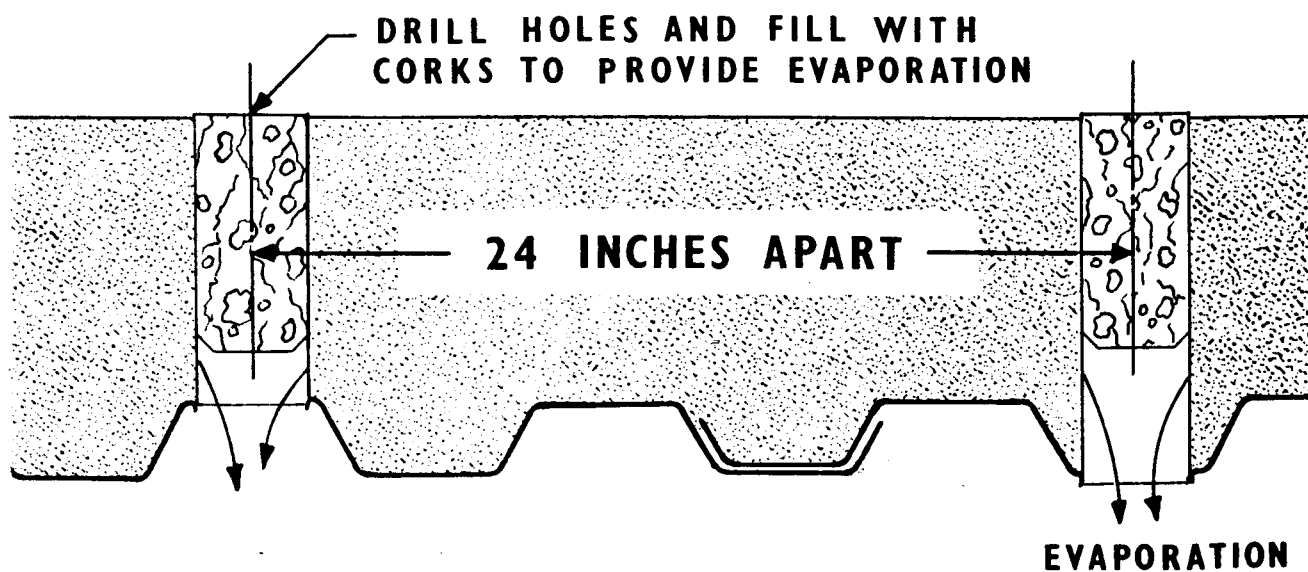


Figure 3 The basic problem



*The other problem (with insulation)*



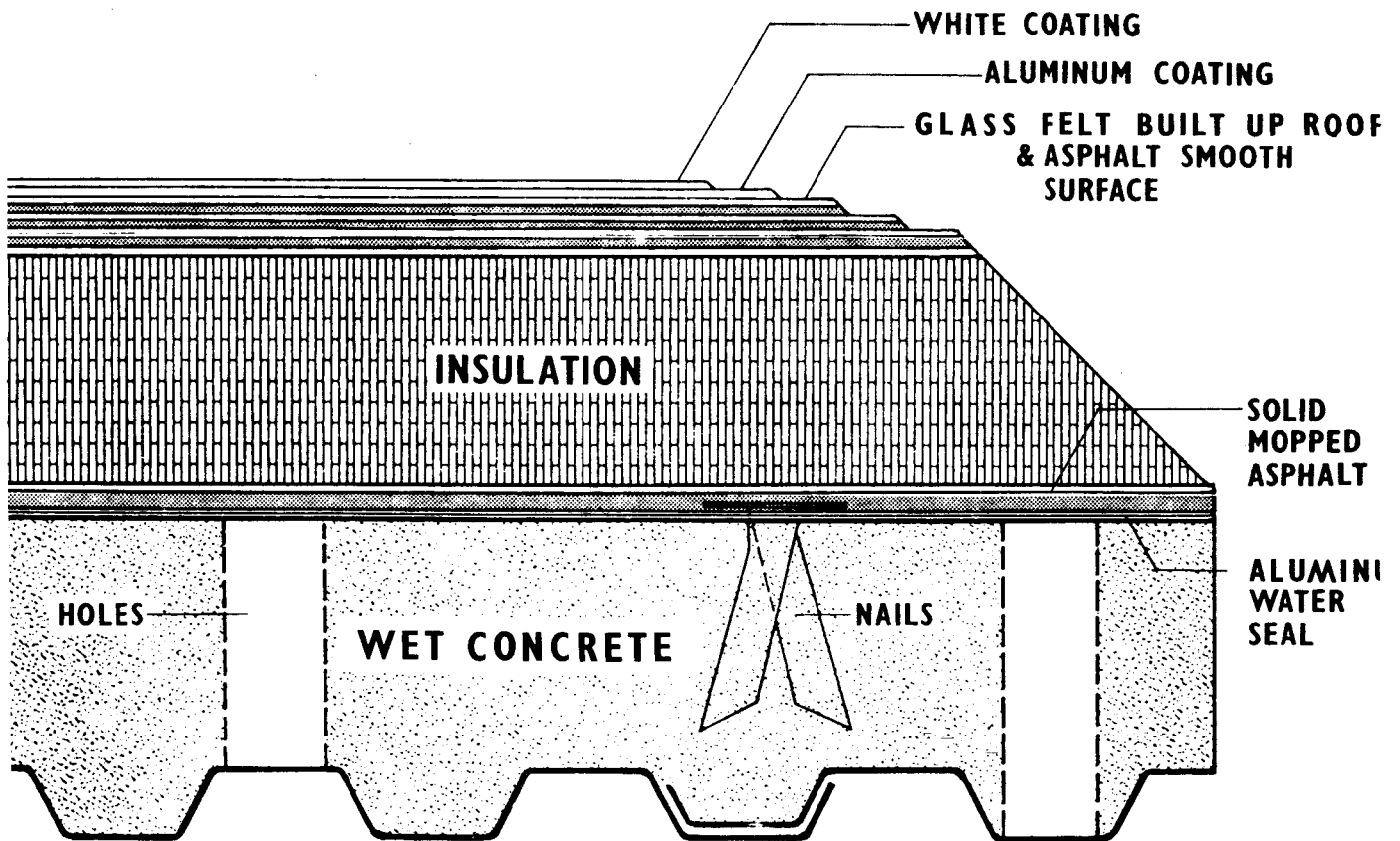


Figure 6 Glass felt built-up roof



Figure 7 First drilling of holes, August 1982, Riverview School, Fla.



Figure 8





Figure 9 First use of foil, Riverview, August 12, 1982

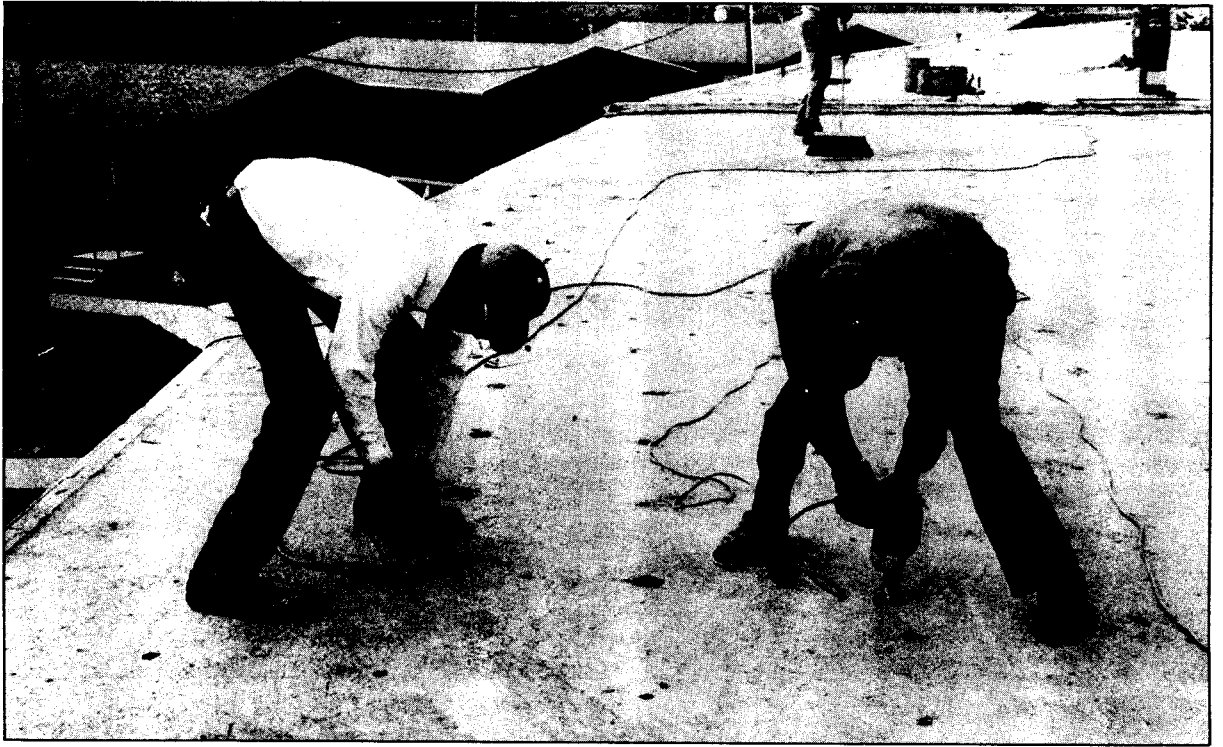


Figure 10

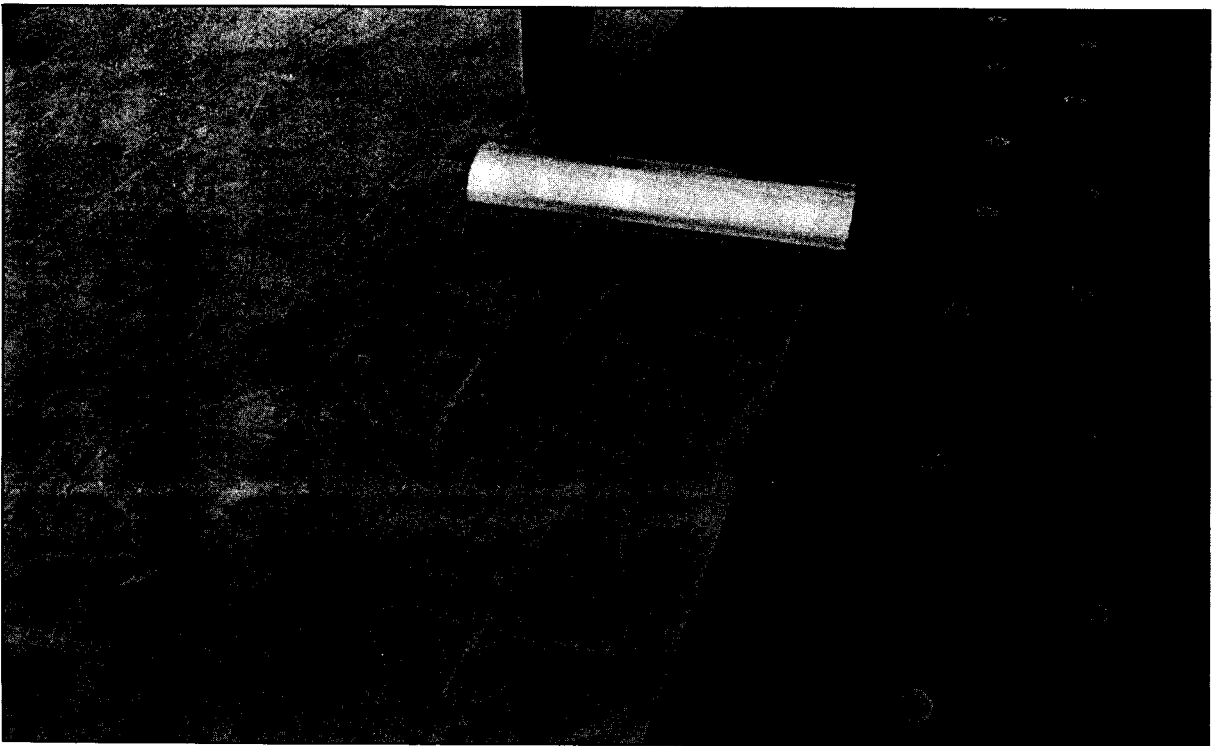


Figure 11 Riverview cut 1984: membrane dry, foil in good condition

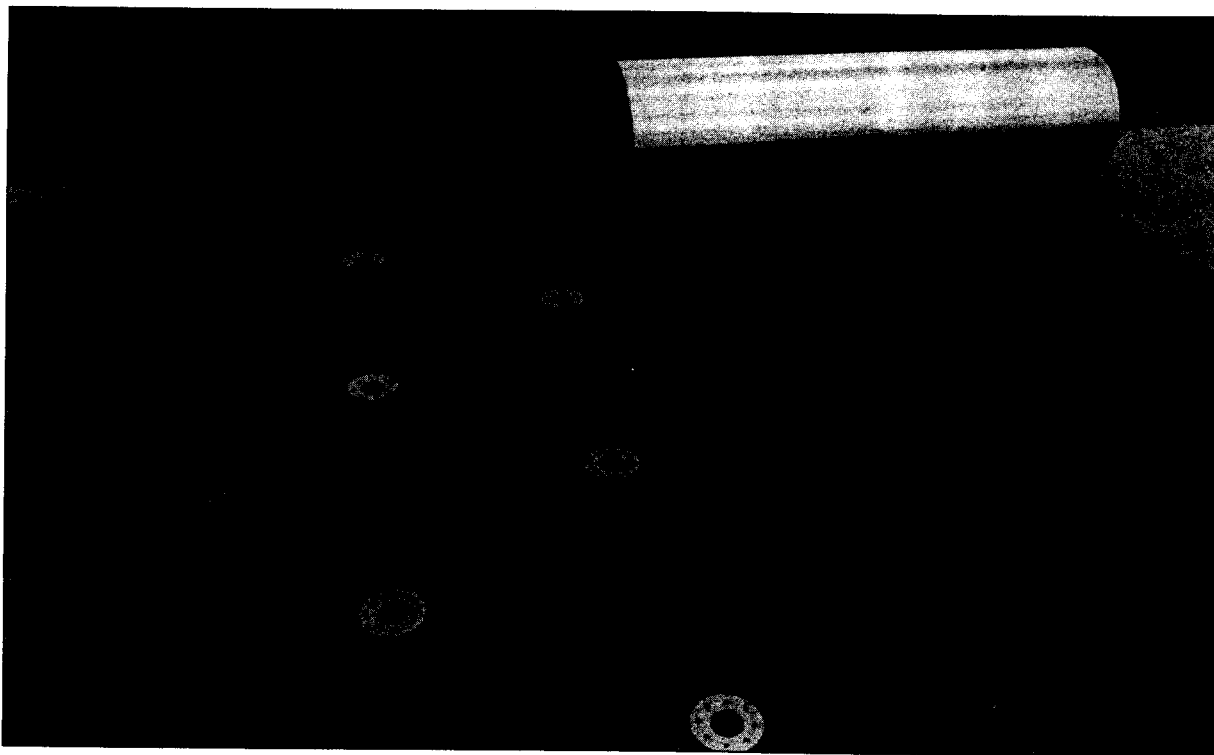




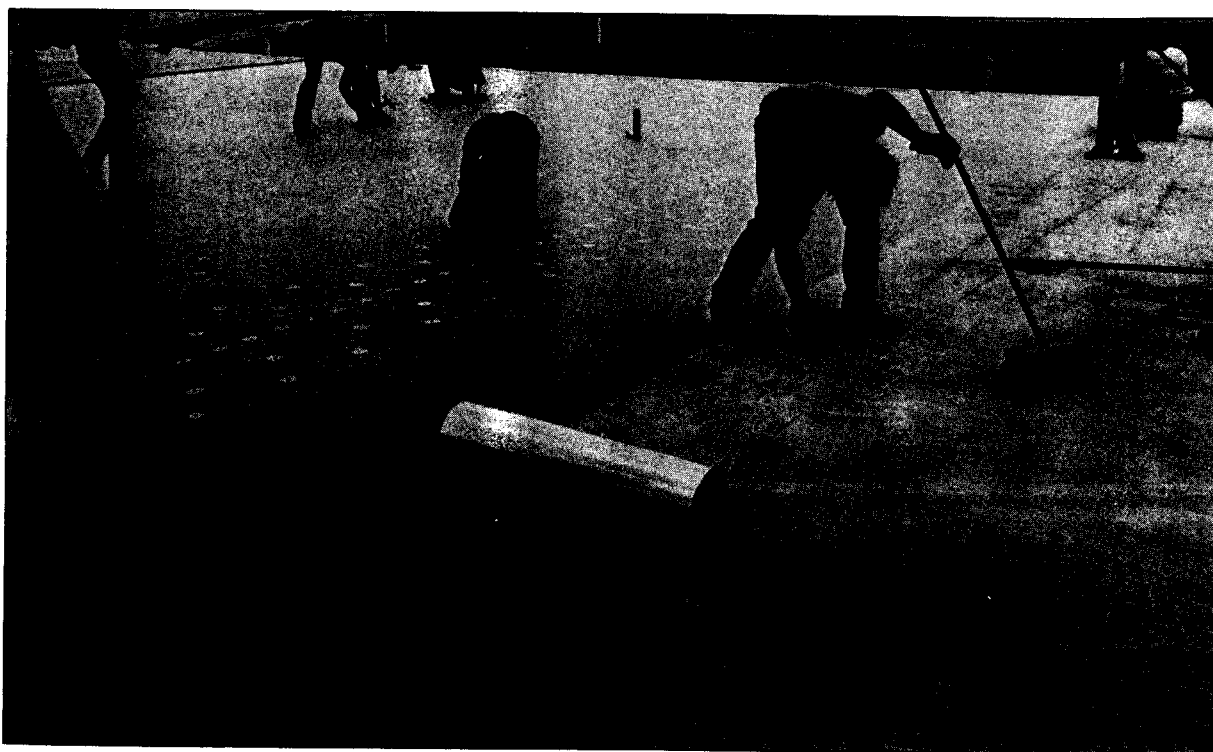
*Figure 12 Drilling Limona School, Brandon, Fla. 1982*



*Figure 13 Foil placement over drilled deck*



*Figure 14 Laps to be nailed; note nails and discs*



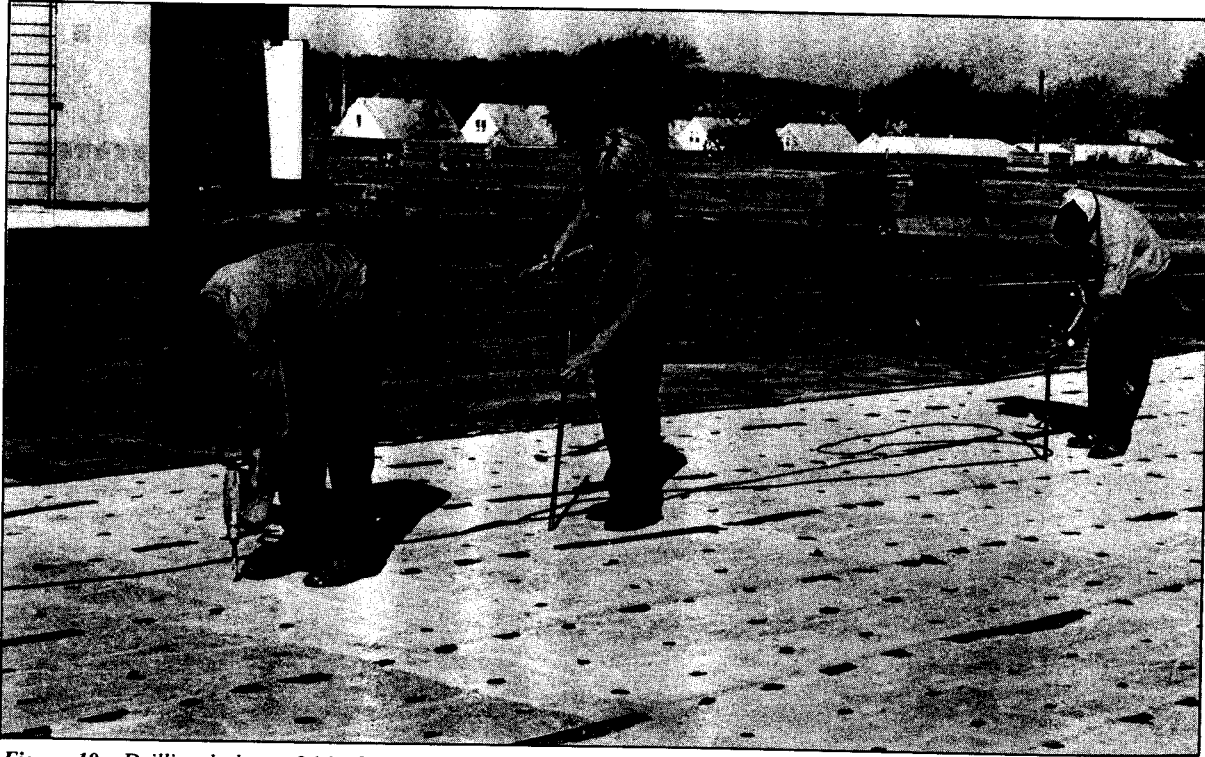
*Figure 15 Application of foil water seal, Kingswood School, Brandon, Fla. 1982*



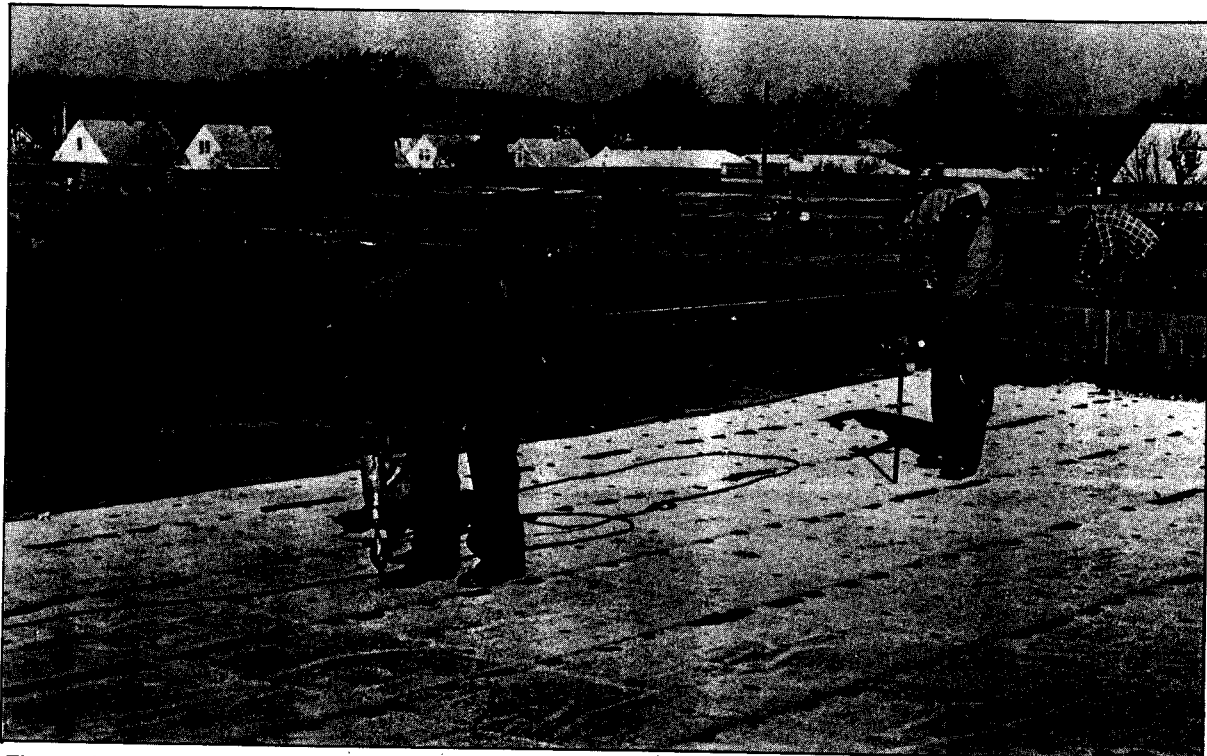
*Figure 16 Foil water seal, Kingswood School*



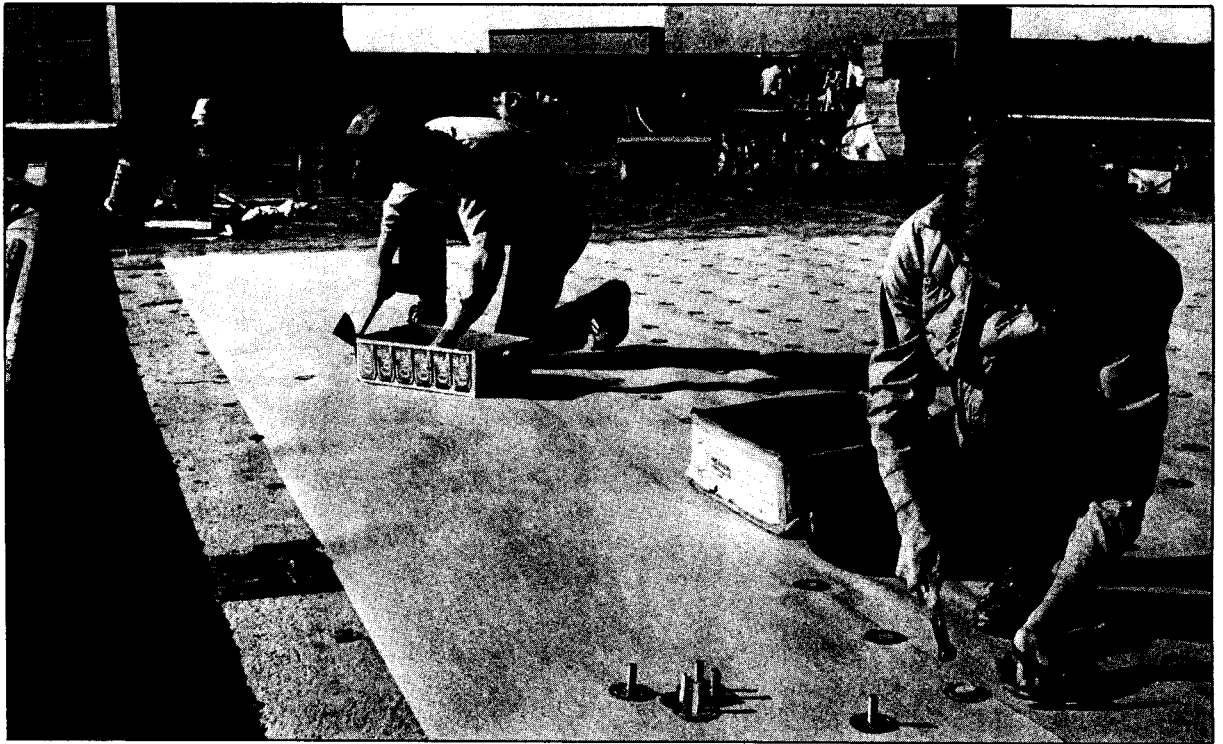
*Figure 17 Tear-off of original built-up roof from wet deck*



*Figure 18 Drilling holes at 24-inch centers. Steel rod is used as punch when drill bit slides on surface of flutes.*



*Figure 19 Drilling and punching deck. This steel supporting deck had deep flutes. Punching not usually required.*



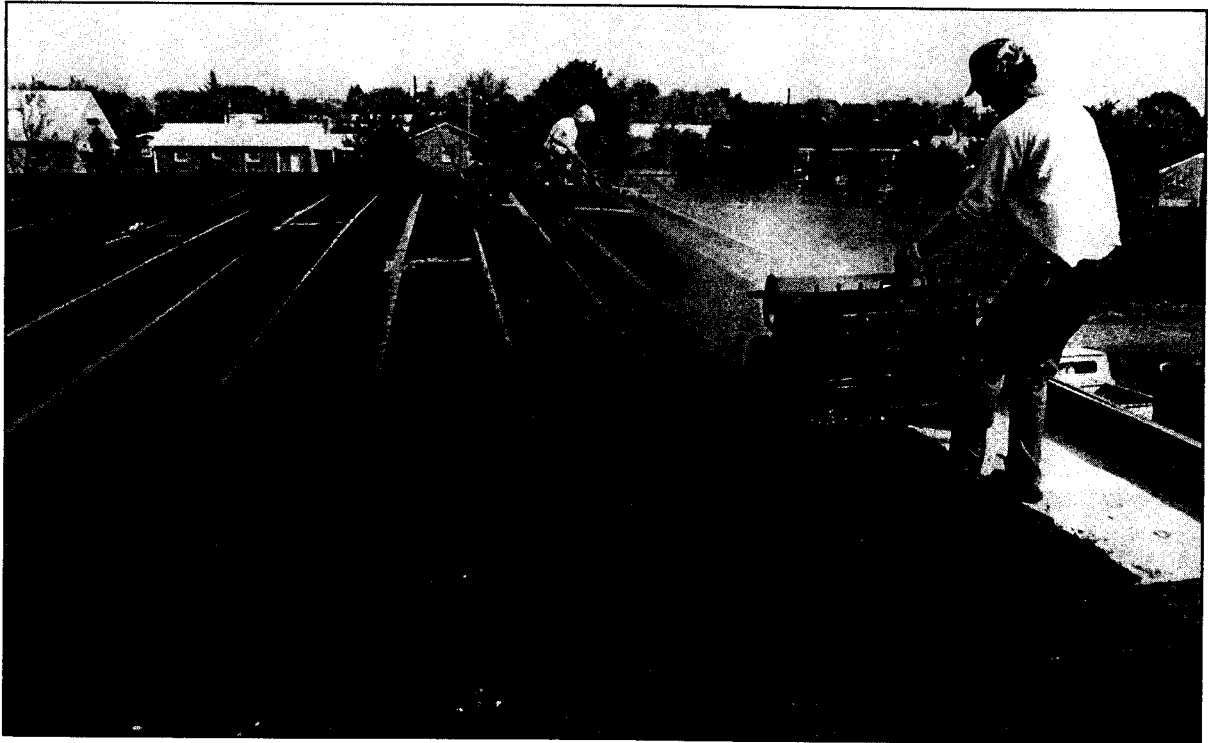
*Figure 20 Nailing aluminum foil water seal with nails and discs, 100 nails per square*



*Figure 21 Close view of nailing and pre-assembly of nails and discs*



*Figure 22 Covering large area with foil water seal*

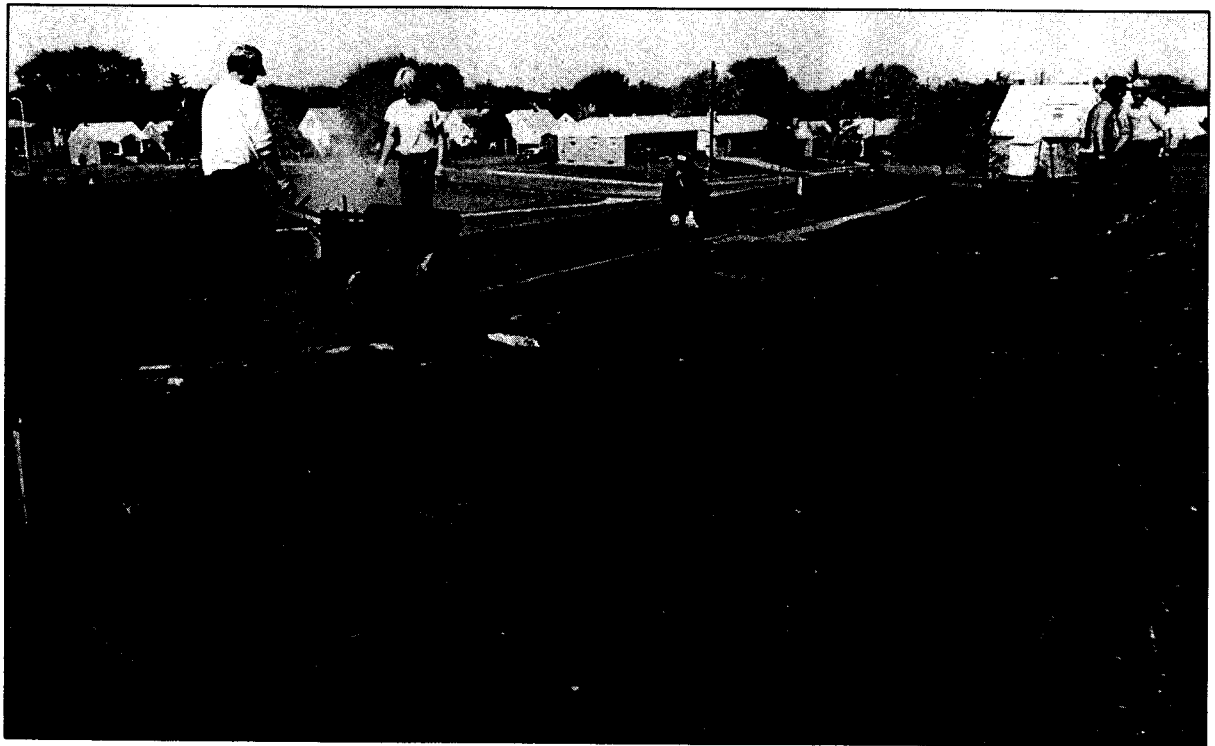


*Figure 23 Covering water seal with No. 15 felt and glazing surface to prepare for insulation application*





*Figure 24 Mopping No. 15 felt over water seal as temporary roof ready for insulation*



*Figure 25 Application of insulation. First layer is 1.4 inch urethane. Top layer is ½ inch fiberboard.*

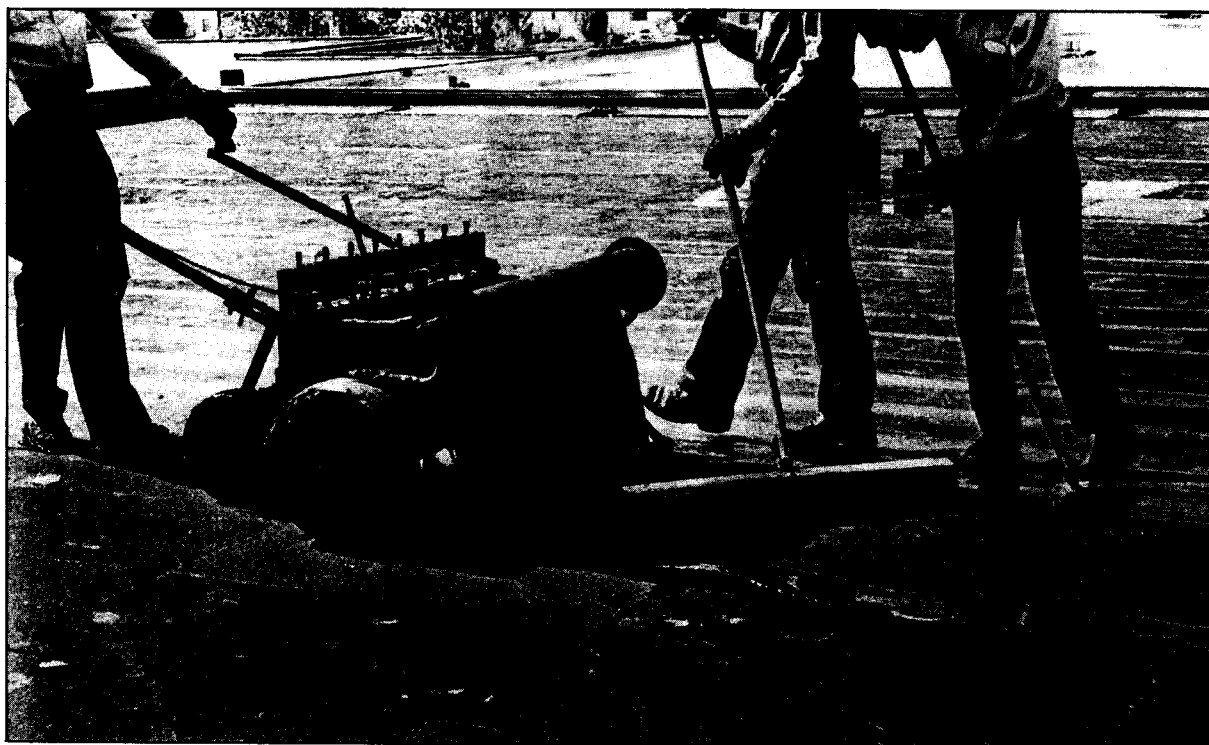




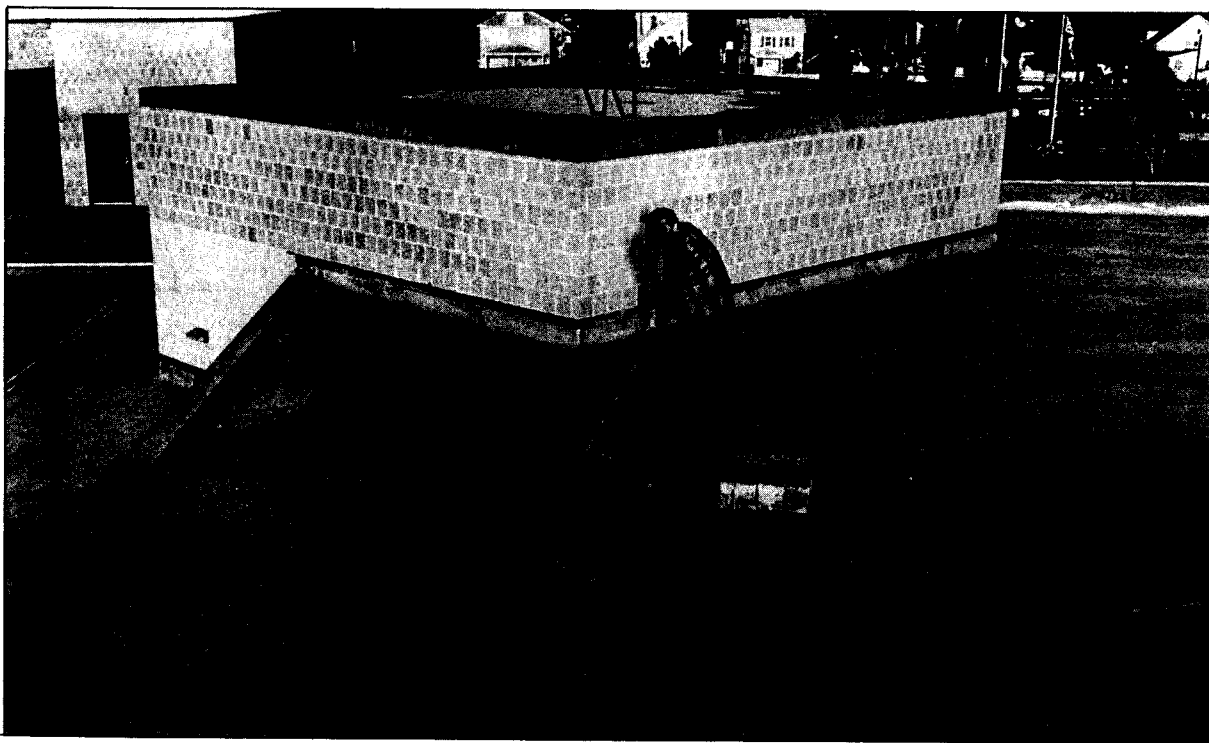
*Figure 26 Application of 1/2-inch fiberboard*



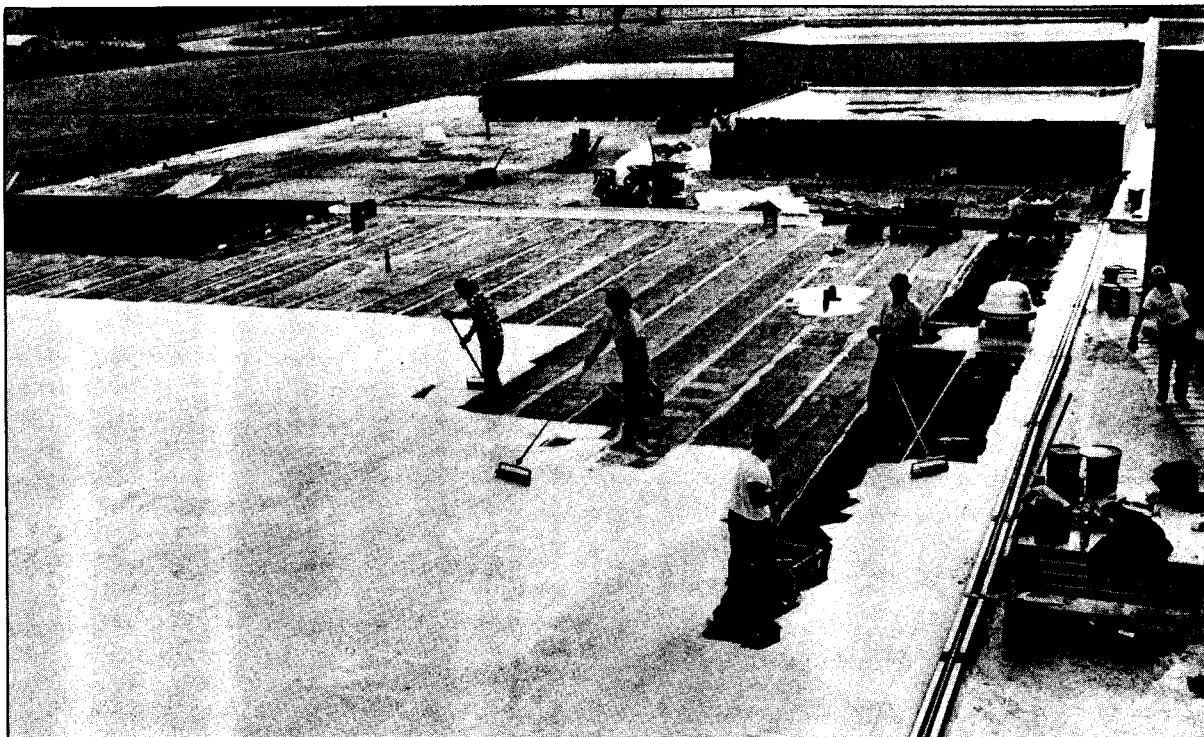
*Figure 27 Application of 3-ply glass felt membrane*



*Figure 28 Application of 3-ply glass felt membrane*



*Figure 29 Application of aluminum roof coating over glass felt membrane*



*Figure 30 Application of aluminum coating over glass felt membrane*



*Figure 31 Application of white coating over aluminum for maximum reduction of solar exposure and heat*



*Figure 32 Application of white coating over aluminum as final wearing surface of roof*