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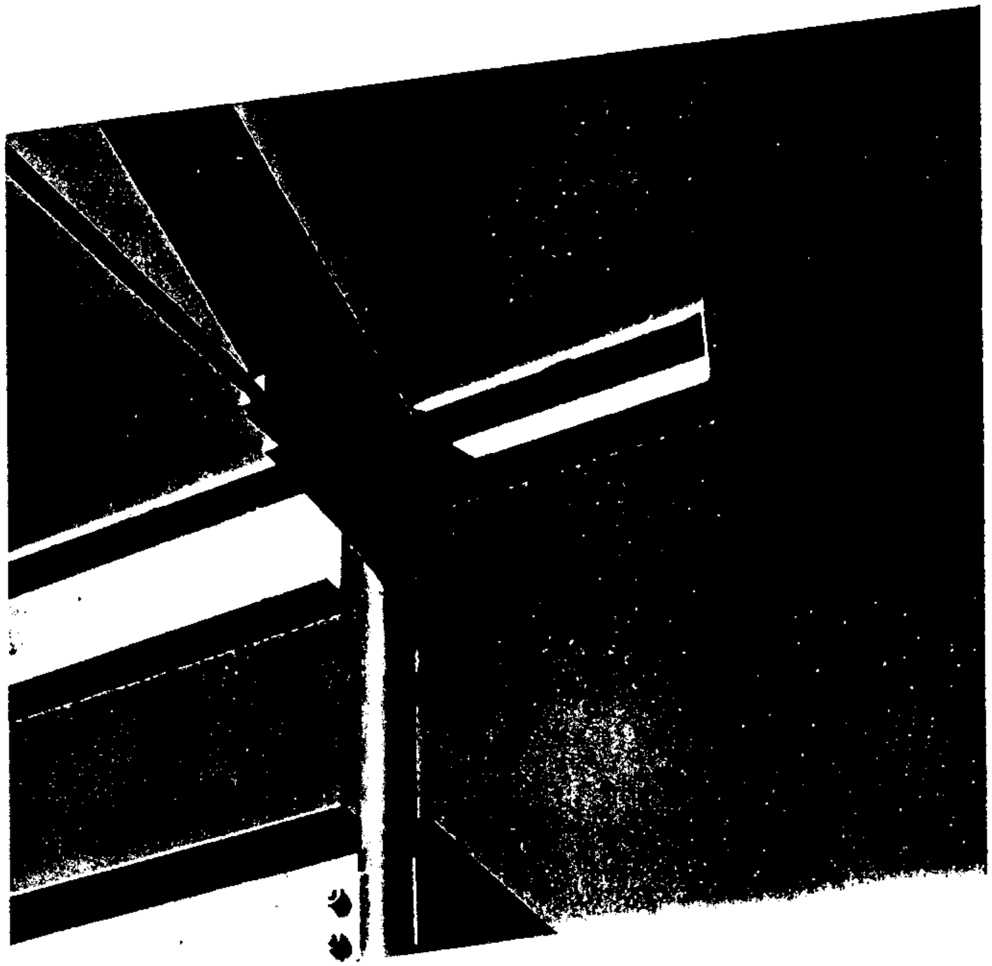
Development of Materials for a Short Course in Roofing Maintenance



Luther J. Strange Jr.

School of Building Construction
University of Florida
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DEVELOPMENT OF MATERIALS FOR A SHORT COURSE
IN ROOFING MAINTENANCE

A report of the Construction Research Project
by Assistant Professor Luther J. Strange Jr.
School of Building Construction, University of Florida
Gainesville, Florida
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EXECUTIVE SUMMARY

DEVELOPMENT OF MATERIALS FOR A SHORT COURSE IN ROOF MAINTENANCE

Previous studies have indicated that the four main areas that affect the life of a roof are design, materials, installation and maintenance. To get maximum service out of new roofs, all of these factors will have to be improved. To get maximum service out of existing roofs, maintenance must be improved. Maintenance is the total responsibility of the owner of the roof. This manual was prepared to bring together information on maintenance in such a way that it can be presented to the owner or his representatives in a short course.

This information is prepared to be presented in one day. If at all possible it should be followed by a walk-over of some of the types of roofs described in the text. Maintenance of all parts of the roof are explored and the effort is made to help a maintenance person select the proper maintenance for each part. Maintenance of all types of roofs is discussed also and the proper maintenance for each type is covered.

The plan, when gathering this material, was to have a short course available to offer to school maintenance personnel at the county level throughout the state. There is no single source of this information available to these people. This short course is designed to give these people the information they need to improve the maintenance of the roofs for which they are responsible. It is also designed with the idea that one person from each county could be given this information in a one day seminar, thus giving it maximum exposure when they carry it back to their counties.

I. INTRODUCTION AND STATEMENT OF PROBLEM

Built-up roof systems have been giving good service to building owners for a long time. There are, of course, exceptions to this general statement, and also certain reservations. For instance, for a good roof to give proper service, it must be properly maintained. This is just as true of automobiles as of roofs, but most of us know more about cars than we do about roofs and therefore automobiles get better treatment.

"Preventive Maintenance programs - including detailed inspection - to avoid serious problems in built-up roofing caused by moisture should begin the day a building is completed."[1] While the roof is not a particularly expensive part of the building, usually representing 3-5% of the construction cost, its function is vital to the utility of the building. Further, if the roof fails and has to be replaced prematurely, it can cost as much as 15% of the building cost.[2]

There are those who think roof maintenance should begin even before the building is finished, with the beginning of a historical file. One such is Gainesville architect and University of Florida Professor Robert E. Crosland, who in his 1983 Roofing Maintenance Manual set forth, on page 1, what should be included in a good roof historical file. The information should include:

1. Roof plans and specifications (as built).
2. Contract documents.
3. Name and address of architect, consultant, contractor and other persons concerned with roof installation.

4. All correspondence and/or notes between parties involved with roof installation.
5. Bonds or guarantees from material manufacturers and/or roofing contractor.
6. Record of all decisions and/or instructions to the roofing contractor.
7. Report of each maintenance inspection with photographs.
8. Record of any changes made to or on the roof surfaces, including mechanical or electrical installation, antennas, repair work, etc.
9. Reports of any problems and corrective actions taken.
10. Record of all maintenance done.[3]

Every bit of the performance of a roof system is related to four things. These four things are: design, materials, installation and maintenance. Of these, the design represents 5% or less of the cost, material about 10%, installation another 10% and operation and maintenance over a period of years approximately 75%. Let us look therefore very carefully at maintenance and at the effects of design, materials, and installation on maintenance.

The design of the roof requires attention to details such as flashing, curbings, expansion joints and deck layout. The designer must also select the materials to be used and the quantities (i.e. lbs per square etc) required. All of the above will have an effect on the amount and type of maintenance required.

The design of the roof and the design of auxiliary equipment that is installed on the roof can also make quite a difference in the amount of maintenance required. Basically there is very little excuse for putting equipment on top of a building. If the decision is made to put equipment on the roof anyway, there is no excuse for not putting it in a penthouse that is readily accessible from inside the building. The designer can also extend the life of the roof by specifying a roof deck, a membrane and flashing details that are compatible.

The material selected for the roof should be delivered to the jobsite in the proper condition. When ordering truckloads of material, it is not uncommon for the last part of the load to be made up of rolls of felt lying down. This is bad for the material. If this is compounded by the load being delivered wet, that load of materials should be refused and returned.

The material should also be of the quality specified. Just about the only way to make sure the material meets the appropriate ASTM specification is to require that it be so marked. With roofing material, this can be somewhat of a problem, as not all roofing material is marked with the specification it is supposed to meet.

Installation is another component of the roof that can have a definite affect, either good or bad, on the amount of maintenance that will be required. The owner should definitely have an inspector on the site at all times when the contractor is working.

Some of the things that must be monitored during installation are the temperature of the material as it is installed, the coverage of the felts, the amount of bitumen used and the quantity of surfacing material. The elements must be watched to make sure the contractor is not surprised by a sudden shower or does not leave material unprotected from the elements at night.

The installer should have good equipment (this can be specified along with the type of roof) and the installer's men should be experienced and well trained. It should go without saying that the installer should have a state license to install roofs. Many school districts require this, but not all by any means. The amount of time any contractor spends in his industry's trade association is a good indicator of his interest in the total business, and it is not a bad idea to require that the installer be a member of the appropriate state association.

If the roof is not properly installed, then maintenance will be more difficult. Installation that allows the incorporation of blisters and ridges makes early repairs necessary and generally prevents the roof from doing a satisfactory job.

It may seem odd to speak of "maintenance" as having an effect on maintenance, but it does. For instance, if maintenance is not started at the proper time, then the problem becomes in short order one of repair and not maintenance.

Foreign items left on a roof, after they should have been moved during a routine maintenance inspection, can plug up drains or puncture membranes. Maintenance then is part of the overall job of making and keeping the roof easy to maintain. When the program falls behind, it is very difficult to catch it up, and there is the constant danger of maintenance becoming repair.

"The failure to find and correct minor roof defects and deterioration at the earliest stages is probably the greatest cause of premature roof problems. This is particularly true of built-up roofing materials applied on relatively low sloped roofs."[4]

II. THE EFFECTS OF DESIGN ON MAINTENANCE

The designer is the first person related to the building project who can make the maintenance of the roof easier on all concerned. There are several ways he can do this and we shall look at a few of them.

The first choice the designer makes that relates to ease of maintenance is the shape and slope of the roof. Is the roof to be square, rectangular, L shaped, U shaped, etc? Is the roof to be flat, sloped gently, sloped steeply, a dome, or a parabaloid? Many of these questions are dictated by the use of the building - others are at the choice of the designer.

Which is the best slope for purposes of maintenance? There is no hard and fast rule on this, but more and more people are going to moderately sloped roofs with shingle covering. The theory behind this is twofold. One is that the best way to keep water out of a building is to keep water away from the building. The other is due to problems some designers have encountered with built-up roofs. This trouble is usually caused by putting the wrong roof in the wrong place.

Instead of us looking at all of the possible poor choices of shapes a designer might choose, let us instead look at some of the good choices available to him. After all, the designer is the only one who can use structural and roofing components together to get the best results. Where possible, the shape should be near the square in plan and should be sloped to drain. This sloping should be done with the structure, and should be a minimum of ¼" per foot for built-up roofs.

The use of the structure (high and low columns) to achieve slope in a built up roof can save thousands of dollars by avoiding tapered insulation. The avoidance of tapered insulation can in turn give the roof the same insulation value over its entire area and this will make for a uniform life for the membrane.

The membrane will most likely be a built up roof, for these are still used in 75% of all commercial buildings.[5] While shingle roofs appeal to some people, and are in themselves cheaper than built up membranes, they require a good deal more structure, and this does away with much of their apparent cost advantage. Then too, shingles are not without their problems.

Many times the size and use of the building required shapes like the L, H, U, E and T as well as very long and narrow straight buildings. In cases such as these, it is imperative that the designer make allowances for control or expansion joints in the roof. These joints should be placed at every change of direction, and/or weakness in the roof shape. They should also be used at every change in the roof deck material - whether that change shows in the shape of the roof or not.

When using control or expansion joints in a roof, they should be arranged so that, where practical, there is an equal area of roof on each side of the joint. They should also be arranged so that in no case is there ever a run over 200 feet of roof without an expansion joint. Not 201 feet but 200 feet. Why 200 feet? Because it works. Even so there are those who say they should be closer. The idea of putting them closer together must be weighed against the fact that each control or expansion joint is another penetration in the roof.

On the subject of roof penetrations, early in the design period is a good time to limit them to an absolute minimum. Most leaks start at the edge of the roof or at one of the penetrations in the roof. There are probably several reasons for this, such as the fact that frequently the flashing material used for gravel slopes and other flashings has a different coefficient of expansion from the roof. Then too, where you have a four ply roof, it is very rare to have a four ply flashing.

Equipment on the roof is another cause of penetrations in the membrane. This is a sufficiently complex subject to warrant spending some time on it. For years people have been putting all manner of things on flat roofs. If there is an elevator in the building, there is a motor house on the roof. Air Conditioners are routinely placed over the space they are expected to cool. Vents from below go out the roof as close as possible to the area to be vented.

The roof penetrations caused by equipment are about evenly divided into two categories. Roughly half are specified and the other half are not forbidden in the specifications, so they happen. Roof penetrations by equipment are not usually necessary and should be severely limited. Further, roof penetrations by various types of vents are largely unnecessary and should be kept to an absolute minimum.

What has just been said is heresy, of course. One can hear the designer now, saying "Where can I put my air conditioner?" Design an equipment room for the equipment. "But these things you speak of cost money." Yes they do, but then so do new roofs, not to mention water damage inside the building. The water damage, incidentally, is never covered by the roof bond, and not always by insurance on the building.

The roof of a building is one of the cheapest parts of the building, costing 1 to 2% of the total project cost. If, however, the roof fails before its projected lifespan, it can cost up to 5% of the project cost to replace it.[6] It is therefore in the best interest of everyone to see that the design of the project gives the best roof possible.

What can be done to impress designers with the need to keep the roof clear of equipment? One school maintenance chief here in Florida solves the problem by simply prohibiting any equipment on the roof. His answer to the complaints that this "can't be done" or "presents a difficult problem" is "It seems we have a design problem. That is why we hire a designer; solve the problem." In addition to no equipment on the roof, this same person will not allow parapet walls in the design of new schools in his county.[7] Considering the trouble people everywhere have with leaking masonry in parapets, not to mention the ongoing problem of parapet flashing, this may well be as important as keeping the equipment off the roof.

In summary then, equipment belongs in equipment spaces, not on the roof. Additional reasons for this are the people who service the equipment. Pick any roof mounted air conditioners and you will find oil on the roof membrane under it as well as trash and debris all around the area. Equipment should be in equipment rooms. If the equipment must be on the roof, there should be a penthouse on the roof to house the equipment, to act as a terminal for vent pipes and to serve as a roof access point. Needless to say, the number of people who get access to the roof should be very limited.

One other area that needs to be discussed at this time, while we are on the subject of design, is the relation of the deck to the membrane. There has been a tendency since the mid 1940's to build roof decks of thinner and thinner material. Light metal decks over bar joints are one of the most popular decks at this time. Plywood decks over wood trusses is another popular deck, as is thin cast insulating concrete or gypsum over widely spaced bar joints.

These light decks of recent times take the place of structural concrete decks or mill type heavy wooden structures of the first half of the century. Several characteristics of the new, lighter decks are having unanticipated results. One fact is that the new thinner decks respond to changes in temperature much more rapidly than did the older, heavier decks. All too often this sudden movement is reflected in the roofing membrane by cracks and other faults. An even less understood phenomena of the new decks is the result of their much greater vibration and movement due to wind and even noise factors.

The need for insulation of the buildings built since the fuel crisis of 1973 has led to vast quantities of insulation being used directly under the roofing membrane. This insulation above the deck causes a decrease in the deck movement caused by expansion and contraction. This is the good news, but the bad news is that the insulation holds heat against the back side of the roofing membrane, thus causing increased heat stress. Another minus to this system is the fact that it produces extra problems such as how to fasten the insulation to the deck and how to fasten the membrane to the insulation.

Let us look at the various parts of the roof that the designer must take into account and come up with some helpful suggestions. The base for the entire roof system is the deck. The type of deck will have a bearing on the type of insulation and membrane to be used. The deck should be sloped. The deck should be sloped structurally, but in any case it should be sloped.

Metal roofs on longspan bar joints can cause design problems even when they meet all code requirements, if they do not have sufficient slope. The permissible deflection for one of these joints is 1/240. On a flat roof with a 100 foot span, this comes to 5" allowable deflection. This much deflection will allow the ponding of a good bit of water. Water is heavy, and the weight of water will cause more deflection. This process will not stop until the roof frame fails and drops the entire structure into the building.

Steel decks must be over engineered to stand the abuse they will get during the construction process. While the design "live load" may seem adequate for the loads imposed on the roof after it is finished, they will rarely be adequate for a fully loaded gravel spreader or stack of felt rolls. The 20 pound normal live load specified in the Standard Building Code will almost certainly be exceeded during construction. Specifications can be of some help here, in that they can spell out the techniques to be used in construction and help minimize overloads on the deck.

Another reason for over engineering steel decks is the common practice of adding new roofs without stripping the old one off. In a case where the old insulation is soaked with water (not at all unusual) and the new roof is one of the ballasted types, most of the allowable live load is used up before any outside loads are put on the roof.

The ballasted roof mentioned above brings on at least two extra problems for light steel decks. First of these is during construction, when ballast at the rare of 1000 lbs per square must be put on the roof. Any slow up in the distribution of this ballast that allows it to pile up on the roof can result in a serious overload in a matter of minutes.

The other obvious problem comes when the roof needs reroofing or major repair. In nearly every case, the ballast gets pushed into one or two large piles which will cause a load problem. These later problems are usually made more serious by the fact that they happen after the plan and load carrying design of the roof are forgotten or misplaced.

One feature of metal decks that seems to be not too well understood is the proper way to attach them to their supports - usually bar joints. Attempts to weld the sheetmetal deck to the heavier structural steel will usually to fail. In fact most of these spot or puddle welds will fail during construction, due to the movement and vibration of construction traffic.

One of the better ways to fasten sheet metal to structural steel is to use heavy metal washers. First a hole is burned in the sheetmetal, then the washer is put over the hole and the inside of the washer is welded to the structural steel. The outside of the washer then holds the sheetmetal in place, and there is less danger of the weld breaking, as when the sheetmetal is welded directly to the structural steel.

The membrane that goes on the steel deck should be fastened to the deck. That is elementary, but how? It is very difficult and requires great care to mop anything - insulation or membrane - directly to a metal deck. Attempts have been made to use cold process adhesives (glues) to fasten insulation to metal decks. The problem here is that as the insulation is glued in place, it is walked on and generally used as a work platform to continue work. This has the effect of squeezing the glue out to approximately the thickness of glue on an envelope flap. The glue then doesn't have uniform contact and the insulation, and anything on top of it, is not well bonded. Great care must be used in this method of fastening insulation to the deck.

When efforts are made to mop the first course of insulation down with hot bitumen there are several conditions that must be avoided, such as penetration of the hot bitumen through the joints of the deck, and wastage of large quantities of material in the corrogations of the deck. Another problem with mopping the insulation directly to the deck is the radiator effect of the metal deck. The deck draws heat from the asphalt so fast that it is difficult to imbed the insulation before the asphalt has cooled. The National Bureau of Standards and the National Roofing Contractors Association proved that under ideal conditions the roofers have eight seconds in which to place the insulation on steel decking after the asphalt has been applied. This requires very careful work. One possible solution is to mop the insulation and flop it into place.

How then are we to fasten the insulation to the metal deck? It should be fastened with positive metal fasteners, such as screws or clips where practical. There are a number of special devices designed particularly to fasten insulation to metal decks. Some of these devices are of the screw type and others are annular ringed friction nails. Heavy gauge metal decks, in either case, may require pre-drilling.

No matter which type of fastener is used, it should draw the steel deck and the insulation tightly together no matter how badly it is twisted, deflected or dented. Also, care must be taken to see that the nailing disc atop the fastener is not compressed to the point that either the disc of the fastener will puncture the roof membrane when a load is applied. During construction it is a certainty that loads will be applied.

Insulation should always be laid with the longest side of the piece at right angles to the flutes in the steel deck. This assures that there will be a minimum length of unsupported edge of the first layer of insulation. Mention is made of the "first layer" here because it should be an unbreakable rule for all designers and specifiers to require that insulation be installed in two layers. This way the first layer can be fastened mechanically to the roof, the joints taped and the second layer mopped in place with the joints staggered so that they do not fall over the joints of the first layer.

The above is absolutely essential to the placing of insulation on any deck. It prevents the easy flow of moisture and/or heat from inside the building to the bottom side of the roofing membrane. This in turn helps prevent the phenomenon known as "ridging" which is one of the prime causes of roof failure. This is mentioned now, while steel decks are the subject, since due to the flutes of steel decks, it is very difficult to put a roof on a steel deck without first placing insulation.

We have taken so much time on steel decks because they are so popular at this time. They are not the best deck by any means, but they are one of the least expensive, so we can count on people continuing to use them for some time to come.

In a book called "Roofing Systems: Materials and Applications", the author John A. Watson lists fifteen types of roof decks and twelve types of built up roofs. He goes even farther and suggests that certain types of roofs go better with certain types of decks. This is something that designers should study very carefully before putting a line on a piece of paper. To facilitate that study, those tables are reproduced herewith.

TYPES OF ROOF DECKS

1. Boards on wood joists or purlins. Square edge, shiplapped, or tongue and groove (T&G).
2. Plywood on wood joists or purlins.
3. Plywood over T&G decking.
4. Steel, with plywood, gypsum board, or insulating board overlay.
5. Poured gypsum.
6. Precast gypsum.
7. Poured concrete.
8. Precast concrete with insulation or concrete fill over.
9. Cellular concrete.
10. Lightweight concrete.
11. Vermiculite concrete.
12. Perlite concrete.
13. Wood fiber and cement slabs.
14. Asbestos cement cavity decks, with insulation or concrete fill over.
15. Thermal insulation on structural deck.

TYPICAL ROOF MEMBRANES

Materials	Deck Nos.	Incline
Organic base sheet, nailed. Three plies No. 15 asphalt felt. Asphalt flood coat and gravel. Approx. total asphalt weight per square 120 lb (54 kg).	1,2,3,6,13	0 to 3 in. per ft: notes A, B, C, D, F
Organic base sheet mopped to deck. Three plies No. 15 asphalt felt. Asphalt flood coat and gravel. Approx. total asphalt weight per square, 140 lb (63 kg).	2,3,4,7,8, 14,15	0 to 3 in. per ft: note D
Four plies No. 15 asphalt organic felt. Asphalt flood coat and gravel. Approx. total asphalt weight per square, 140 lb (63 kg).	2,3,4,7,8, 14,15	0 to 3 in. per ft: note D
Four plies No. 15 tarred organic felt. Pitch flood coat and gravel. Approx. total pitch weight per square, 175 lb (79 kg).	4,7,8,14, 15	0 to 1/2 in. per ft.
Asbestos base sheet, nailed. Three plies No. 15 asphalt asbestos felt. Asphalt flood coat and gravel. Approx. total asphalt weight per square, 120 lb (54 kg).	1,2,3,5,6, 9,11,12, 13	0 to 3 in. per ft: notes A,B, C.D.F.
Asbestos base sheet mopped to deck. Three plies No. 15 asphalt asbestos felt. Asphalt flood coat and gravel. Approx. total asphalt weight per square, 140 lb (63 kg).	2,3,4,7,8, 10,14,15	0 to 3 in. per ft: note D
Four plies No. 15 asphalt asbestos felt mopped to deck. Asphalt flood coat and gravel. Approx. total weight of asphalt per square, 140 lb (63 kg).	2,3,4,7,8, 10,14,15	0 to 3 in. per ft: note D

TYPICAL ROOF MEMBRANES (continued)

Materials	Deck Nos.	Incline
Asbestos base sheet, nailed. Three plies No. 15 asphalt asbestos felt. Mopped coat of asphalt. Reflective surfacing. Approx. total asphalt weight per square, 90 lb (40.5 kg).	1,2,3,9,13	3 to 6 in. per ft: notes A,B, C,D,F,
Four plies No. 15 tarred asbestos felt. Pitch flood coat and gravel. Approx. total pitch weight per square, 175 lb (79 kg).	4,7,8,14,15	0 to 1/2 in. per ft.
One ply No. 15 asphalt felt. Two plies mineral-surfaced selvageedge roofing, lapped 19 in. and nailed. Approx. weight type 3 or 4 asphalt per square, 40 lb (18 kg).	1,2,3,6,13	1 to 6 in. per ft: notes E,F
Coated glass base sheet, nailed. Three or four plies glass ply sheet. Asphalt flood coat and gravel. Approx. total weight asphalt per square, 150 to 180 lb (67.5 to 81 kg).	1,2,3,5,6, 9,11,12, 13	0 to 3 in. per ft: notes A,B, D,F
Coated glass base sheet, mopped to deck. Three plies glass ply sheet. Asphalt flood coat and gravel. Approx. total weight asphalt per square, 180 lb (81 kg).	2,3,4,7,8, 10,14,15	0 to 3 in. per ft: note D

Notes:

A. Add one layer of unsaturated building paper stapled to deck 1.
B. Nail base sheet through flat nailing discs at 12 in. on center in both directions.
C. Recommended for warm-weather application, i.e., above 50°F (10°C) so that the coated base sheet will be flexible and will lie flat.
D. Back nail mopped felts above 1 in. per foot incline on nailable decks. Use self-locking nails in low-density materials.
E. Inorganic felts are preferred with white or light-colored granules on the mineral-surfaced portion to reduce the surface temperatures.
F. For nailable decks only.

There is one other area in which the designer can do much to see that the roof performs well. That is in the area of practicability of installation. This means such things detailing expansion joints and flashings that are easy to undersand and build, realistic locations of roof drains, and specification of materials available in the area. Designers have been known on occasion to select a material at random from a catalog which it is later learned is available only in very limited areas - in Alaska.

Designers should take every opportunity to avoid unnecessary complexity in the roof system design. Keep the shape and the various levels of the system as simple as possible. Do not use several types of decking or membrane when one will do. Do not specify a gravel from some distant location when a local material will do a satisfactory job.

If there is any question in the designer's mind as to how any part of the roof is to go together, he should stop and find out. He can check a good reference book such as Roofing Concepts and Principles, by Paul Tente and Associates, or the Manual of Built-up Roof Systems, by C.W. Griffin - McGraw Hill Book Company or he can ask his friendly local roofer.

In any case, the designer needs to take the little bit of extra effort required to be certain that what he designs is practical to build. A general rule is that simpler is better, but during design is the time to be sure.

III. THE EFFECT OF MATERIAL ON MAINTENANCE

Much has been said lately about changes in the traditional materials used for roofing. Much of what has been said is true, some is not. This is a good time to examine exactly what has happened to materials over the past few years, try to find out why it happened and evaluate the effect of these changes on the roofing membrane.

Most of the trouble began about the time of the Arab oil embargo of 1973. Prior to the time asphalt was plentiful, inexpensive, and the sources were very stable. After the embargo, prices have steadily climbed to the current very high rates. Companies that once knew almost what well supplied them now have trouble telling which continent furnishes their crude oil.

About the time all this was happening to the petroleum industry (asphalt), the steel industry in this country was in the process of winding down. That meant less coke and less tar. Tar was the original bitumen used for built-up roofs when that type of roof was developed in the middle 19th century.

At about the same time that the bitumens were having their problems, the felts began to change also. Fifteen pound rag felt became #15 organic felt. This, felt which at one time weighed 15 lbs per square and consisted mostly of recycled cotton rags has changed so that it is mostly wood fiber and waste paper, with a weight of 11 to 13 pounds per square.

At about this same time, glass fiber began to be used as a material from which to make roofing felt. Also, about this time there began to be questions asked about asbestos felts. These questions, and other problems caused by asbestos led in 1983 to the bankruptcy of Johns-Manville Company, the world's largest producer of asbestos fibers for roofing felts.

For all practical purposes, there will be no more asbestos felts in roofing in the United States. This, unfortunately, means the end of the built-up asbestos roof, which many people felt was one of the very best of the built-up roofs.

At the present time, the asphalt based built-up roof is probably the most popular of the build-up roofs. One of the prime reasons for the popularity of asphalt is that it can be modified to stay on steeper slopes than tar. These modified asphalts range from Type 1, or "dead level" asphalt to Type 3 or steep asphalt. With the current emphasis on sloping the roof, it is not surprising that asphalt, with its ability to be tailored for the job, is the more popular bitumen at this time.

Let us examine asphalt more closely and look at some of the properties that require special attention from those charged with its maintenance.

Roofing asphalt is very sensitive to ultra violet light, and further it is not meant to remain exposed to the elements. Because of this,the roof needs to be protected from exposure to solar radiation, which will break down the asphalt, and it needs to be drained of unnecessary moisture as soon as possible.

To protect the roof from the solar radiation, it needs to be protected by either a layer of <u>opaque</u> gravel or by some sort of reflective coating. Either of these should be inspected at regular intervals, at least annually, and preferably semi-annually. To protect the roof from unnecessary moisture, drains must be kept open and flashings kept in good order. Again, an inspection, at least annually, is recommended.

The roof must also be protected from vandalism, both intentional and otherwise. School roofs have been subjected to such things as motorcycle races[7] - obviously intentional -, and spillage of air conditioning fluids - probably not intentional. The results are the same: damage to the roof membrane and extra maintenance expense. Asphalt membranes are very easily damaged by petroleum products, since these tend to dissolve the asphalt. Remember, asphalt is a petroleum distilate also.

The asphalt based material is <u>extremely</u> important. While there is a tendency to refer to all that black stuff on the roof as "tar", it is either asphalt (petroleum based) or pitch (coal tar based). The two materials are not usually chemically compatible, and frequently an attempt to patch an asphalt roof with pitch based patching compounds will do more harm than good. It can, for instance, do such things as void the roof warranty.

An asphalt roofing membrane is, particularly in hot weather, a rather delicate thing. Unnecessary walking on the roof can easily force some of the gravel into the membrane, causing leaks. If it is absolutely necessary for someone other than a trained maintenance man to walk on the asphalt membrane, that person <u>must</u> be accompanied by a trained maintenance man. If the design of the roof is so poor that equipment should be installed, at the first re-roof of the area, the equipment should be relocated somewhere besides the roof.

Asphalt roofing membranes, even when well protected and properly maintained will occasionally be attacked by water or other problems left maintained will occasionally be attacked by water or other problems left over from construction. This usually shows up as blisters or ridges in the membrane. These occur most often at joints in the under-membrane insulation, and should be repaired before they cause trouble. Blisters should be repaired if they grow to 2 square feet in area.

The top coat of asphalt roofs, called the "flood coat" in which the gravel is imbedded can be damaged if wind scour clears the gravel off of areas of it. These areas must be discovered quickly and re-coated with asphalt and gravel before checks and cracks form that will allow water to penetrate the roof felts.

Coal tar pitch (pitch) membranes are more likely to "heal" cracks, since the material tends to remain softer than asphalt. This same trait of pitch roofs tends to make them most suitable for low sloped roofs, and roofs with low slopes are much more likely to pond water. Ponded water is bad for any roof for two main reasons. One is that the available water in the pond will seek out the tiniest flaw and penetrate the membrane. The other reason is the continual thermal stress at the edge of the pond. The membrane under water is cool and the membrane just outside is quite warm. Ponding should be avoided or corrected wherever it is found.

Coal tar pitch and the fumes from it are quite caustic, and people working with it must take precautions to protect their eyes and skin. It can also be dangerous in another ways. Pitch melts at a lower temperature than asphalt and has a lower flash point. A crew that is familiar with asphalt could easily exceed the flashpoint of pitch while getting to the higher temperature which they have safely used with asphalt.

Properly installed pitch roof membranes probably need less work to maintain than asphalt, but they are by no means maintenance free; no membrane is. Drains must be kept open, flashings must be kept in good repair, walking on the membrane is not recommended and the top surface needs to be protected.

Since the period in the early 1970's that led to what now is called the energy crisis, there has been a call for more insulation in buildings. One of the places where this insulation has caused about as many problems as it has solved is in the roofs of buildings. Roof insulation is usually placed directly under the roof membrane, and this causes a heat buildup in the membrane as heat which once penetrated it is now trapped and held against it by the insulation.

One of the first results of this extra heat in the roof membrane, coming as it did at a time when felts and asphalts were changing, was to cause marginally designed and/or constructed build-up roofs to fail. In an effort to overcome problems caused by the insulation and at the same time to save on the cost of expensive petroleum products, the idea of a manufactured single ply membrane was re-examined.

The idea was for a single ply of waterproof material that would cover the entire roof. This material could be fabricated in a factory and sent to the job where a minimum number of seams would be sealed in the field, giving a totally waterproof roof. The idea was well received, and a tremendous number of solutions to this idea were developed by various sources. By 1979, there were more than 300 new roofing and waterproofing materials registered in North America, with half of them in Canada.[10] Of these some have been withdrawn from service, some have had their chemical formulas modified and several new companies have come into the field. Indeed, at times it seems as if everyone who has ever made - or thought of making - a shower curtain now has a single ply roofing membrane on the market.

As long ago as January, 1964, M. C. Baker, Division of Building Research - National Research Council of Canada, wrote in Canadian Building Digest No. 49, entitled, "New Roofing Systems" a conclusion that may still be appropriate:

> Many new roofing systems appear to have considerable advantage over conventional bitumenous roofing, but most have not yet been extensively field tested. Unlike conventional roofing, which from the beginning was largely the utilization of waste products, most of the new systems have been developed specifically for roofing. Gravel, as a protective coating, has been dispensed with entirely in the newer systems, so that inspection and maintenance during and after application is greatly simplified. Imperfections and damage can easily seen and repaired. Reflective and decorative coatings are easily applied. Most systems are light in weight and have much greater elasticity than conventional systems. Promoters, however, in their enthusiasm tend to forget or ignore some of the factors that cause failure, such as building movement, trapped moisture, and poor workmanship. These factors will exist with the new as well as the old systems. These systems also introduce new factors such as dependence on thin layers of adhesive to provide watertightness at narrow joints, and bridging characteristics of fluid systems over rough surfaces and joints, as well as the need to adhere strictly to recommended materials and procedures. Despite any new problems that may arise, it is certain that the percentage of roofing using these new systems will increase during the next decade."[11]

Single ply membranes, as they are called, have indeed increased since that was written, and now account for a substantial share of the market. As mentioned above, they require very special attention when it comes time to maintain them. Some of the materials used in singly ply membranes are totally incompatible with asphalt - others with pitch. A well meaning attempt to stop a leak on a rainy night could very easily cause a bigger problem than it attempts to solve, as well as voiding the owner's warranty or bond. Anyone charged with maintaining single ply roofs must know exactly which products are meant to go with each particular roof membrane and have a supply of those products at hand.

A variation on the single ply roof is the liquid or foam formed in place membrane. Of these probably the polyurethene foam roof is the most popular at this time. Odd as it may sound, this type of roof is adversely affected by water. This requires that the roof be installed only on a dry deck or surface and be coated before it becomes wet. When these precautions are carefully observed, the urethene foam roof is capable of serving quite well and offering a good bit of insulation value also.

When this material first became available it was, as so many materials are, oversold. It was sold as the cure-all for all problems. It is light, can cover any troublesome material already in place, insulates, is self flashing, etc. Perhaps some of these things could come to pass under ideal conditions, but conditions are rarely ideal.

In actual practice there are a few problems unique to this type of membrane. First, the entire roof is no better or no worse than the operator who applies the spray to the deck. As mentioned earlier, the membrane is adversely affected by water, and frequently there will be water in an old roof that is being recovered. This may not be obvious at the time the membrane is being installed, but will cause much trouble later. Also, the surface of the membrane must be coated before it gets wet or this will cause trouble. This feature of the material can cause problems when it is necessary to fix a leak during a rainstorm.

All roofs are not built up or membrane roofs. Shingle roofs of various types on steeper slopes are still in wide use for smaller buildings. By far the most popular shingle to day is the asphalt and felt shingle coated with mineral granules. These shingles come in several weights from 225 lb/sq to about 350 lb/sq, although they are usually described by their proposed life span of from 20 to 30 years.

All shingles, of whatever material (this includes tile, slate, wood or metal), keep water out of a building by shedding it away from the building before it has a change to penetrate any of the numerous cracks in the shingled area. Because of way they work, shingles are useful only on buildings where the roof slopes 4 to 12 or greater. Also, if anything slows the flow of water, such as a stopped up gutter or valley, there is a better than average chance that the water will find its way inside the building.

Shingles made of asphalt and felt have also had all the problems, in one form or another, that the various asphalt and felt membranes have had. At present, most shingles are made of glass felt (as are most membranes), they are coated on both sides with asphalt and then coated with talc on one side and granules on the other. The shingles are laid up with about 40% exposed and 60% covered by the next shingle above.

IV. INSTALLATION

This is probably the most important part of building a good roof, and one of the most difficult to get done correctly. No matter how much money is spent on design of the roof, no matter how fine the materials supplied, if those materials are not properly applied under the correct conditions, that roof will very probably fail to give good service.

The quality of the design and materials must be matched by the quality of the installation. This will do more to reduce future maintenance expenses and guarantee that the roof will last out its expected life span that any action that can be taken. One of the most satisfactory ways to get this quality is to see that there is a qualified roofer on the job and a qualified inspector on the roof at all times.

The built up membranes have many critical areas as they are being assembled in the field. Each of these areas can create problems and multiply maintenance costs. Each must be monitored during construction and accurate records must be kept.

The problems mentioned above start as soon as the first material arrives on the jobsite. Felts must be protected from absorbing moisture from the time they arrive. Proper protection includes a plastic ground cloth, stacking the felts on end on pallets and covering the rolls with a tarpaulin - not plastic.

The insulation must also be kept completely dry during storage, installation and completion of the membrane. One of the major causes of trouble in the roof assembly is water built in during construction. One unfortunate cause for this sort of thing is frequently a call for the roofer to "dry in" the building so that other trades can go to work inside. This usually means put down the insulation and about ½ of the plies on the roof and when all the other trades are finished, the roof gets the last few plies, and a gravel surface. The procedure almost guarantees that the insulation and some of the membrane will absorb unacceptable amounts of water. This, in turn, practically guarantees that the finished roof membrane will have blisters and ridges in it.

If a temporary roof is needed on the building at some time during construction - no problem. It must be outlined in time for the contractor to bid on it, then it must be installed, used, and ripped off and replaced with a properly built membrane. Unfortunately, temporary roofs are much rarer than the "dry-in" procedure mentioned above.

Another very common entry point for moisture during the construction phase is failure to properly close off work at the end of each day. Only as much work should be started on any given day as can be finished and glazed on that day. Special care must be taken at the edges of the insulation or the felt, lest rain, dew, or other moisture get into the roof. If this should happen, then the next day, when hot bitumen is placed, the moisture turns to steam and causes inter-layer blisters.

Blisters are an all too common cause of roof failures. Let's take a little time to examine what they are, how they are formed and why it is that they always grow - never go backward on their own accord.

Blisters are formed when there is a void in the inter-layer mopping of a built-up roof. The void can be formed by steam form a damp layer of felt, by a small piece of trash in the fresh bitumen (such as a cigarette butt) or by a bare spot that is missed by the hot bitumen.

A blister formed in this way contains air. Air is made up of a number of gasses including water vapor. Now a combination of physical properties comes into play. When a built up roof gets hot from the sun, as all of them do, the bitumen softens somewhat. When water vapor becomes hot, it expands. This combination is the driving force for making blisters expand.

Very well, but why don't blisters contract at night when the roof cools down, as all roofs do? Again, a combination of things comes into play. When the bitumen coated dome of the blister cools, it becomes a very stable and strong structure with no reason to collapse. (Even if it did collapse, the bitumen under it ceases to be sticky, when it too cools). Therefore, there is the strong dome structure of the blister, and under it, the water vapor condenses to water and causes a partial vacuum. This vacuum pulls into itself moisture from other parts of the roof, so that the next warm day, the blister is ready to expand again.

The process described above continues until the blister is collapsed or broken by some outside force. That force may be a careless footstep or it may be the weight of the gravel on top of it. In any case, when the blister does collapse, it usually breaks, thus giving water an entry into the roof membrane where it causes further problems for that membrane.

The roofing crew and the inspector should make every effort to see that there are no blisters built into any membrane roof. This will require good housekeeping on the part of the roofer and careful observation on the part of the inspector. It is possible and it certainly worth doing.

Other areas of workmanship that can cause problems in the maintenance of a roof abound at the time of insulation. The felt must be applied smoothly, with no "fishmouth" at the edges. This seems elementary, but sometimes in cool weather, it is very difficult to do.

Another problem area can be the temperature of the inter-layer bitumen. There are limits beyond which bitumen simply cannot be heated - flashpoint is one such. Bitumen pumped up on a roof tends to lose about one degree Fahrenheit per foot of uninsulated pipe. Also, while this bitumen is transferred to a bucket or spreader, carried to where it is needed and spread out on the roof it loses even more heat. Sometimes on a tall building or a large roof the temperature of the bitumen as applied and the recommended temperature for felt embedment are so close together that the installer has only a matter of seconds to put the felt into the bitumen. Situations of this kind can cause real problems when the crew gets too far ahead of the actual felt laying operation.

One problem that is unique to roofing installation is the lack of any formal quality tests, such as the slump test for concrete, to be used during installation. How does one guarantee a 60 lb. glaze coat? At this time the only solution seems to be to adhere closely to the recommended temperature (E.V.T.) for the bitumen and make sure that the inspector and the applicator are experienced persons.

Roofing authorities generally realize the need for more research to solve the problem of promulgation of installation standards. The need is perhaps best set forward by C. W. Griffin in the second edition of his book "Manual of Built-Up Roof Systems".

Need for research and standards - The roofing industry has lagged in the promulgation of installation standards and test methods. Instead of focusing on the whole field-manufactured roof system, the true guide to roofing-system performance, the industry has concentrated on component-material quality. There are appropriate American Society for Testing Materials (ASTM) and federal standards for testing important properties of surfacing aggregates, felts, bitumens, insulation, vapor retarders, and structural decks. But except for fire and wind-uplift resistance, there are no generally accepted tests for performance of the entire built-up roof system assembled from these components.[12]

At the time of the roof installation great care must be taken to see that the installation procedure itself does not damage the deck or that part of the membrane that has already been finished.

This situation most frequently arises when material is being stacked on the roof deck or being moved from where it is brought onto the roof to where it will be used. A roof deck is normally designed for a dead load and a live load, as are most deck structures. The dead load is calculated as the weight of the various parts of the roof and the live load for a built-up roof is required to be no more than 20 pounds per square foot.[13] Pallets of felt at @ 50 lbs per roll or a pile of gravel 3 feet high exerts a force of considerably more than 20 lbs. per square foot.

Equipment and people moving over a finished section of the roof frequently pick up gravel that gets tracked into new construction areas where each piece serves as the nucleus for a blister. Care should be taken to keep this to a minimum.

Generally speaking a well planned, well run job usually looks like a good job. If things appear to be disorganized and disorderly, that makes a job look like a bad job. Chances are it is.

Material selection during installation can have a very definite effect on the life and ease of maintenance of any roof. Unfortunately, too many specifications are very vague about exactly what materials will be used, what flashings shall be used and they frequently fail to describe certain properties of counter-flashings.

The same code is very specific about gravel stops. Gravel stops are a frequent cause of trouble because when they are properly installed - to meet the code - they have a tendency to cause leaks. This is because of differential movement between the metal gravel stop and the membrane roof.

The general concensus of the roofing industry is that about 2/3 of all roof problems start at edges or penetrations of the roof. In other words, if you find a leak in the roof and you don't know where it comes from, start looking at the nearest penetration in the roof or at the closest edge.

Good flashing and edge details are very difficult to locate. Unfortunately, even when shown on the plans, they are not always built exactly as detailed. This is another place where a good inspector, on site at all times, can be a great help to the owner.

Another part of good roof technique frequently ignored by designers is the control or expansion joint. A roof membrane reacts to temperature change rather like a chain. When it gets cold it contracts, when it gets warm, while there is the tendency to expand, this is thwarted by the fact that the membrane softens in the heat. (Joints in the deck are frequently expansion joints).

To protect the roof from itself, it is necessary to install control joints to relieve these stresses. Control joints are also required when the roof area is designed with a shape like an L, T, E, and F. In each case, control joints should be installed to separate the roof into manageable, rectangular sections.

How large should a roof area be before a control joint is required? If unusual shapes do not have anything to do with the decision, the roof area should have a control joint at least every 200 feet in both directions. How then should a 202 foot by 202 foot roof have control joints? It should be divided into four equal areas, each 101 feet square. Why is 200 feet the "magic" number? For the simple reason that it works.

The roofs mentioned above that have shapes such as L, T, E U, or F, which are very popular in school construction to get light into classrooms, have to be divided into smaller rectangular areas to prevent angle stress from ripping the membrane where it forms right angles. When any one of these rectangular areas then exceeds 200 feet in length, it must be divided again by a control joint.

Control joints do not keep shrinkage from happening. They do, as the name implies, control where the effect of that shrinkage takes place. This, in turn, keeps this effect from rupturing the roof membrane and causing problems.

V. MAINTENANCE

Maintenance is the fine art of doing those things that will prolong the life of a roof and seeing to it that those things that will harm the roof don't happen. One of the very necessary parts of any maintenance program should begin when construction starts on the roof system. That part is a set of "as built" plans. When the installation inspector first notes an extra vent or a change in flashing details (even if it is an improvement) it should be marked on the plans. Sometimes additional mechanical equipment is added during construction. The location of that equipment should be marked on the plans.

Hopefully, when the building is finished, the roof system plans will be complete. Hopefully, also they will be filed somewhere the owner can get his hands on them later when needed. This is especially true of load carrying parts of the roof system, such as the deck and the rafters, joists, etc. Many of the new systems suggested for re-roofing are ballasted systems that depend on at least 1000 lbs. per square of ballast to hold the membrane on the roof. Before any such roof is put on a building, engineering review should be done of the roof that is on the building now, hence the need for as-built plans.

Every builder and owner is aware of the value of as built plans. Still, there seem to be more cases where they get lost in the first few years of a building's life than where they do not. Sometimes a new person, coming onto a maintenance job will find there simply are no as-built plans.

On fairly new schools, usually the architect or engineer will have a set of as-built plans in his file. Usually they can be copied for the owner. Another method of reconstructing the as-built plans is to send a group of people up on the roofs to measure and draw everything that is there. It should be noted at that time the sizes and spacings of structural members, decks, etc., in case engineering studies are needed later.

In the Pinellas County School system, when an effort was started to upgrade their roofs on 109 schools, they discovered that they were short of as-built plans. They also discovered that some of the as-built plans they had, had not been updated when the buildings were. What to do? Many of the buildings were of an age that made it impossible to get any help from the architects office, so they had to do the job themselves. The thought of starting form scratch to draw so many buildings was overwhelming, so a better idea was sought.

Mr. Robert Menard, Engineer for the Pinellas County School District, hit on the idea of doing an aerial survey. He refined the idea to have the survey done from a helicopter at 500 feet with pictures taken at a 45° angle, to bring out details by use of their shadows. These pictures, made in color, dated, and blown up to 14" x 20", give excellent detail and show some clues as to which roofs need work immediately. When the next person goes up on a roof, that person takes a black and white photo-copy of the photograph and dimensions the roof surface on that copy. This is much easier than trying to do an accurate sketch in the hostile roof top environment. From these dimensioned photo-copies, the engineering department can then draw as built plans.

Mr. Menard's method may sound expensive, due to the high cost of helicopters, but if the photo missions are well planned, this is not the case. A properly used helicopter is a very efficient machine, and compared to the cost of sending a drawing crew onto each building of each school, the cost of this method is quite reasonable.

Next to the as-built (or as-reconstructed) plans, one of the most important parts of any maintenance program is a schedule of regular inspections. The office of the School Board Architect in Tallahassee has put out a maintenance, guide, Maintenance & Operations Guidelines, Office of Educational Facilities, that calls for at least one annual inspection of all school roofs. Unfortunately, attempts to enforce this rule were rebuffed as an attempt to concentrate power in the state capitol, so it seems that each school district does pretty much as it pleases.[14] This is extremely unfortunate because little things, such as picking up items that might stop up drains, can frequently prevent serious trouble in the future.

What is being said is that if maintenance does not start with the building of the roof, and continue throughout the life of that roof, the life of that roof is likely to be short and very unhappy.

VI. MAINTENANCE OF BUILT-UP ROOFS

Maintenance of built-up roofs will cover the care of the membrane, the insulation and the flashing. There are two main types of membranes, asphalt based and coal tar based. There are some differences in the care of these, but also many similarities. Let us discuss the similarities first.

The basis of all roof maintenance is an inspection at least once a year. Best practice calls for the inspection to be made twice a year with special inspections after any particularly unusual weather, such as a hurricane, a wind storm, or hail.

At all of these inspections a check list should be carried by the inspector (see Appendix A) and filled in to show the time of the inspection, repairs that need prompt attention, repairs that will need attention in short time, as well as housekeeping chores performed at this time such as drains cleaned, location of minor caulking repairs, etc.

These minor repairs and housekeeping, when done at or shortly after the semi-annual inspections, do a great deal to keep minor problems from becoming major problems. A pinhole in a flat roof is very easy to repair, but left unrepaired for a long period of time will allow water to penetrate the insulation. This reduces the efficiency of the insulation and also can begin to rot the membrane from the bottom up. A simple buildup of pine straw on a roof can clog a drain, backing the water up over a pinhole causing trouble. Regular inspections _must_ be made and the roof _must_ be kept clean.

As mentioned earlier, asphalt and coal tar roofs require a little different treatment. First, since the two materials are incompatible, it would be wise to determine which type of roof is on the building in question. Fortunately, there is a very simple test to tell asphalt from coat tar. Since asphalt is a by product of petroleum distilation, it is soluble in the higher (lighter) distilates of petroleum. Therefore, take a sample of the the bitumen from the roof and put it in a jar and fill the jar half full of kerosene or lighter fluid. Allow to sit for about 15 minutes than shake vigorously. If the color becomes dark brown and opaque, the bitumen is asphalt. If the liquid remains essentially clear - possible slightly greenish - then the material is coal tar pitch. Another way to tell these materials apart involved the use of a well trained and experienced nose.

Both coal pitch and asphalt need to be protected from direct rays of the sun. Asphalt, in particular is very subject to "alligatoring", a form of interconnected shrinkage cracks that leave the roof looking rather like an alligator's back. This is a progressive problem, and allowed to continue will bare the felts and encourage water to penetrate them with all the damage that can incur.

If this alligatoring is discovered before it penetrates to the felts (and certainly should be if there are semi-annual inspections), it can and should be corrected. Once repaired, the area should then be protected by a fresh coating of stone.

Coal tar bitumen is less susceptible than asphalt to damage by ultra-violet rays. Coal tar bitumen is also more self healing than asphalt, hence alligatoring is not quite the problem with coal tar that it is with asphalt.

This same self healing property of coal tar, which keeps it more fluid at lower temperatures, also makes it more susceptible to slippage on a sloped roof deck. As we said earlier, all decks should be sloped to allow for drainage, but in the case of coal tar membranes, the slope must be held to a minimum, lest the entire membrane "drain" from the roof.

Occasionally a vapor barrier is installed in a roof system where it is felt that the area under the roof will generate detrimental quantities of moisture vapor. The idea of a vapor barrier, under the insulation is that it is supposed to protect the insulation from the moisture inside the building. Sometimes it seems that the idea generates more problems than it solves.

First, in the case where the insulation is mechanically fastened to the roof deck, there are many penetrations in the vapor barrier. This not only makes it less effective, it also makes it so that moisture that does get into the insulation around the penetrations has a very hard time getting out of the insulation. A far better solution is to vent the area over the ceiling and under the roof.

The second big problem with vapor barriers is that any water that penetrates the roof membrane, instead of leaking immediately, is soaked up by the insulation where is spreads over a building. As this water spreads through the insulation, two things happen. One is the thermal protective valve of the insulation is destroyed and the other is the water may leak into the building as much as 100 feet from where it penetrated the membrane. This presents those charged with fixing the roof with a problem of the first magnitude. Vapor barriers are required in only very special situations and should be used with great caution.

On the subject of insulation, what are the options after it has gotten wet? First, the question has to be answered, "Is the insulation wet?" There are several ways to tell if insulation has gotten wet and each has its place in proper roof management.

First would be a leak inside the building. If there is insulation under the membrane and on top of the deck, some of it got wet when water penetrated the roof system. As mentioned above, if there is also a vapor barrier as a part of that roof system, it is likely that in addition to a leak in the roof, there is a problem with wet insulation. How much wet insulation is there?

To determine the answer to that question, some sort of roof survey is in order. The two most common survey methods are infra-red and with the use of nuclear moisture meters. Both of these methods are approximate, but they will usually give sufficiently accurate results to indicate where some plugs should be cut to determine the limits of the wet insulation.

At one time a popular solution to wet insulation was the installation of a great number of small one-way vents in the roof membrane. These were supposed to release moisture vapor when the insulation heated up during the daytime, then close at night when the coal insulation might draw moisture into the roof. A number of problems with the vents have caused quite a loss in their popularity, not the least of which is they don't work very well. Other problems are: there is no driving force to move the moisture horizontally in the insulation to get it to the vents, each of the vents represents a penetration in the roof membrane and as we saw earlier, 85% of all leaks come at penetrations, and there is always the possibility of one of the many vents malfunctioning or being broken by foot traffic and compounding the original problem. Still another problem is that certain types of insulation are changed by the wetting and drying process to such an extent that even if the insulation does get dried, it is no longer effective as insulation.

More and more people are coming around to the idea, shared by this author that the proper thing to do with wet insulation is to replace it. While this means cutting away and replacing a part of the membrane, it does give the repair team a chance to examine the deck and check for damage there. (This is a distinct possibility with gypsum and with light steel decks).

As we have mentioned several times before and may mention again, penetrations are likely places to find leaks. Therefore, everything related to maintenance should take into consideration the flashings used with the built-up membrane. Flashings should be made of the same material as the membrane and counter flashings should be made with metal. Unfortunately, this practice has not always been observed and a number of older buildings (and some new buildings with old specifications) have such things as gravel stops laminated into the roof plys. The problem here is that the coefficient of expansion is quite different for the roofing membrane and for the embedded flashing. This situation causes the flashing to destroy the membrane it was designed to protect.

At each maintenance inspection close attention should be paid to the condition of the flashing. Minor corrections and touch up in this area of the roof is most rewarding in extending roof life and all around better service on the whole membrane.

VII. MAINTENANCE OF SINGLE PLY ROOFS

The single ply membranes were designed to do away with most of the problems of the built-up roof membranes. They come, mostly, in wider width, allowing fewer joints and as a result less opportunities for leakage. Most of these membranes are plastic or rubber and in general they follow the trend in the entire building industry to do more work in the factory and less in the field.

In other segments of the building industry we have seen plaster give way to sheetwork, framed roof structures to trusses and a huge increase in the amount of precast concrete used today. It is only natural that an effort should be made to do essentially the same thing in the roofing industry. It must be remembered though, that this is a developing industry, and at the moment that fact is causing some unique problems.

Since single ply roofs are a developing industry, there is no standard material for building the membrane. Worse than that, some of the materials used with one membrane can do great harm to other membranes. This makes it very important that the people charged with maintaining any given single ply roof be familiar with the materials required to repair that particular roof and have a supply of those materials at the location where they are readily available. In dealing with single ply roofs, we are not talking about a long term incompatibility. We are talking about a well meaning maintenance man who goes out in the rain at night to put some roofing bull on an obvious leak and finds in the morning that he has dissolved part of the roof membrane. You can imagine what this sort of thing does for the roof warranty!

Insulation with single ply roofing has one additional problem when compared to insulation used with built-up roofing. How to attach the roof membrane to the deck - or to the insulation? With the built-up roof, the membrane can be mopped to the insulation. This is not possible with most single ply systems, and here again those charged with maintenance must be aware of the particular system they are using.

Single ply membranes are especially popular with specifiers who specify that so called "upside down" or ballasted roof. This is a system where by the membrane is put directly on the roof deck, when covered with loose laid insulation and the entire assembly held in place by ballast weighing approximately 1000 lbs per square.

Several problems come to mind when using this type of single ply roof system. First, will the structure carry the extra weight of ballast safely? Second, will the ballast successfully resist wind uplift for the area where the building is located. Finally is there excessive danger to people or property form flying ballast in a heavy windstorm? According to news stories at the time, much of the damage done in Houston Texas in the hurricane of 1983 was broken glass, much of it caused by rocks blown off the roofs.

Variations on this type of roof have the insulation under the membrane - again loose laid - and the ballast on top of the membrane. This allows a wider choice of insulation, but puts the roof membrane under greater thermal stress. In this and all variations of the ballasted roof, leak tracing is a serious problem as is leak repair. In the repair case, the main problem is to avoid dangerously concentrated piles of ballast while exposing and repairing the membrane.

Single ply roof are in many cases self flashing, meaning that the membrane is flexible and strong enough to serve as the flashing. Even so, it must be remembered that flashings occur around openings, and because of this whoever is doing the maintenance on a roof must take special pains to check the flashings at each of the proscribed roof inspections. Because most single ply roofs are capable of withstanding such large amounts of movement, they are sometimes designed with extreme movements in mind. Because also single ply roofs are such a new product, it is sometimes possible to use a brand of roofing that meets the specifications but does not have the flexibility and/or strength that the designer had in mind. When this situation occurs it usually results in ruptures at openings and it must be repaired promptly and frequently.

VIII. MAINTENANCE OF SHINGLE ROOFS

Shingle roofs are more water sheds than water proofing and as a result they work in a different way from the various membrane roofs used on the flatter roof surface. Asphalt shingles are the most common kind of shingle, should not be used unless there is a slope of at least four inches per foot.

When shingles are properly installed, there is not a lot of maintenance required for the main roof areas. There is always need for maintenance at penetrations and edges. Therefore the regular roof inspections should be made to check for open gutters and downspouts, to be sure that valleys are not obstructed and to check for cracked or split shingles. As with any type of roof covering, defects should be repaired at once and a record kept of their location, the date and the action taken. This all becomes part of the ongoing roof history and will be useful to future owners as well as the present owner.

One of the prime causes of failure of asphalt shingle roofs is wind damage. The manufactures have all started to use stripes of stickum that melts under sun heat and sticks the tab of each shingle to the shingle below it. This helps, and along with a good nailing schedule is probably the best protection available against roof blow-off.

Repairs on shingle roofs, short of a total re-cover job, usually consist of replacing the occasional shingle damaged by a foreign object, such as a falling limb. Shingle roofs are also very easily damaged by traffic, and all inspection walks should be done at a time when the roof is not already under stress. That is, early in the morning in hot weather and up in the day in very cold weather.

Shingle roofs, like other roofs, have edge flashings. They are not the same as the edge flashings of other roofs, but they serve essentially the same purpose, that is, to keep water form penetrating the structure. Shingle roofs also have a type of flashing that is unique to them. That is the valley flashing. Where two different wings of a shingled building come together there is a valley. Valleys must be kept clean of trash, pinestraw etc., because any water that does not flow smoothly and swiftly down the valley is almost certain to be pushed under the shingles where it will very likely find its way into the building.

Shingle roofs, because they are made up for a number of small pieces of material, do not need expansion of contraction joints. There is, in effect, one of each between each single.

Shingle roofs have been with us for many years and shingles are and have been made from a number of materials. These materials include wood, clay tile, concrete, sheet metal, asbestos cement and slate. In some areas shingle roofs are gaining in popularity as various problems with the other types of roofing seem to defy solution. Dr. Donald E. Brotherson, a researcher at the University of Illinois in Champaign Illinois says that the local bankers there will not finance condominiums with any sort of roof other than shingles.[15]

IX. SUMMARY

There is a continuing need for maintenance of all types of roof systems. Just because a roof is sold as a twenty year roof does not mean that it will last twenty years without any help. The reverse of that is also true. Just because a roof is advertised as a 10 year roof doesn't mean that the life of that roof cannot be extended considerably by a good schedule of maintenance.

Of course, nearly anything can have its usable life extended by good maintenance. Everyone hears of cars that have been driven for extremely long periods of time. Antique airplanes are a hobby with growing numbers of people. Roofs too, simply <u>must</u> have proper maintenance if they are to perform at anything like their design capability.

A roof on a new building represents only a small proportion of the overall cost of the building, usually 3 to 5%. To replace that roof will cost 10 to 15% of the building cost plus the repair of any water damage inside the building. In addition to this there is the fact that a re-roof job almost never lasts as long as the original roof.[16]

We have seen that the four things which control the quality and hence the life of a roof are: 1) Design, which is the responsibility of the designer, 2) Material, which is the responsibility of the manufacturer, 3) Installation, which is the responsibility of the roofer who installs the roof, and 4) Maintenance, which is the sole responsibility of the owner. He had the roof designed, approved the materials, paid the roofer, and each of these professionals were expected to do their best work. Now that the roof has been built and it is the owners total responsibility, it is up to him to do his best work in maintaining that roof. If he is unprepared or unable to maintain the roof he owes it to himself to hire someone who is capable of doing regular maintenance on the roof. A good place to start looking for such a person is with the roofer who installed the roof.

ENDNOTES

[1]Professor E. C. Shuman of the Institute for Building Research of the Pennsylvania State University writing in the April, 1970 issue of ABC - American Roofer and Building Improvement Contractor.

[2]E. J. McCormic, Roof Consultant, writing in the April, 1976 issue of ABC - American Roofer and Building Improvement Contractor.

[3]Roofing Maintenance Manual for Vista De Mar Condominium, Robert E. Crosland, 1983.

[4]Causes of Roof Problems, A Lack of Maintenance, NRCA/ARMA Manual of Roof Maintenance and Roof Repair.

[5]E. J. McCormic, Roof Consultant, writing in the April, 1976 issue of ABC - American Roofer and Building Improvement Contractor.

[6]Ibid.

[7]Interview with Chris McConnell, Maintenance Supervisor for Nassau County, Florida.

[8]Roofing Systems: Materials and Application, John A. Watson, Restin Plumbing Company, 1979.

[9]Interview with R. W. Menard, Structural Engineer for School Board of Pinellas County, 11/11/83.

[10]Roofing Systems: Materials and Application, John A. Watson, Restin Publishing Company, 1979.

[11]Ibid.

[12]Manual of Built-up Roof Systems, Second edition, C.W. Griffin, McGraw-Hill Book Company.

[13]1982 Standard Building Code, 1203.7 Southern Building Code, Congress International Inc., Birmingham, AL.

[14]Interview with Mr. Paul Krone, State of Florida School Board Architect, 3/11/83.

[15]Interview with Dr. Donald A. Brotherson, Director, Building Research Council, University of Illinois, 3/1/83.

[16]Manual of Built-Up Roof Systems, second edition, C.W. Griffin, McGraw-Hill Book Company, 1982.

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3. Roofing Spec magazine, NRCA.

4. Roofer magazine, D & H Publications, Inc., Ft. Myers, FL.

5. Building Maintenance Management, Mel A. Shear, Reston Publishing Company, Inc., 1983.

6. Manual of Built-up Roof Systems, Second Edition, C.W. Griffin, McGraw-Hill Book Company, 1982.

7. Paper by R.L. Fricklas, RIEI, 1980.

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APPENDIX A

ROOFING INSPECTION REPORT FORM

ROOF INSPECTION REPORT FORM

Building No. ______________ Date of Inspection: ________________
Inspected by: ____

ROOF MEMBRANE

1. General Appearance:
   Good _________ Fair _________ Poor _________

2. Watertightness:
   No leaks reported ____________
   Leak reported at (give location)
   ____

3. Reported leak occurs:
   Every rain ___________________
   Only with long continued rain ________________
   Only with high winds _______ Direction of wind? ________
   Only when ponding occurs ______________________

4. Condition of Aggregate:
   Uniformly distributed ________________
   Bare areas _________________
   Inadequate amount of aggregate ______________
   Excess amount of aggregate ___________________

5. Condition of Membrane:
   Uniform coverage of bitumen __________________
   Exposed edges of felt _______________________
   Edges of felt curled _______________________
   Blisters in felt _______________________
   Fishmouths in felt _______________________
   Tears, splits, cracks in felt ________________
   Felt dried out _______________________
   Buckling or sagging of felt __________________
   Alligatoring of bitumen ___________________

6. Recommended Treatment of Membrane:
   ____
   ____

FLASHINGS

1. Base Flashings:
   - Good Condition ____________
   - Deteriorated surface ____________
   - Vertical joints open ____________
   - Base of flashing loose ____________
   - Sagged or separated from parapet wall ____________
   - Tears, splits or cracks in base felt ____________

2. Counterflashing:
   - Well-anchored in masonry ____________
   - Condition of caulking at masonry ____________
   - Bonds, buckles or damage to metal ____________
   - Lap joints sealed ____________

3. Coping:
   - Good condition ____________
   - Lap joints sealed ____________
   - Bends, buckles or damage to metal ____________
   - Loose fasteners ____________

4. Vent flashing (lead boots):
   - Good condition ____________
   - Base flange loose ____________
   - Boots turned down into vent pipes ____________
   - Holes or damage to lead boots ____________

5. Chimney vents:
   - Good condition ____________
   - Base Flange loose ____________
   - Collars sealed ____________
   - Rain caps secure ____________
   - Galvanized metal painted ____________

6. Pitch Pans:
   - Good condition ____________
   - Base flange loose ____________
   - Filled with bitumen ____________
   - Galvanized metal painted ____________

7. Gravel Stops:
   - Good condition ____________
   - Lap joints sealed ____________
   - Bent, buckled or damaged metal ____________

8. Dissimilar Metals:
   No dissimilar metals in contact ______________
   Dissimilar metals are insulated or isolated __________
   What metals are involved: ____________________

9. Recommended Treatment for Flashings:
   ____
   ____

DRAINAGE SYSTEM

1. Scuppers:
   Open and in good condition _____________
   Sealed to flashing ______________
   Base flange sealed ______________

2. Roof Drains:
   Open and in good condition _____________
   Sealed to membrane _____________
   Deterioration of metal _____________
   Condition of strainer _____________

3. Gutters
   Open and in good condition _____________
   Securely fastened _____________
   Lap joints sealed _____________
   Bent or damaged metal _____________

4. Downspouts:
   Open and in good condition _____________
   Securely fastened _____________
   Bent or damaged metal _____________
   Splash blocks in place _____________

5. Recommended Treatment for Drainage System:
   ____
   ____

GENERAL HOUSEKEEPING

1. Cleanness:
   Roof is clean and free of trash and debris ___________
   Found liter. Type _______________
   Found loose objects. Type ______________

2. Painting & Caulking:
   - All ferrous metals well protected ______________
   - All masonry/concrete surfaces sealed ______________
   - What areas need caulking? ______________________________
   - What areas need painting? ______________________________

3. Dissimilar Metals:
   - No dissimilar metals in contact ______________
   - Found dissimilar metals in contact;
     type ____

4. Repair Work Recommended:

   ____

   ____