PDHonline Course C812 (2 PDH)

Roofing Solutions (Part Two)

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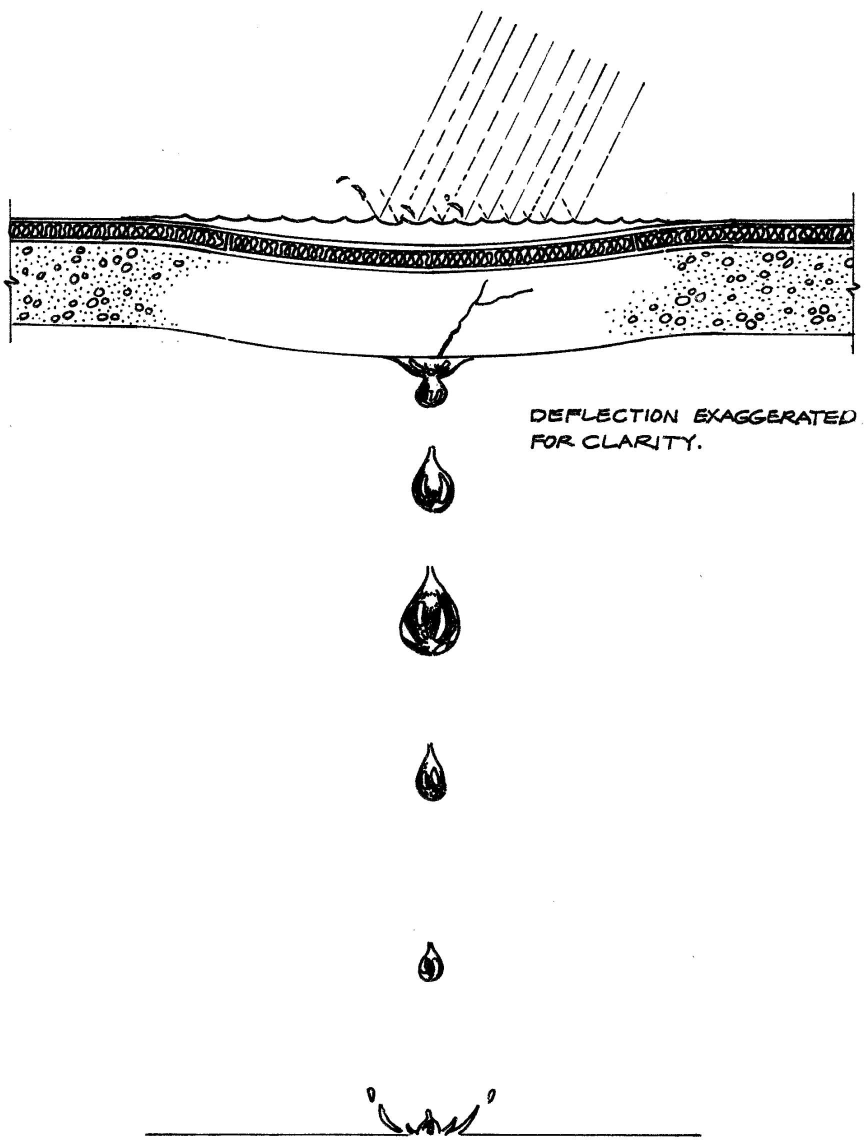


THE ACHILLES' HEEL OF ALL FLAT ROOFS

ROOFING SOLUTIONS (PART TWO)

Ruben A. Gomez, P.E.

1.0 INTRODUCTION

In the same manner that the foundation system is intended to transmit and distribute the building loads to the soil, as well as to preserve the continuity, stability and integrity of the building structure; the roof is intended to enclose and protect the building contents from rain water, sleet, hail, snow, wind and the rest of the perils dished out by the weather.

As we already indicated in the Part I of this course, and as a matter of simple logic, the moment rain water enters in contact with the roof surface, the primordial purpose is to dispose of every drop of that water as soon as possible, therefore, it becomes evident that there is no better solution for the roof than to shape it with a slope, so to accelerate its drainage and run off.

By virtue of such logic, the inevitable conclusion should be that the best roof is one that follows the *watershed* configuration. Then, one may wonder, why not building all roofs with such configuration? Unfortunately, there are situations in building design and construction practice where a flat roof is an unavoidable necessity. Therefore, we must not only live with the flat roofs, but need to figure out the best way possible to design those roofs, so they successfully meet the purpose already established in the first paragraph above, and further, that they perform such task in an adequate manner, and allow for their maintenance and replacement when necessary.

This Part II of this course is entirely dedicated to study all the common and uncommon detail solutions and conditions that may become necessary to defuse the extended belief that *all flat roofs leak,* and replace it with another one which may rather read *flat roofs leak only if you let them.* In order to meet the challenge, we have listed below the culprits and their solutions as they have been laid ahead:

a. less than perfect substrates,
b. structural deflections,
c. inadequate detailing,
d. defective materials,
e. proliferation of joints,
f. substandard supervision and inspections, and
g. absent maintenance programs.

Once those seven areas of concern are acknowledged and get under control, the rest is an easy ride home.

2.0 THE AGONY OF THE FLAT ROOF

Because of the necessity we face of providing flat roofs that don't leak, this part is entirely dedicated to such proposition. In order to accomplish such task, we must bring down effective solutions for the above breakdown of maladies. The failure or success of a flat roof assembly may depend in great extent to how much attention is paid to the rules herein described.

One condition that was not listed above happens to be a derivative of the same list. All those phases as listed, are generally performed or provided by different people who are not terribly concerned, or may we say, not concerned enough about the step after to be performed by others. The only link amongst those subcontractors is their supervisor, foreman or superintendent of the field operations, who in return and more often than not, rely too much on the abilities and experience of others, rather than in their own responsibility to make sure that all the "pieces of the puzzle" fit as intended.

It is very dismaying, after a stormy Sunday evening to go back on Monday morning to your business locale built under the cover of a flat roof, and perceive that smell of musty air, and immediately after, to find those dreaded fresh water stains and rain water dripping from the ceiling. It feels as if suddenly your world has been turned upside down. For a moment you wouldn't know whom to call first, whether the general contractor, one of those roofers advertising on the yellow pages or the Internet, your insurance agent, your uncle Charlie, or whomever else. In spite of all, your building is only five years old.

After the initial hesitation, you end up deciding for your uncle Charlie; after all, before his retirement five years ago, he used to be a building inspector for the City of Santa Poca. Uncle Charlie advised you to call three roofers and ask for a free quote from each and free lip service. Before the day was out, you, the hero of this story, had a lot of conflicting and contradicting ifs and buts and three different quotations for a roof repair job where the high quote was twice the amount of money than that of the low bidder's quote.

My intention was not to make you laugh, but just to show you how unnerving that experience may be for the unsuspecting and naïve building owner who had no idea that this was coming his way. Fortunately, the person reading this course is either an architect or an engineer who have had his feet wet many times over and is not impressed by this "small change", and I am glad that is the case!

3.0 LESS THAN PERFECT SUBSTRATES

Substrates are subject to imperfections which sometimes reflect differences among the supporting members or even sagging deflections from beams and joists, or even from the rafters directly underneath. Those imperfections may come out and be perceptible on the roof deck itself. Such imperfections may not make much difference and get dissipated on watershed slopes, however on flat roofs of limited slope, say 1/8 in. per foot, they may make all the difference in the world.

When it comes to cast-in-place concrete slabs, small depressions and unevenness are commonly produced by the way concrete in cast. The most common method to spread concrete is by two men holding a wooden screed. The workers do the spreading by sliding the screed between two given points or alignments. More often than not, the wet screeds have sags which get transmitted to the concrete surface, some other times the workers themselves may exert some downward pressure that brings about the blemish or imperfection, and lastly, irregularities may also be introduced during the final troweling and finishing of the concrete surface.

All those imperfections on the concrete surface will result in ponding depressions of all sizes on the roofing surface which invariably will become apparent while the concrete is setting, or after the very first rain shower. Small depressions will not be of any great consequence; however, larger depressions will allow accumulation of rain water, some of it will evaporate, and the rest of the rain water will persistently start on degrading the roofing membrane.

Those unintended but expected depressions can be prevented in large degree by providing -before the concrete pouring- enough control points with the proper spacing according to the case. The second recommended remedy would be to use steel straightedges with convenient handles, rather than the wood screeds described above.

4.0 STRUCTURAL DEFLECTIONS

In more or less degree, all horizontal structural members develop a sag, such sag is a function of load, span, modulus of elasticity and moment of inertia. Although those variables can be manipulated to the advantage of the design engineer, there will always be a sag, a short term and a long term sag that is. By the same token, those deflections can be calculated and thus counteracted with a camber, which will hopefully and slowly relax back to a leveled position. In an ideal world, deflections can be overcome, but in the real world the engineer will be better suited if he counts with the presence of those variables. In practical terms, it makes more sense to allow for the reality of deflections, even though deflections may mean more rain water ponding on the low spots and then the extra weight triggering more deflections and so on, in an endless circle.

Considering the alternatives, either all horizontal members get oversized (at an extra cost) to reduce deflections or the roofing membrane gets water-tightened, as well as, seams and splices being avoided to occur at mid-span. That brings us down to a more elaborate and more accurate detailing, which we will be seeing next.

5.0 ADEQUATE OR INADEQUATE DETAILING

In the large majority of the cases, regular working drawings do not cover roofs in detail enough as they should, they mostly include the plan views and a few generic details copied from a catalog or a handbook and unfortunately, those same details which may be abbreviated or left behind are the ones that would come back and haunt everyone involved. A lesson that needs to be learned is that those special conditions that appear in practice, but are omitted on the roof plan, cannot be left out for the roofer to decide and/or improvise as he goes; they need to be part of a good set of working drawings.

The same way, the manufacturer's generic details cannot be copied or transcribed into the plans and expect the problem to being solved. Those omitted tetrahedral conditions are the ones that likely end up leaking and embarrassing all those involved, namely the architect, the roof design engineer, the roofing consultant and even the contractor. One more thing to bear in mind as "insult adds to injury", in many instances during the bidding process, the roofer and/or the general contractor would notice certain errors, contradictions or omissions and instead of making them public, he would keep them quietly to himself until the "eleventh" hour came up, when it was time and opportunity to take advantage and submit a juicy change order, thus holding the architect wide open for a malpractice indictment.

The best way to operate in the design office, so to assure an error free completeness, is by having an uninvolved but experienced designer from another team in the office, playing the Devil's advocate and challenging every detail and every possible situation, and have those cases discussed, debated and "taken apart" until perfection is achieved. In reality, that kind of task cannot be left to the drawing "checkers", since they generally only follow up on the drawing's plans and details to assure consistency and dimensional accuracy.

We are not advocating here for excessive and superfluous detailing that may add to the confusion though, but just for the necessary detailing to assure completeness, no more and no less.

6.0 DEFECTIVE MATERIALS

In most instances manufacturers have quality control inspectors and in some cases even full quality control departments that don't allow any piece of material to leave the factory un-inspected for quality assurance. However, in spite of all that defects may and do happen. Therefore, the roofer also has the responsibility to check every piece as it comes out of the roll or out of the can. Generally, defective materials have little consequences when caught before installation, contrary to what happens when they are caught after their installation.

Small defects, such as punctures and small through holes can be solved by patching them up, but large creases or cracks are somewhat more difficult to solve. Fortunately, because of the constantly improving quality control procedures, those cases are very rare.

Dirty or contaminated material should not be allowed on the job. Rolls that have been left outside in the cold overnight or for extended periods of time in freezing weather and consequently may have become brittle, need to be discarded or sent back to the warehouse for a different application.

7.0 PROLIFERATION OF JOINTS

The same manner that every change in direction, every change in materials and every encounter with a vertical surface carries the potential for leaks due to carelessness, neglect or human error, the more joints are in a roof the higher are the probabilities of trouble. By the same token, by eliminating all joints we could eliminate all possibilities of leaks. Naturally, that would be easier said than done. Since all roofs are different in shape and size, it would not be possible to manufacture a "one fits them all" roof. However, the point we are trying to make here is directed to the fact that the number of joints could be reduced by manufacturing larger components and better yet, by prefabricating complicated tridimensional joints which could minimize the possibility of leaks and reduce some of the field work.

Unfortunately, the production of larger rolls is limited to the weight that could be handled by the workers at the point of installation, which in fact, is one of the contentions that provide validation to the whole concept of pre-assemblage and/or prefabrication.

8.0 SUPERVISION & INSPECTIONS

Those two men (or women) in every construction job, the project superintendent and the building inspector, fail too often to fulfill their duty and responsibility to make sure that things are done as indicated on the drawings, or at least, that the required work is done according to the best known practice available.

While it is true that the key to a maximum roof life is an effective maintenance program, very little could a good maintenance program do if the roof is not built correctly the first time around.

Before any roofing work starts, the substrate must be inspected to make sure that the geometry and slope of the roof have been provided correctly and all alignments are straight and free of sags. Make sure that all roof carpentry work is complete, such as, cant strips, curbs, fascias, nailers, blockings, base flashings and drip edges, are installed straight, well spliced and secured with the proper number of fasteners.

Also, before the roofing work begins, the substrate must be swept clean or air blown, and free of debris and nails that otherwise could end up being trapped underneath the roof covering.

As the roofing work starts, the person in charge must make sure that priming is done correctly and the underlayment is applied flat and with the correct splicing and overlaps, without creases, bubbles or blisterings.

Observe installation of the insulation panels and the required wedges as they are set or embedded in bitumen or whatever adhesive is required in the drawings notes or specifications, so to also ascertain that slopes are provided where they are called for.

Check installation of the membrane in such a way to make sure that overlaps are correct and the roofing surface is free of bubbles, fishmouthings, loose laps, splitting and/or punctures. Do not release and approve the roofing work until all requirements are fully met, even if that means to extend the process one or two extra days.

9.0 ABSENT MAINTENANCE PROGRAMS

Normally and as we have indicated elsewhere, once the roof is finished and accepted by the right and authorized representative, everybody get their hands off the roof case and it is left forgotten and to its own fate. However, experience shows convincingly that the existence and execution of an adequate preventive maintenance program is of extreme importance to get the best results and to obtain the maximum life span out of any roof.

Semi-annual or at least annual routine inspections must be implemented. Naturally, those inspections must be performed by a roofing professional. That person should be an experienced roofer or someone with a proven track record in the roofing industry.

In addition to the routine roof inspections, extra examinations must also be performed immediately after severe wind storms, hail storms or blizzards. We have included in the Appendix at the end of this course, a guide for a typical inspection checklist which could be helpful so as not to miss important items needing attention on part of the designated inspector or maintenance crew. Such guide has been divided in seven main categories as follows:

a) supporting structure,
b) roof condition,
c) flashings,
d) drip edges and fascias,
e) penetrations,
f) expansion joints, and
g) pitch pans and insulation vents.

It should be noticed that inspection of all exterior and interior bearing walls has been included as part of the roof inspection, this has been done for one important reason: condition of the supporting walls is important and has an impact on the general condition of the roof, as any settlements in those walls will eventually reflect and have a detrimental effect on the roof above them.

Damages shown on the inspection report should be properly fixed and without delay in order to effectively arrest the possible continuing deterioration of the roof. We will see more about all these at the end of this part of the course.

With this item we call completed the requirements and areas of interest, those listed conditions must be met in order to achieve a flat roof that is generally humidity free and without the dreaded leaks that nobody wants to see.

10. FUNCTION OF THE INSULATION

Insulation is used in roofing systems to improve thermal efficiency. Considering the fact that heat rises independently of function, location, or any other physical characteristic;

therefore, the design engineer or architect should expect *heat losses* to take place through the thickness of any given roof.

The total heat loss is proportional to the ratio of the gross roof area to the total volume under such roof. Therefore, such ratio is considerably less for hi-rise buildings than it is for single story buildings. In clearer words, the expected relative *heat loss* through the roof is much less for hi-rise buildings.

Insulation not only reduces heat transmission, but also reduces condensation on the underside of the roof deck. Further, by reducing temperature variations and therefore differences in expansion and contraction, insulation tends to stabilize not only the deck components, but also to reduce the induced stresses amongst the membrane layers.

Some manufacturers may recommend the use of vapor barriers under the insulation, in such case, venting is a required feature. A common venting device has been depicted as part of Figure 12.2(c); in this instance we have shown a spun aluminum mushroom type vent. Installation of this device is relatively simple, after the roofing coverage has been completed; the vent locations are laid out on the finished roof surface and the centers marked accordingly. At every marked location, a hole is cut through the membrane layers and the insulation thickness as well, but carefully done without cutting the vapor barrier underneath. The vent is centered over the cut hole, then a 24 x 24" piece of membrane is cut with a hole in the middle to match the opening in the vent, the device is placed over its flanges and then set and properly sealed around with the specified roofing cement.

11. BITUMINOUS BUILT-UP ROOFING

The traditional bituminous built-up roofing (BUR) is the original attempt to provide for a reasonable water resistant solution in spite of all its many drawbacks. Generally speaking, we do not recommend built-up roofs, unless it is well understood that life expectancy and performance of such roofs are at the low end in the scale of desirability.

BUR's consist of multiple layers of felts (generally described as pitch soaked fibrous boards) adhered to each other and to the substrate by generous coats of either petroleum asphalt or coal-tar pitch, generally referred to as bitumen. In order to protect such assembly against the degrading forces of the weather, a thick *gravel ballast* is spread over the entire roof surface. Gravel stops need to be installed around the perimeter of every panel to hold the aggregate in place.

The surface gravel ballast will protect the roofing surface from the erosion caused by the rain, hail, sleet and wind. On the negative side, the gravel ballast will retain humidity thus promoting algae growth and adding extra weight that must be carried permanently by the roof structure. Further, because gravel is a non-renewable material, the ecological advocates have placed it on their black list to oppose to their use every time they have an opportunity to do so. More information on this item is given below.

The rest of the components in a built-up roof are as follows:

CANT STRIPS

Since a ninety-degree (90°) angle causes too much strain on the applied materials, therefore, by breaking it in two forty-five-degree (45°) angles the condition is ameliorated at the base. Experienced roofers know (or should know) that right-angle bends where cant strips could have been omitted just for the sake of convenience, will invariably result in a premature fatigue failure of the assembly. Figures 11.1, 12.1, 12.2 and 14.1 illustrate a few conditions where a standard cant strip have been used to solve the problem of the right angle encounter between the roof and a parapet, as well as the roof and curb conditions.

SURFACE GRAVEL BALLAST

It consists of round river-washed gravel with a diameter of one inch as described in the ASTM Designation D-448 as a #4 stone. Allegedly, this stone is large enough to resist wind forces unanchored, as compared to pea-gravel #6 corresponding to ASTM Designation D-1863 which needs to be anchored to the roofing surface by being embedded in bitumen to help keep it in place.

What has been stated above is the official version disseminated by those who have some vested interests, however, in our opinion gravel roofs are quite undesirable because their extended use not only requires the depletion of a non-renewable resource, but they also become a serious hazard in case of hurricane winds. To say the least, in such cases the stones become flying missiles breaking windows, glass panels, sky roofs, car and truck windshields and contributing to litter even more, the areas around them.

BASE FLASHINGS

Base flashings can be formed out of galvanized steel, aluminum or copper and provide effective seal at regular joints, expansion joints, parapets, curbs and penetrations. They must be designed and installed in such a way that they can achieve dependable water-tightness by themselves and without help from the counter-flashings.

COUNTERFLASHINGS

Counter-flashings provide added protection to the upper edge of the base flashings, as well as making the joint to look better dressed and finished.

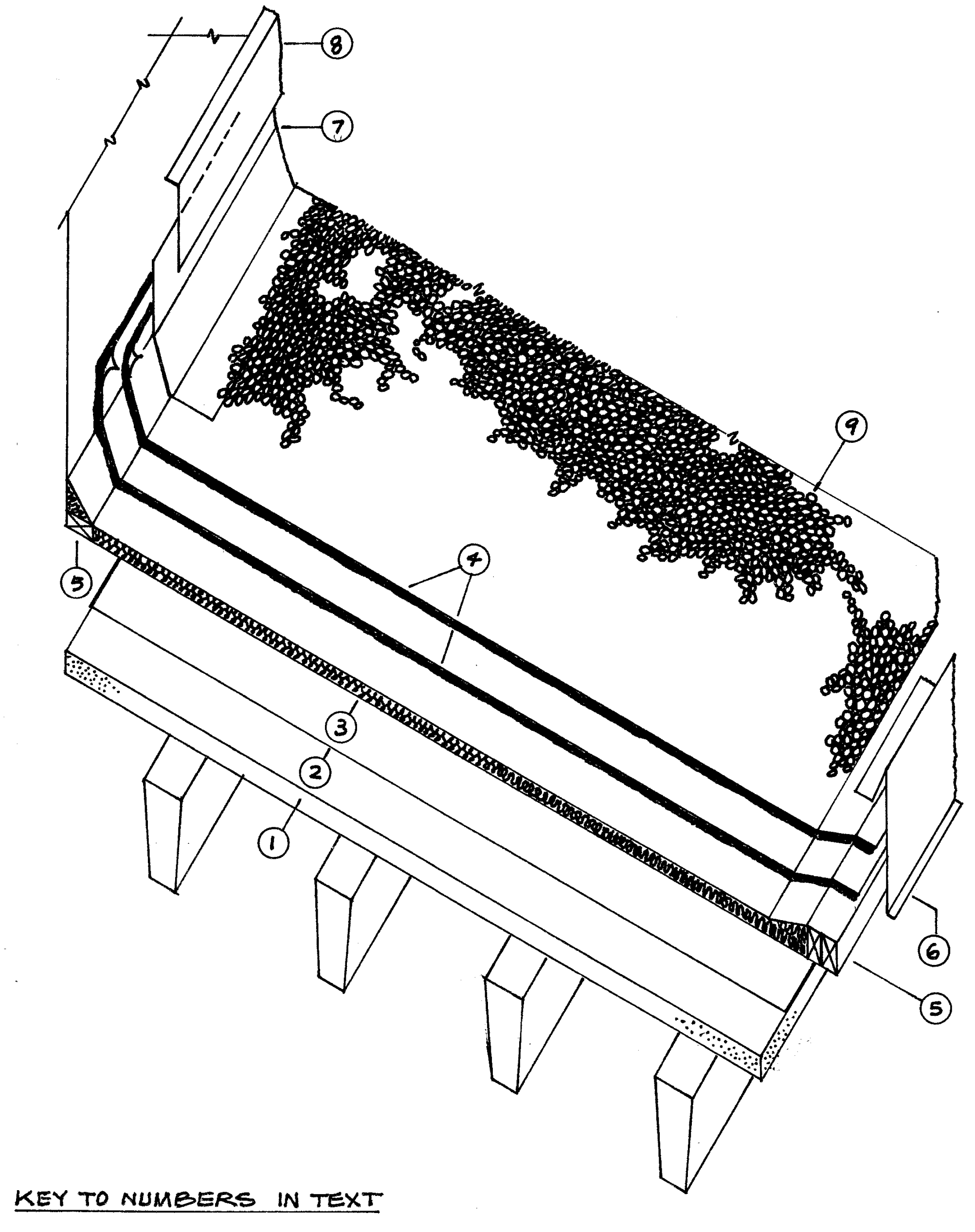
GRAVEL STOP/FLASHINGS/FASCIAS

These provide retention to surface gravel and also provide the finishing touch to the roofing surface when properly designed, fastened and installed.

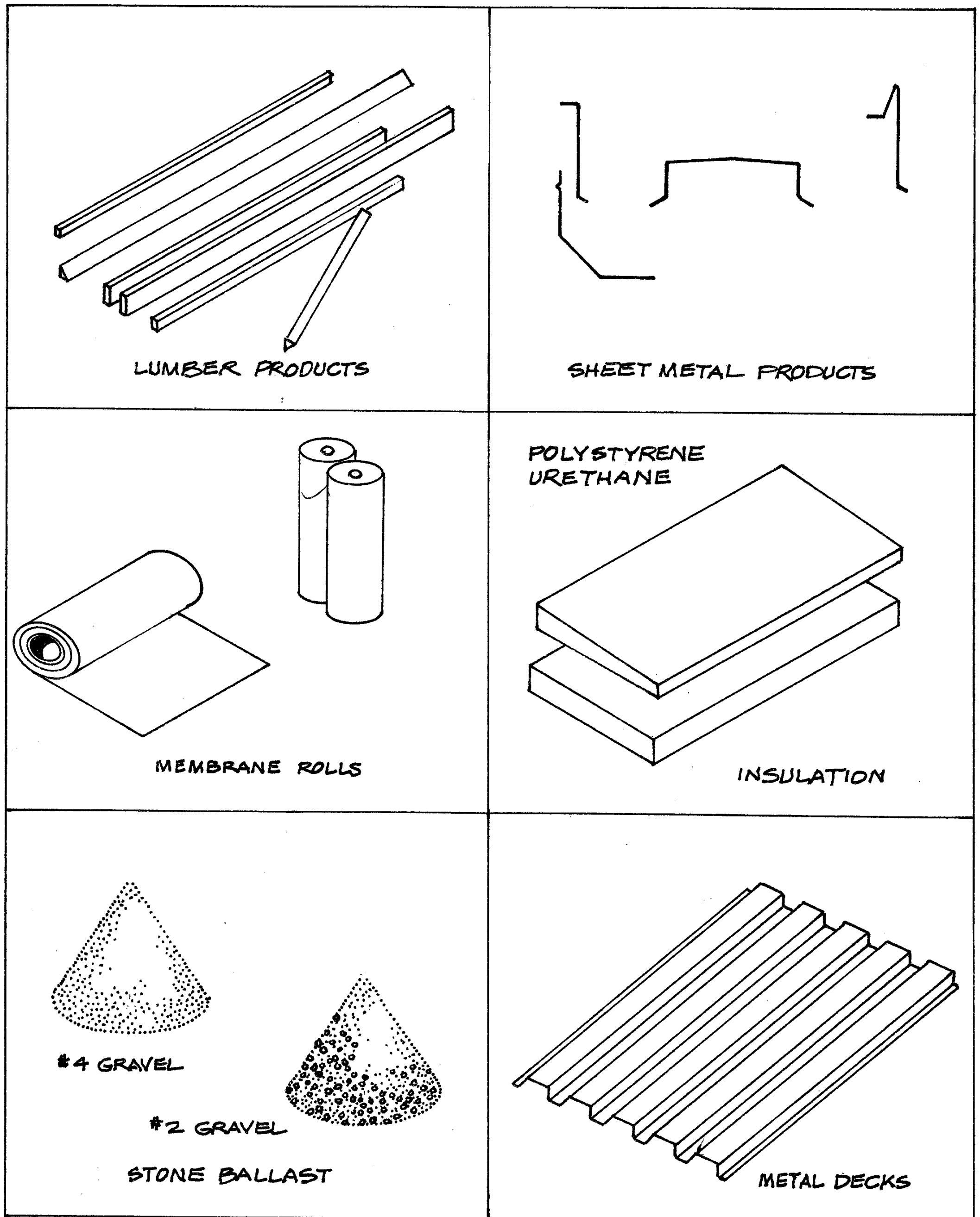
Figure 11.1 provides a picture of the generic components of a bituminous built-up roof assembly in the form of an isometric section. Although the figure is pretty much self-explanatory, we have included below a key to the numbers as they appear in said figure:

Key Number	Description
1	Supporting roof structure (in this case non-nailable type)
2	Underlayment/moisture barrier
3	Thermal insulation
4	Felts applied over hot asphalt moppings
5	Wood nailers
6	Gravel stop/fascia
7	Base flashing
8	Counter-flashing
9	Stone ballast.

On the other hand, Figure 11.2 illustrates several of the unassembled roofing parts and components as commonly used in roof design and construction. Familiarity with those parts is a must for those individuals interested in this very important part of the construction industry.



BITUMINOUS BUILT-UP ROOFING
FIGURE 11.1



COMMON ROOFING MATERIALS
FIGURE 11.2

12.0 MODIFIED BITUMINOUS ROOFING

Modified bituminous membranes generally consist of an asphaltic mix *modified* by adding Atactic Polypropylene (or other similar materials). The resulting sheathing is further reinforced with a polyester fabric. The material is produced in thicknesses of 160 mils (0.16”) to 180 mils (0.18”) and comes in rolls of about 39 in. wide with an overall length of 33 ft. In order to reduce the number of joints they could be produced in wider rolls, however, increasing the width would also increase the weight of the roll, possibly exceeding the limits of the *human scale* for handling, as the regular rolls as described above range close to one-hundred pounds each.

The system’s application over a structural concrete deck must be done after the concrete surface has fully cured and should be followed by the application of an approved primer conforming to ASTM Specification D41. To determine the suitability of the concrete, most manufacturers recommend a test consisting of the following procedure: heat up a pint of primer to 400 deg F and pour it on the concrete deck, if the primer turns foamy or forms bubbles over the concrete surface, that means there is still too much humidity and therefore the concrete is not ready. To further test it, when the primer cools off, try to strip it off the deck. If the material comes off clean, it confirms the fact that the deck is not dry enough. If the deck is found to contain too much humidity, wait a week and repeat the test, if the roof passes said test, then the roofer can proceed with the installation as planned.

After the primer has cured, the *insulation* may be installed over hot mopped asphalt meeting ASTM Specification D312. Another coat of hot asphalt is then applied over the insulation to receive the *base sheet.* Apply another coat of hot asphalt and install the *top sheet* making sure that there are overlaps of 3 inches. When the positioning of the top sheet has been done, apply heat along the laps to assure the fusing of the edges watertight. Heat should be applied until the material has a glossy appearance and the two edges are ready to weld together as one piece.

This heat applied procedure gives the roofing membrane substantial substrate adhesion and excellent lap joint strength, excellent wind uplift capacity, as well as providing a watertight assembly. Once the material is properly installed, it produces a long lasting continuous membrane that is waterproof, puncture resistant, flame retardant and capable of enduring almost any kind of weather that may come along.

Most manufacturers recommend their material installed with 3 in. laps and desirable slopes varying from 1 to 3 in. per lineal foot. If the deck is not sloped by itself, then wedge insulation panels can be used for that purpose. Conditional to strictly followed and documented periodical inspections, most manufacturers will offer warranties of up to 20 years.

The superiority of the Modified Bituminous Roofing (MBR) over the Bituminous Built-up Roofing (BUR) is based and demonstrated by two main factors,

a) the quality of the material itself, and

b) the method of installation, meaning in this case that the laps are fused together by applying heat rather than depending on mopped-on hot tar.

Figure 12.1 gives us a tridimensional view of the common components at a typical edge condition. Please notice that the *key to numbers* shown in Figure 12.2 also apply to this figure. The way the "over the parapet" *coping* works is by insertion in a metal cleat previously fastened along to the near side and evenly screwed along on the rear side of the figure.

The curious reader will not likely miss the two opposite pair of shear vectors (marked "V") at the base of the cant strip. To make a long story short, what takes place down there is that those forces are either caused by building differential settlements or by temperature differentials, they will constantly induce movement on the two contiguous sides of the low vertex, and thus the inducement of variable shear stresses which will eventually produce fatigue in the membrane.

After a year or two under those circumstances, the roofing surface may show some creases, twists and bubbles and eventually they may turn into cracks, and unfortunately, the beginning of the roof troubles for the building owner. That would certainly be the case, unless the roof is periodically inspected -as we have emphatically recommended here and everywhere- and problems such as the one just described above get taken care of with due anticipation. For a comprehensive inspection and repair procedures, we have included some easy to follow guides and instructions which are part of the Appendix at the end of this course.

When preparing roof drawings, the designer may have doubts when he gets down to draw the laps, and wonder which side of the membrane goes on top. The best way to decide in an exact and foolproof manner is to remember that the laps must step down by following the flow of water from the high point to the low point. That condition is best visualized by examining Figures 12.2 (a) and (b).

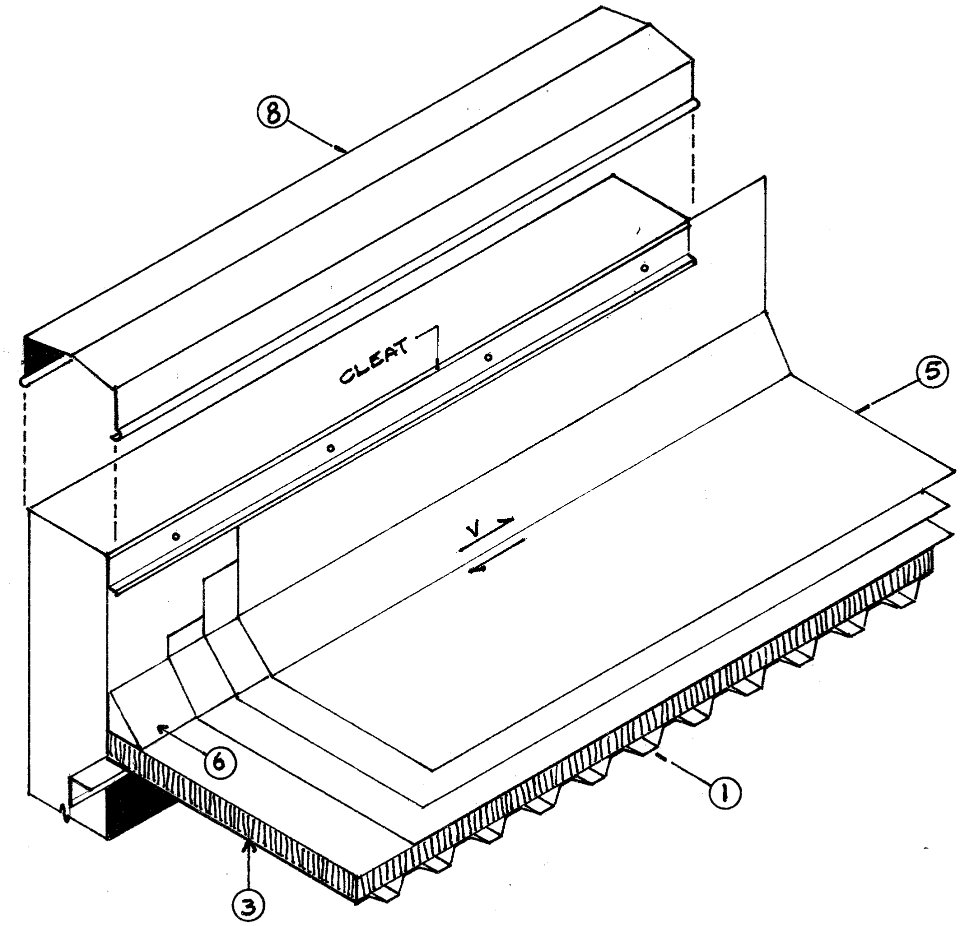
Figure 12.2 (c) also covers the roof vent which becomes necessary to relieve moisture vapor and help dissipate trapped humidity from within the thickness of the roof composite. It also shows in (d) the arrangement of a plumbing vent penetration by using a lead flange installed at the upper end of the vent pipe.

A key to the numbers shown in Figure 12.2 is shown immediately below:

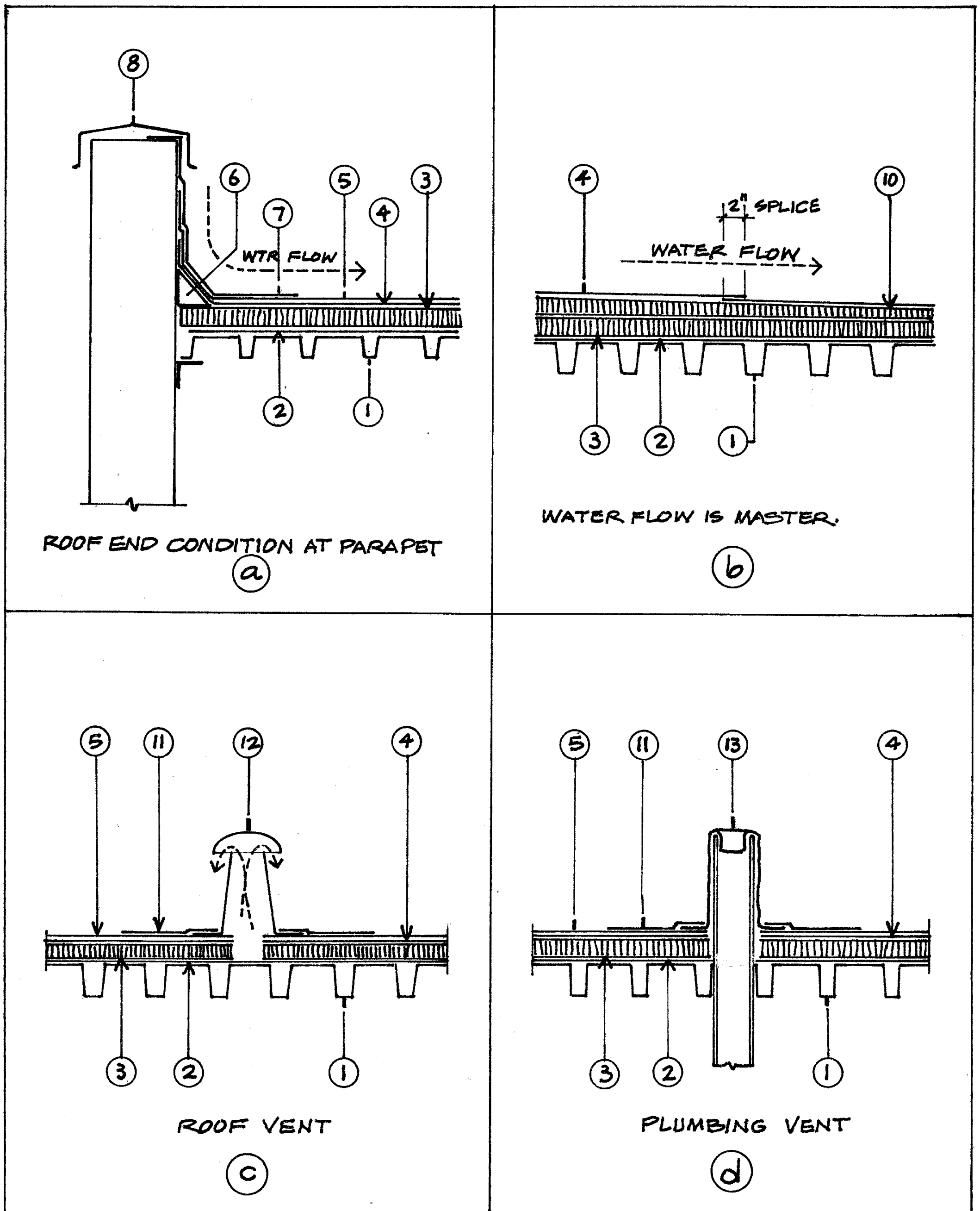
KEY TO NUMBERS

(1) Roof structure
(2) Underlayment/Vapor barrier
(3) Thermal insulation

(4) Bottom roofing sheet
(5) Upper roofing sheet
(6) Fire retarding cant strip
(7) Continuous fatigue strip
(8) Coping/rust resistant metal cap
(9) Premolded neoprene cover
(10) Wedged insulation (used as a slope filler)
(11) 24 x 24" piece of membrane material
(12) Roof vent



MODIFIED BITUMINOUS ROOFING
FIGURE 12.1



GENERAL ROOF DETAILS
FIGURE 12.2

13.0 UNORTHODOX ROOFING METHODS

The history books tell us that in the year 1492 Christopher Columbus and his heterogeneous crew of volunteers, after a long trip accidentally landed in one of the Caribbean islands. The beginning of their adventure was rough and unpredicted, but soon enough they overcame the odds. Eventually their achievements became known to the world and they awakened the greed of their king who gave them orders to colonize whatever places they found for his Spanish Kingdom and the Roman Catholic Church as well.

By the beginning of the 16th century, the Spaniards were engaged in building facilities for their people where they could stay well protected and with a sense of permanency. At the same time, they had no choice but to use whatever materials they could find locally, in doing so, they became familiar with an abundant variety of softwoods, such as white pine and spruce; hardwoods such as oak, ausubo, guayacan and mahogany; fibrous woods such as palm and coconut. They also found plenty of river and volcanic rocks and from the local Indians they learned how to make *caliche* (ground lime rock). In the final analysis, the chemical composition of that tan colored grainy material was nothing else but *Calcium Carbonate.*

The above mentioned Caliche was not only inexpensive but useful, versatile and abundant. This natural material when mixed with hydrated lime and water could produce a whiteout used as a *poor man's paint* for the embellishing of walls and ceilings. Further, when mixed with sand, gypsum and water they were able to produce a certain mortar used for binding the rocks together in a form of *rubble masonry*, or just as a plaster for finishing walls, vaults and arches, as well as for other construction uses.

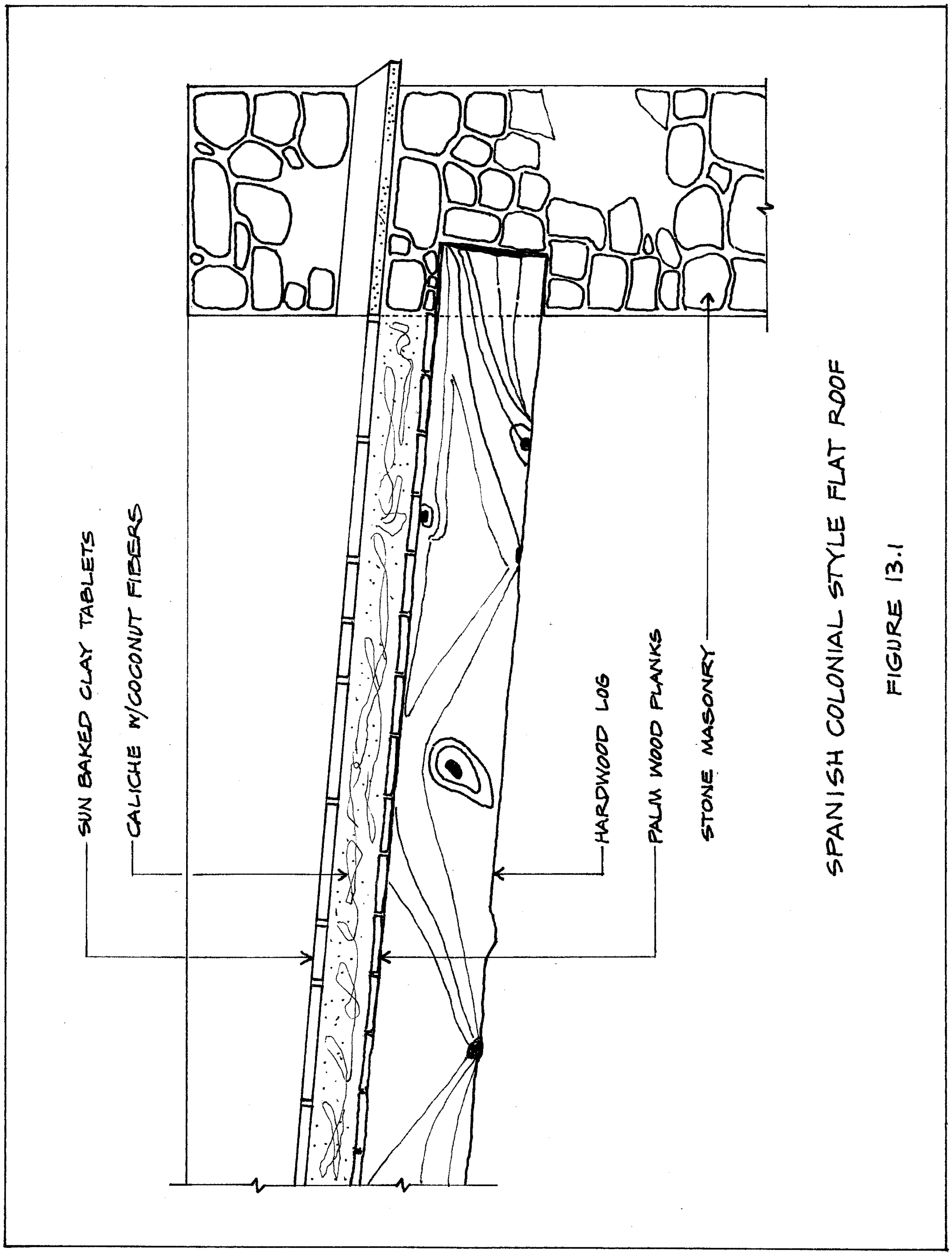
After familiarizing with all those materials they were able to use them in building and house construction. Figure 13.1 depicts a cross section illustrating how, by using such materials, they were able to put together walls and roofs as the basic elements to create structures suitable for long term human habitation.

As their methodology evolved for the next 400 years, from the 16th century through the 20th century, they improved their techniques while maintaining the same basic methods and principles. Figure 13.2 illustrates a reproduction of a certain roof built in 1906, and scores after, examined by this author in the year 2008.

The building in question was located (amongst hundreds of others) in the colonial area in the southeastern Santo Domingo, Dominican Republic. This building in particular had survived dozens of large and devastating hurricanes, amongst others, Hurricane St. Xenon in 1930 with estimated winds of 135 MPH, and Hurricane David in 1979 with measured sustained winds of 155 MPH and wind gusts nearing 175 MPH.

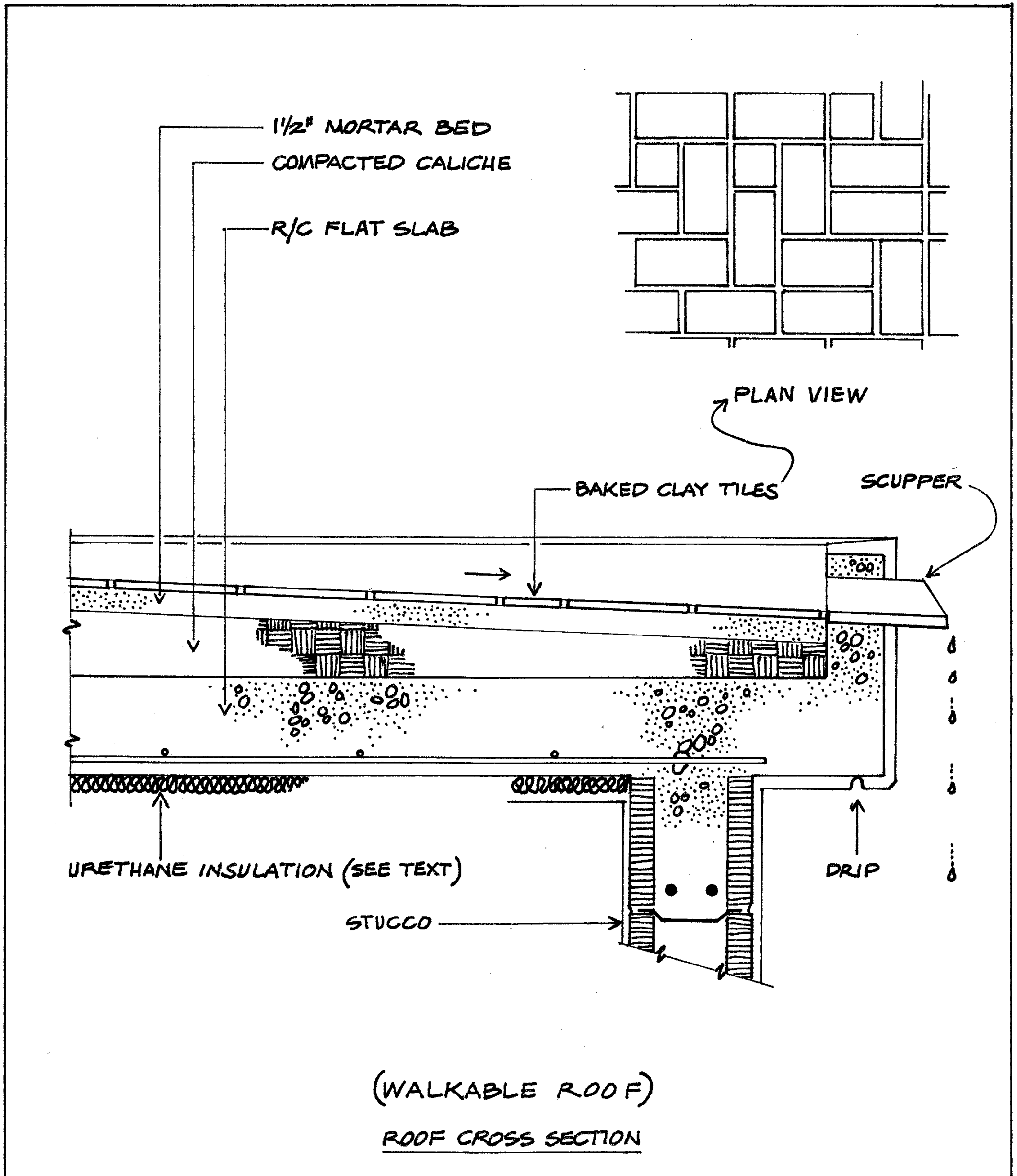
The roof structure consisted of a reinforced concrete slab topped and finished with the very same materials used by the colonizers: baked clay tiles set in mortar over a layer of compacted caliche, used to provide the roof slope as needed, as it has been shown in the same figure. The result was a reasonably impervious and walkable roof surface.

Although caliche is a conveniently inexpensive and plentiful material, however, it could easily add some weight of 45 to 50 PSF, thus becoming a burden in the slab design. Please notice that the author has taken the liberty of adding urethane insulation to the underside of the concrete slab as an interesting option, however, that added insulation was not part of the assembly as examined in Santo Domingo.



SPANISH COLONIAL STYLE FLAT ROOF

FIGURE 13.1



OLD SPANISH STYLE FLAT ROOF
FIGURE 13.2

14.0 EXPANSION JOINTS

Expansion joints are very sensitive areas in a roof since they experience a lot of movement back and forth and almost on continuous basis. In order to obtain a good long term performance from an expansion joint, it has to be well thought out, well detailed and well installed.

The approximate expansion in a concrete building can be calculated based on the following formula conceived on the assumption that the building can move freely:

$$\Delta_L = 3(\Delta_t \,.\, L \,.\, \delta)/100$$

Where:

Δ_L = Expansion (ft)
Δ_t = Temperature differential
L = Building length (ft)
δ = Coefficient of Expansion

Let us give that formula a try to determine its suitability. Assuming a temperature differential of 30 deg F, a building length of 100 ft. and the expansion coefficient for concrete taken as 0.00055:

$$\Delta_L = 3(0.00055 \times 30 \times 100)/100 = 0.0495 \text{ ft} = 0.594 \text{ in.}$$

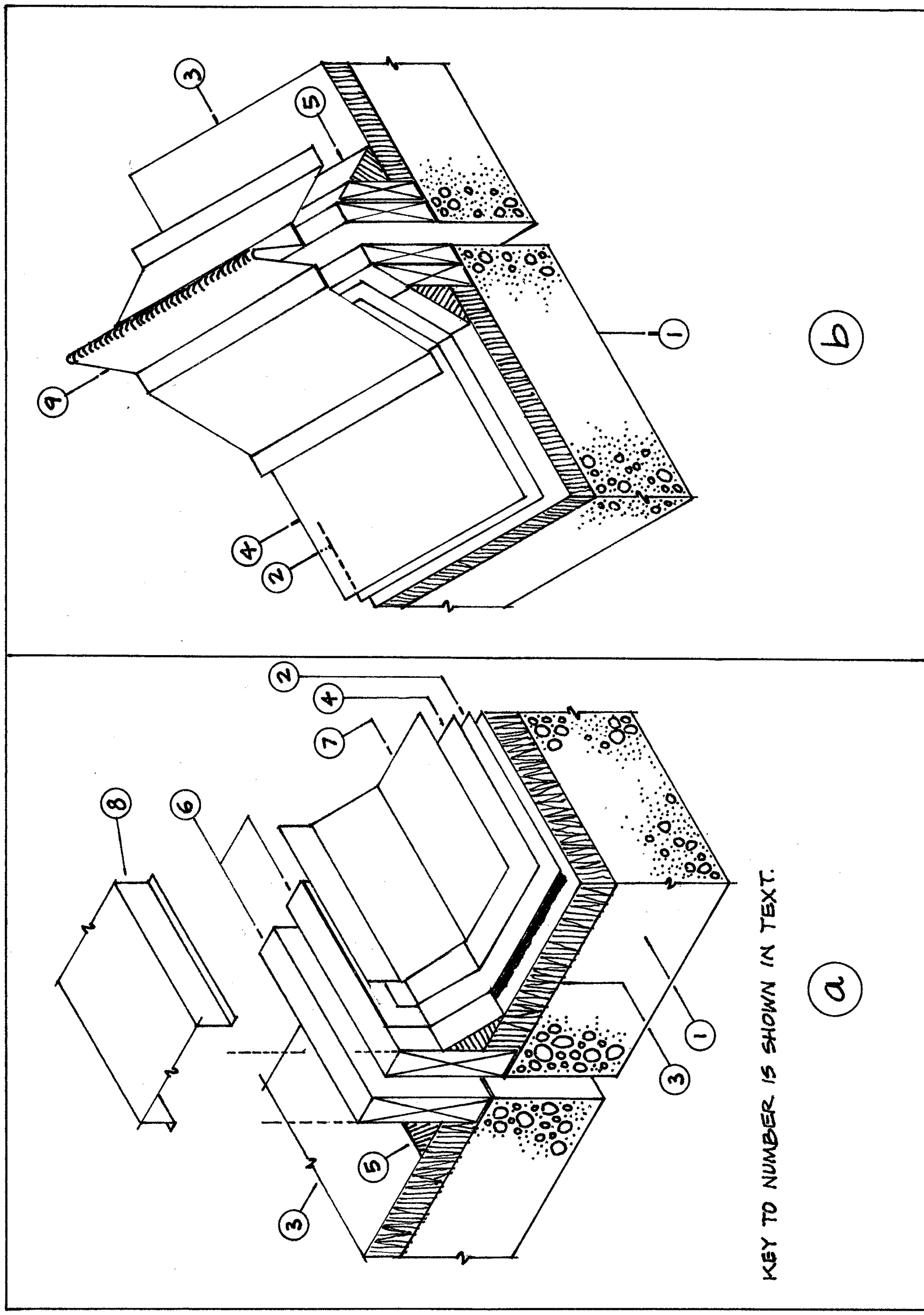
In addition of what it was said in the first paragraph above, the best expansion joint is one that is laid above the roof level, rather than leveled with all the rest of the roof components. Figure 14.1 depicts two details that we have used in the past with excellent short and long term results.

Both expansion joint solutions work in a similar fashion, but they are not identical and their use must be evaluated to fit the particular conditions of the application. In case (a) an additional 16 in. band of the modified membrane is placed on top (see key number 7), on both sides of the joint to help reduce the fatigue produced by the constant motion back and forth. This band has been omitted on the joint marked (b) because the flaps of the premolded joint cover are generally long enough to assume that role.

The joint cover marked (8) on joint (a) serves the purpose of covering the joint to avoid rainwater penetration in the joint, however, it needs to allow movement, and for that reason is only fastened on one side of the joint. Consequently, in case of hurricane winds this cover may be compromised and loose its function. In such case, the joint (b), which is fastened to both sides of the joint, would be better recommended. Naturally, that decision is left to the design engineer to make.

KEY TO NUMBERS

(1) Roof structure
(2) Base sheet
(3) Rigid insulation
(4) Top sheet
(5) Fire resistant cant strip
(6) Wood blocking (2" x 10" or larger)
(7) 16" or wider, continuous band of modified sheet
(8) Joint cover (rust resistant) designed for a particular wind speed
(9) Premolded neoprene joint cover.



TYPICAL EXPANSION JOINTS
FIGURE 14.1

CONCLUSION

In this Part II we have covered what some consider being the most intricate roofs to maintain and warranty: the flat roof, for the variables are hard to anticipate and control. After more than one-hundred years offering warranties and insuring flat roofs, both the roofing material supply manufacturers and the insurance companies have accumulated a slew of available statistics and experience on flat roofs.

Once one is stuck with a flat roof and has become aware of its common trail of aggravations which commonly starts with the first leak, the resulting apprehension is dual headed, when one asks himself: a) when will this leak re-appear?, and b) how long will this roof last?

The reasonable life expectation of a modified bituminous roof is dependent upon the following variables: quality of design, material quality, installer's ability, slope and maintenance program. One more variable that we keep separate from the others because it is an Act of Nature and that is the Weather. Assuming all those variables being equal, of good standard quality, and no extreme weather occurrence during such time, the expected durability should be in the twenty years range.

When it comes to the first leak, given the acceptability of all those conditions above, the probability of occurrence is almost entirely dependent on maintenance, slope and weather and should be expected to be about and within the period of 8-12 years.

On the other hand, the bituminous built-up roofing, again, all conditions being equal as indicated above, should have an expected durability of 12 years, and the first leak, even more heavily dependent on slope and weather, should be expected to be 3-5 years.

Needless to say that those time expectancies indicated above are only estimated averages with the normal probability deviations. However, they may be useful for depreciation and prorated residual value calculations. More accurate predictions could be achieved by using applied analysis on the case by case modality.

The following Part III of this course will be devoted to specialty roofs and speculative views and examples of what may be in store for the roof design of tomorrow.

APPENDIX

1- MAINTENANCE PROGRAM

The checklist is an important part of any maintenance program. It does not matter how experienced the roof inspector could be, everyone and anyone needs a checklist it does not matter what, because without it the inspector will tend to over concentrate in some areas and forget some others of equal or more importance. Therefore, a check list is a must to follow up on an adequate maintenance program, in addition, a checklist will provide a standard and uniform source of information by which all cases can be rated on the same basis and further, will allow a comparative analysis in a tabulated form.

INSPECTION CHECKLIST

BUILDING NAME & LOCATION: ____
____

DATE OF PREVIOUS INSPECTION: __________________

DATE OF CURRENT INSPECTION:___________________ TIME:_________________

NAME OF INSPECTOR:____________________________

RATING KEYS: A- Excellent Condition
B- Good Condition
C- Needs periodical monitoring
D- Retouching required
E- Needs light repair
F- Needs major repair

Item Description	Remarks	Date Repaired

I- Structural

A. Exterior Walls
1. General Appearance
2. Physical Damage
3. Settlement Cracks

4. Moisture Stains
5. Other________________

B. Interior Bearing Walls
1. General Appearance
2. Physical Damage
3. Settlement Cracks
4. Moisture Stains
5. Other________________

C. Underside of Deck
1. General Appearance
2. Physical Damage
3. Expansion/Contraction Cracks
4. Moisture Stains
5. Support Condition
6. Other________________

II. Roof Condition

A. General Appearance
1. Debris accumulation
2. Drainage
3. Physical Damage
4. Mechanical Equipment
5. Other________________

B. Roofing Surface
1. Bare Spots in Gravel
2. Coating degradation
3. Alligatoring
4. Overlap Slippage
5. Other________________

C. Membrane
1. Blistering
2. Splitting
3. Loose overlaps
4. Ridging
5. Fishmouthing
6. Punctures
7. Fasteners
8. Other_________________

III. Flashings

A. Base Flashings
1. Open Splices
2. Punctures
3. Rust/Decay
4. Detachment
5. Ridging/Wrinkles
6. Other___________________

B. Counter-flashings
1. Open Splices
2. Punctures
3. Rust/Decay
4. Detachment
5. Fasteners
6. Caulking
7. Other___________________

C. Copings
1. Open Splices
2. Punctures
3. Rust/Decay
4. Drainage
5. Fasteners
6. Caulking
7. Other__________________

D. Parapets/Walls
1. Spalling
2. Expansion Cracks
3. Mortar Joints
4. Other__________________

IV. Edgings/Fascias

1. Punctures
2. Backing Fasteners
3. Splitting
4. Rust/Decay
5. Detachment
6. Other___________________

V. Penetrations

A. Equipment Base Flashings

1. Open Laps
2. Punctures
3. Detachment
4. Other___________________

B. Vents
1. Detachments
2. Physical Damage
3. Rust/Decay
4. Drainage
5. Occlusions
6. Other____________________

VI. Expansion Joints

1. Open Splices
2. Punctures
3. Detachments
4. Rust/Decay
5. Fastener Failure
6. Other_____________________

VII. Pitch Pans

1. Filler Shrinkage
2. Drainage
3. Detachment
4. Other__________________

Notes:

____
____
____
____

Naturally, you could have the best checklist around and that would not be enough, for the work as called for on that checklist must be followed up and properly executed for it to be a worthwhile conclusion of the effort.

It is recommended that the inspections be performed every six months, in the Spring and the Fall, when the roofs are the driest and the most accessible. Additional inspections are also recommended immediately after any severe rain, wind and/or hail storm, but at the very least, a minimum of once every calendar year. The bottom line is:

early detection and speedy repairs are critical to the durability and good performance of any roof.

When it comes to doing the work that the checklist requires, large housing complexes, institutional facilities or industrial parks, generally have their own well organized maintenance departments. On the other hand, small housing developments or lesser condominium apartment buildings can get by with just having a reduced crew just to do small and emergency repair work, and then hire commercial providers to take care of the larger and more involved repair and renewal programs.

2- RECOMMENDED REPAIR PROCEDURES

The following repair procedures apply mostly to Modified Bituminous Roofing, however, some of the procedures could be used on other roof types, for as long as the difference in material applicability is kept in mind.

It is wise to watch for the right weather conditions before any repair procedure is put under way. Do not try any roof repairs in a rainy or snowy day or when the air temperature may be falling under 40°F.

SPLITS OR CRACKS THROUGH ROOFING MEMBRANE

Sweep the repair area clean and free of loose material. Before you attempt to repair a split or crack through the finished membrane, make sure to check on the condition of the insulation underneath. If it is dry, you may proceed with your procedure. If on the other hand, the insulation is wet, it must be opened up and allowed to dry for a given period of time, or to remove the wet part and have it replaced.

Apply generous amounts of *plastic cement* and install a precut piece of membrane. Use the torch to seal watertight all the laps around the repair area.

BLISTERS, BUCKLES & RIDGES

For as long as they are no cracked or punctured, it is better to leave them alone and place them under observation by raising a flag on the inspection report. If on the other hand, they show signs of ruptures, it means that rain water likely went through the roof, then, they must be cut and repaired in the same fashion as described above.

In most cases those conditions are surrounded by a wet roofing surface, in such instance the roof must be cleaned and dried up before any repair attempt is made.

OPEN ENDS OF LAP JOINTS

If there is stagnant water, dry up the area well and see if the moisture went in the open joint, check the insulation for wetness. When the conditions permit, reseal the joints by applying heat with your torch. If any rebellious spots are found, make a cut in the difficult area and apply a patch of fresh material, finish the job by applying heat to the patch.

TEARS OR SPLITS IN MEMBRANE FLASHINGS

Lateral splitting or tearing of membrane flashings is most commonly caused by one of three occurrences:

a) differential movements of the building structure,

b) temperature expansion and contraction, or

c) impact from flying objects.

Temporary repairs may be made by applying a high quality flashing cement reinforced with a fiberglass fabric mesh embedded in the patch. Make sure to extend the patch in at least 6 inches in every direction passed the damaged area.

OPEN JOINTS IN MEMBRANE FLASHING

Try applying heat with the torch first, if it does not work, apply a patch with minimum overlaps of 3 inches on each side.

MEMBRANE PUNCTURES

This damage is most often caused by foot traffic, but it may also be caused by flying objects impacting the roofing surface on windy days. If the heat from the torch does not solve the problem, then it is time to put in practice your patching work abilities.

PITCH PANS

We have repeatedly predicated against pitch pans, however, you may find them around in buildings where you would least expect. They are prone to leak and in most cases the water intrusion has to do with shrinkage or over drying of the tar filler.

Check the outside perimeter of the metal flashings for water intrusion, then remove all dried up tar from the pan and pour fresh material inside the pan up to about ¾ in. from the top edge.

EQUIPMENT MOUNTS

The most common pieces of equipment found on roofs are air conditioning condensing units. Most of the installations are made by the refrigeration technicians and they tend to do very poor work when it comes to the way they are installed on the roof, in addition after a certain age those units tend to produce a lot of vibration which cause membrane splits in the vicinity of the equipment mounts. In order to correct such conditions the roofer may have to do a very detailed work by placing them on curbs specially made for the case. That would also be a good opportunity to ask the air conditioning mechanic to change the worn out parts which are responsible for most of the vibration, and if necessary, to request that the units be placed on vibration isolators.

One more important warning about air conditioning condensing units mounted on the flat roof tops of hi-rise buildings. The design engineer should check the hurricane probability maps for the geographical area where his particular building is located. For hurricane areas subject to category II storms and higher, the condensing unit frames must be mechanically anchored to the roof structure, otherwise those units will be blown away by either lateral wind pressure or up-lift forces.

END