# REPAIR OF ROOFING MEMBRANE SYSTEMS

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Because there very often is confusion about the use of such terms as "repair," "replacement," "minor maintenance," and "major maintenance" for membrane roofing systems, we will begin by properly defining important terms. Three main categories corresponding to three distinctive aims will be discussed.

- **Minor Maintenance.** Minor maintenance is aimed at prolonging the service life of the membrane and does not entail any further action on the system itself. It is the owner's responsibility to oversee this work periodically (twice a year).
- **Major Maintenance.** Major maintenance consists of prolonging the service life of the membrane, often with the addition of other materials. It is the responsibility of a roofing contractor.
- **Repair.** The repair of the membrane system requires a complete overhead operation, capable of giving the roof covering a new lease on life. It may include mechanical support and thermal protection. It is the responsibility of a roofing contracting firm, which often relies on the expertise of a special consulting firm. This paper is concerned with repair.

## REPAIR OF MEMBRANES

Whether its purpose is residential, industrial or commercial, the roof of a building is a living product and it withstands much throughout the years:

- Natural climatic elements such as heat, rain, ultraviolet radiation, ozone, frost, snow, ice and wind.
- Outside environmental elements such as dust, fumes, vegetable debris, insects and birds.
- Natural elements connected with the internal life of the dwelling place such as vapor migration or thermal shock connected with built-up thermal insulation.
- Artificial elements connected with the building process such as cracking and puncturing.

There are many reasons why a roof covering may decay and age. Each instance presents a special case which calls for a preliminary investigation in person. This is called the diagnostic operation.

## VERIFICATIONS TO BE CARRIED OUT AT THE TIME OF REPAIR INSPECTION SURVEY FOR ROOFING MEMBRANES

The craftsmanship of the specialist rests upon his observation of the roofing and his assessment of the causes of its degradation. His observations must not limit themselves to the system membrane, but also must take into account the support, fittings, various joining elements, the environment, the way the roof has been used, its regular servicing, etc.

### Deck

The deck will have to be checked as a function of its nature.

### Concrete

There usually is no problem with concrete, but the possibility of a change in the dead weight or the addition of further load surcharge should be considered.

For example, the adding of a heavy aggregate layer to a granular surfaced system, or the transformation of a non-accessible roof to one where foot traffic will occur, would increase roof loads.

### Steel

If steel becomes corroded or its thickness has been calculated at its minimum value, then it may be insufficient if a supplementary dead weight is added.

### Wood

Generally, several kinds of wood are used as decks.

- **Board or roof plank:** usually its performance is good over time, and the repair of one unit is easy.
- **Particle board:** this assemblage of shavings or wood fibers holds together only if the gluing is of good quality. If the particle board is subject to water damage, a complete deterioration of the structural properties may take place with the danger of a collapse. Proceed very carefully with the examination if leaks have been observed over a long period of time.
- **Plywood board:** the gluing of the plies usually is insensitive to water, and the good performance of this process is observed over time.

For all lignocellulosic decks the inspection also will include the underside ventilation, which often does not work well because of an initially faulty design or a change brought about by the owner (i.e sealing of air inlets or outlets).

If new mechanical performance is required, the deck must be proven sound and able to perform its new functions. When it is light (steel, wood), designers must check feasibility by doing calculations which will take into account the new properties measured by the inspection.

The function of the building may have changed as well, and may involve a higher dead weight or a different load.

Finally, changes in the general use of the building may modify its behavior in the wind (for example, an open building changed into an enclosed building). Whatever the nature of the deck, the change of design of any surface add-on unit may alter its performance.

**Example one:** The removal of a heavy gravel surface, 4 to 6 centimeters thick, and its replacement by a mineral granule surface membrane will completely alter the action of the concrete plate. The mass (gravel) played the role of a thermal flywheel because of its inertia. The support was under little thermal fluctuation. The removal of this mass takes away this capacity.

**Example two:** The removal of a surface thermal insulating material deemed insufficient or defective and its replacement by an integrated thermal protection under the support (i.e., foam spraying) is going to subject a concrete plate or light element to violent thermal shocks, causing dimenstional changes often incompatible with the membrane. It also will bring about slow and progressive water vapor condensation in the support. This moisture penetration could cause problems with the new membrane, and eventually could lead to a deterioration of the deck by causing corrosion of the metal reinforcement or ribbed steel, and decay of wooden elements.

**Membrane System**

This heading includes the membrane, insulation and vapor retarder. These last two items will be included essentially because they are installed by the same contractor.

The vapor retarder must be considered of no use if the old thermal insulation and membranes have been removed. No localized repair can be carried out without rupturing the vapor retarder.

Thermal insulation materials include two cases:

**Case one:** The thermal insulation is used only as a substrate for the membrane without any requirement for special thermal performance (for example, an open storage space). The insulating material may be preserved if it is considered dry and sound after inspection.

**Case two:** The thermal insulating material is sound but is insufficient to fulfill new thermal comfort energy saving requirements. A new insulating material may be directly added on to the old one if its nature permits (as in the case of mineral wool or cellulose perlite). It will be necessary to check penetration heights to be able to construct the flashings acceptably, and past performance of the old insulation by establishing the possible changes in its dimensions (length, width, thickness).

The membrane inspection must first include an examination of the specification set up by the contractor and used during the roofing installation. This written document will let the inspector know the composition of the roofing system as it was intended to be installed. Next, checking of the membrane must be carried out by probing and sampling. Membrane materials will be analyzed in a specialized laboratory so as to identify the installed system and compare it with the system given in the specification. Membrane composition, including kind of reinforcement (organic felt, glass, jute, synthetic fibers) and type of bonding bitumen, also should be identified.

Finally, the change in properties in time should be measured. This phase has only one aim. It prepares the foundation for the new membrane.

The roof covering may either be made up of a membrane with an easily examined attached facing, or a *heavy aggregate-surfaced membrane* which is composed of loose or bound gravel in the case of a roof which has accessibility by pedestrians and cars.

It is difficult to examine the heavy aggregate-surfaced roof without removing this surfacing.

Two types of problems are established in the diagnostic operation.

**Type One:** Leaks within the building which allow the finding of the location of the leak.

**Type Two:** Apparent disorders on the membrane such as splits, seam openings, punctures and shrinkage.

Let us examine the two instances mentioned above.

**Attached Facing**

A membrane with an attached facing is covered either by a mineral aggregate surfacing (ceramic pellets or slate cladding), or a metallic surfacing (aluminum, copper, stainless steel, etc.). It is possible to record leaks, blisters between the plies of the membrane, small surface blisters, surface alligatoring, loss of the metal corrugation and loosening of the metal, and shrinkage of the felts in relation to each other. Experience lets us now connect some of the problems that have been observed to certain kinds of materials.

Small surface blisters are connected to manufactured materials using organic felt reinforcement or jute.

The more substantial air pocket has different causes, including the material, installation during wet weather, and lack of adhesion between plies. Air pockets may be systematic when an underlayer is reinforced with organic felt. This origin of the blister can be ascertained only after investigation.

Surface alligatoring corresponds to shrinkage of the reinforcement. It will be found on mineral granule surface materials reinforced with organic felt and jute. For jute, this alligatoring manifests itself in lengthy cracks parallel to the longest dimension. Organic felt exhibits shorter cracks, without any preferred direction. Glass-base materials are not subject to this phenomenon.

Loss of metal corrugation is the result of variation in the expansion coefficient between the surface protection and the binder. This has been brought out in the case of covering for "hot roofs" and was stabilized in 1964, thanks to the emergence in France of a special treatment (a corrugation resulting in expansion joints every 12 millimeters, and the addition of a special binder on the bottom of the corrugation). Shrinkage of felts recorded at the extremities of the largest dimension (which may go to 5 centimeters) is essentially connected with the kind of reinforcement (cellulosic), and will continue in the course of time. It is most important to be aware of it.

**Heavy Aggregate-Surfaced Membrane**

This membrane is covered with loose or adhered gravel for inaccessible roofs, and pavers for accessible roof plates. After pinpointing the location of possible leaks within the building, it will be necessary to find their origin on the surface of the system. After sweeping away or spudding the aggregate surfacing protection, or removing the pavers in one or two spots, the membrane will be first examined with the eye, then sampled for analysis in a laboratory. The flashings will be carefully examined for cracks, loosening or folds. Drains will be inspected for clogging, and expansion joints will be checked for cracks at the expansion section or at the connection with the membrane.

This diagnostic operation must permit the preparation of a file of all data capable of helping to choose the best solution for each roof. This will constitute the third section of this paper, along with a series of examples of solutions.

## EXAMPLES OF TYPES OF SOLUTIONS FOR RECONDITIONING

### Membrane With Attached Facing on an Industrial Roof

**Description of the Structure**

- **Building Use:** Storage space for spare parts
- **Deck System:** Metal framework with fluted sheet
- **Insulation/Membrane:** Cellulose wood fibers, thermal insulating material, 20 millimeters thick, and an effective cross-sectional area of 3 × 1.5 meters, eight-year old two-ply membrane consisting of asphalt and organic felt; top layer has a granule surfacing

**Description of Disorders**

- Many blisters between the first and second layers
- Shrinkage of two to three centimeters in the end of surface ply
- Appearance of a few cracks at the joint between insulating panels

The leaks have been located at the low points of the slope due to the water running in the flutes of the metal deck. Investigations carried out on the thermal insulant have shown traces of moisture and putrefaction.

**Repair Solution**

The removal of the membrane system all the way to the metal deck was not possible, since it was necessary to preserve the waterproofing of the storage space. The solution to this problem with the best reliability/cost ratio was:

- Adding new insulation, 25 millimeters thick and mechanically fastened (t/m), to the existing system complex (kept in place) after cutting out the blisters and leveling off the membrane surface. Mineral fiber insulation was chosen for thermal stability and fire resistance.
- Addition of a two-ply membrane consisting of a modified bitumen sheet with an adhered surfacing.

**Advantages**

- Keeping the roof out of the rain while work was going on
- Keeping the old membrane complex under a thermal barrier which prevents blisters growing in the old membrane
- Stress distribution of the seams of the large size former insulant over the more numerous seams of the new insulating material
- Making use of a surfaced membrane having elastomeric characteristics well adapted to cyclic movements of the insulation boards, including movements caused by thermal shocks and by vibrations of the sheet under the influence of the wind

### Membrane With an Adhered Facing on a Commercial Roof

**Description of the Structure**

- **Building Use:** Shopping center for food stores
- **Deck System:** Concrete framework with prefabricated slabs made of reinforced cellular concrete
- **Membrane System:** slope 4 percent; area 20,000 meters; 8-year old, two-ply membrane totally adhered to the primed deck; the first ply was glass; the second ply had a jute reinforcement; the top ply had adhered aluminum for surfacing

**Description of Problems**

- Generalized cracks in the tightness complex at the ends of the slabs
- Aluminum losing its corrugation and beginning to lose adhesion to the sheet, and a lengthening of this metal at the end of the felts
- Some blisters over the field of the roof in no given pattern, causing the loosening of the metal

**Reconditioning Solution**

The contractor did not wish to add on a supplementary layer of thermal insulation on the surface.

The removal of the existing membrane was an expensive and difficult solution. The problem brought to light the need to take into account the movement of the cellular concrete slabs, whether mechanical (end of slabs) or hygrothermal (vapor migration and condensation under the metal sheet). Attaching a new membrane to the existing one was impossible for two reasons: the lack of bonding between metal and asphalt, and the instability of this metal and of the jute reinforcement.

This procedure was followed: removal of the aluminum sheet (this was easy because of its weak bond to the asphalt), clean cutting of the membrane at the ends of the slabs, and making use of a material specially designed for reconditioning. This material is made of synthetic fiber nonwoven material of 0.2 kilograms per meter, non-impregnated with bitumen, faced on one side with an improved asphalt layer.

This reconditioning underlayer presents the following advantages: good mechanical characteristics (breaking, elongation, tearing, static resistance to puncture, etc.) thanks to the synthetic fiber material which was not impregnated with a binder. A resilient underlayer preventing transmission of the stress exerted on the support to the membrane. For example, this applies as well to the ends of the slabs. This repair underlayer will be laid dry on the former membrane, and installed mechanically on the cellular concrete slabs with special nails and distribution washers of 50-70 millimeters in diameter, with about a five density per meter. The seams can be temporarily closed with a torch, asphalt, or cold glue, forming a temporary tightness.

In the next step, the underlayer will be covered with a ply of modified elastomeric bitumen with surfacing.

### Membrane Leaving a Light Gravel Layer on Low-Sloped Roofing for Residential Buildings

**Description of the Structure**

- **Building Use:** Residential building
- **Deck System:** Concrete framework with deck also of concrete; Slope 1 percent; Area 5,000 square meters
- **Membrane System:** Three-ply bituminous membrane, adhered with bitumen on a thermal insulation consisting of perlite/cellulose, 30 millimeters thick, the reinforcements consisting of glass fibers and the membrane surfaced with small gravel
- **Age:** nine years

**Description of Disorders**

Splitting of the membrane at the joints of the insulation panels

**Repair Solutions**

The system is flat and does not have any blisters, but it was not possible to remove the protection because of its adherence to the asphalt on the last felt. Mechanical sweeping, suction or scraping of the small gravel are not sufficient to remove all of the protection. Adding a new membrane system directly on the old one cannot be done because of the gravel embedded in the asphalt. Adding a new insulating material with a mineral fiber base may be considered, but the solution is expensive, since new insulation is not always required. A specific material adapted to this particular case was designed. It is a material which combines technical practicality with low cost. It is based on the idea of a repair underlayer, but one which is tougher and made of a thicker nonwoven material (thickness 5 millimeters). This geotextile is adhered on a first membrane layer at the factory and is prepacked in rolls, like the membrane material.

At the job site, it is adhered using poured bitumen (the overlap of the sheets do not have the geotextile). The cohesive bonding strength of this geotextile underlayer must be higher than the strength of its bonding with adhesive asphalt.

**Advantages:**

- Possible to make use of a first membrane layer, perfectly molded to the old complex, even with some gravel on it. This layer protects the roof from the rain and reinforces the membrane system in its resistance to puncturing.
- Possible to have a layer for the diffusion of water vapor or gases, which could create pressure under the new membrane system panels or under any other support element on the new complex
- This geotextile underlayer may be adhered with asphalt to the existing system, nailed on wood and woodfiber supports or be kept loose-laid if a new heavy gravel ballast is used
- Possible to diffuse stress at the joints of insulation panels, wood-fiber panels, or any other support of the new membrane system

**Membrane With Heavy Gravel Surfacing On a Low-Sloped Roof of a Residential Building**

**Description of the Structure**

- **Building Use:** Residential building
- **Deck System:** Concrete framework with upper slab in reinforced concrete; Slope 1 percent; Area 1,000 meters
- **Membrane System:** 6-year-old three-ply membrane composed of organic felts placed on extruded polystyrene insulation board, 40 millimeters thick, and covered with a gravel surfacing 4 centimeters thick.

**Description of the Problem**

Splitting of the membrane at the joints and over the field of the insulation board sections

**Repair Solution**

The prompt treatment of splits after removal of the gravel surfacing would not help resolve the problem, because these cracks could not be pinpointed.

Two solutions were carefully studied because supplementary thermal insulation is required.

**Thermal Insulation Using an Inverted Roof Assembly**

**Advantages**

- Additional thermal insulation.
- Membrane protection against thermal fluctuations.
- Easy assembly.

**Disadvantages**

- Reduced insulating efficiency caused by water flow under the insulation board and the possibility of freezing between the seams.
- Vegetation growth between the joints caused by water stagnation under the insulant and accumulation of various seeds.
- Odors.

The principle of reversed roofing did not cancel out the need for consolidating the existing membrane system and adding on a new two-ply membrane, reinforced with a nonwoven polyester for one of the layers, with disconnecting layers between the membrane and the additional extruded polystyrene insulating material and a filtering synthetic fiber between this insulation and the loose gravel protection.

**Thermal Insulation Using a Conventional Roof Assembly**

The choice was glass fabric-faced polyurethane because of its insulating efficiency.

**Advantage**

- The insulating material may be kept dry while preserving all of its thermal protection properties

**Disadvantage**

- Higher cost at the time of the first investment

The two-ply membrane chosen consisted of a glass-reinforced modified bitumen and a ply reinforced with polyester. This reinforcement provides additional protection against punctures caused by gravel, or foot traffic on the gravel. The solution using an inversed roof assembly remains attractive but will be able to answer the problem completely only when the problem of water flow under the insulating material has been solved. While waiting for the answer, the inversed roof assembly can only be regarded as a palliative.

**Mineral-Surfaced Membrane on a Residential Building**

Type five is a special case. It concerns the principle of roofing renovation using an "in-situ" spraying of polyurethane foam, which is intended to supply both thermal insulation and waterproofing. It is an experiment which has been developed on every continent in countries with a hot and dry climate, so technical assessment is possible.

In France, this technique has been used in several cases of renovation, and the example now described is based on the technique mentioned above.

**Decription of the Structure**

- **Building Use:** Residential building
- **Deck System:** Concrete framework with upper slab made of reinforced concrete; Slope 1 percent; Area 1,000 square meters
- **Membrane System:** Multi-ply asphalt, protected with loose gravel surfacing and placed on perlite insulation, 30 millimeters thick

**Description of Problems**

Membrane splitting at the joints of panels, and a few punctures caused by stored materials on the roof during repair work on an annex building

**Reconditioning Solution**

The solution of spray-in-place polyurethane foam has been used because of the good insulation/cost ratio and because it kept the building waterproofed during installation.

The gravel surfacing was removed and the foam directly applied on the former membrane system, which was adhered to the existing insulation board in a manner deemed sufficiently sound. This foam was next covered with a protective coating made of acrylic resin, and the gravel protection was removed.

The foam was applied in several lifts, across the roof as well as at the flashings and penetrations. Two years later, when leaks were discovered, an examination of the roofing was made again and the following anomalies were recorded.

- Shrinkage had caused loss of adhesion at the flashings and penetrations
- Very uneven thickness of the sprayed foam
- Presence of gas pockets in this foam
- The acrylic protective coating was washed away from areas where water ponded

The observed defects which also occurred at other jobs were caused by several parameters, such as:

- Lack of worker training
- Incomplete examination of the old roofing and its support (polyurethane foam can only be applied to a stable and rigid support)
- Absence of paying attention to proper atmospheric conditions such as humidity and rain
- Lack of experience with the performance of the coating as protection for the foam

Professionals, aware of these defects, are presently setting up regulations concerning installation, which, hopefully, will prevent the repetition of these errors.

A repair solution using an unsatisfactory spraying of polyurethane foam may be covered with a new membrane system consisting of a loose-laid membrane to which has been added a gravel surfacing.

## CONCLUSION

Cost should not be the only consideration in deciding which roof repair method to utilize. A roof which is being repaired is a roof which has lived, and if a viable repair solution is to be found, the roof first must be studied by a specialist. Let us observe the effects of nature with wisdom. Let us take time to analyze the causes for an abnormal aging process before making any decisions.

Years under a comfortable roof are worth a few hours of our time.