ABSTRACT

The need to properly assess the condition of the roof system is critical from an environmental and monetary point of view. The visual and physical inspection of the roof is the first step in deciding whether to repair, replace or recover the system. This information is required to properly budget and manage resources. Additionally, it would help the environment by reducing the amount of material sent to landfills.

Every country has its own standards and all practitioners have their own approach to the assessment. This report attempts to provide a guideline for the assessment of low-slope roof systems. A flowchart for the assessment is presented. Use of this flowchart to carry out inspections should help minimize incorrect actions such as needlessly replacing roofs. Moreover, different test methods and standards are offered from various countries. This report is geared towards individuals who are involved in the roofing industry and who have a general understanding of condition assessment.

The flowchart, standards, and test procedures mentioned in this document are presented as a resource for reference purposes. All decisions as to the use of the flowchart, test methods and interpretation of any data are to be based on professional knowledge and expertise.

RÉSUMÉ

Le besoin d'évaluer correctement l'état des systèmes d'étanchéité des toitures est crucial du point de vue environnemental et monétaire. L'inspection visuelle et physique du toit est la première étape visant à décider s'il faut réparer, remplacer ou récupérer le système. Ces informations sont nécessaires pour fixer de manière appropriée le budget et les ressources de gestion. En outre, il serait bénéfique pour l'environnement de réduire la quantité de matériaux destinés à des centres d'enfouissement des déchets.

Chaque pays a ses propres normes et tous les praticiens ont leur propre approche vis-à-vis de cette évaluation. Ce rapport essaie de fournir des directives concernant l'évaluation des systèmes de toitures à faible pente. L'évaluation est ici présentée sous forme d'organigramme. L'utilisation de cet organigramme pour effectuer ces inspections devrait aider à minimiser les actions impropres telles que les toits de remplacement inutiles. De plus, différentes méthodes d'essai et normes sont proposées dans plusieurs pays. Ce rapport est préparé à l'attention des personnes qui sont impliquées dans l’industrie de la toiture et ont une compréhension générale de l’évaluation des conditions d’étanchéité.

L’organigramme, les normes et les procédures d’essais mentionnés dans ce rapport sont présentés comme documentation à des fins de référencement. Toutes les décisions concernant l’utilisation de l’organigramme, des méthodes d’essai et l’interprétation de toute donnée doivent être fondées sur la connaissance et l’expertise professionnelle.
1. BACKGROUND

1.1 Historic Committee activities

In 1983, a Joint Committee was formed under the auspices of RILEM and CIB to undertake studies of importance to the international roofing community. Of particular interest were the emergence of new membrane roof systems and the need for developing standards to aid in the selection and installation of systems that would provide reliable long-term performance. The initial RILEM 75-SLR/CIB W.83 Roofing Committee was entitled Technical Committee on Elastomeric, Thermoplastic, and Modified Bituminous Roofing Systems. It consisted of members from 18 nations from around the world. The Committee’s main objective was to undertake a state-of-the-art review of the properties and performance of these Roofing Systems along with a tabulation of the standards and specifications that had been developed worldwide to support their proper use. In 1988, this Committee issued its final report [1]. This report outlined the needs for development of performance standards for elastomeric, thermoplastic, and modified bituminous roofing systems. A major recommendation was that the international roofing community should investigate the use of thermoanalytical techniques for characterizing roofing membrane materials and evaluating their performance.

In 1989, RILEM 120-MRS/CIB W.83 on Membrane Roofing Systems was formed. This Committee was comprised of 40 members representing 22 countries worldwide. The Committee had two objectives:

1. to investigate the applicability of thermoanalytical techniques for evaluating roofing membrane materials, and
2. to review the current codes of practice in countries of the world.

Note that the first objective was in response to the recommendation of the initial RILEM/CIB Roofing Committee. To achieve these goals, the 1988 Joint Committee initiated two Task Groups -- with each focused on one of the two goals. In 1995, the Thermal Analysis Task Group issued its final report [2]. This report included the results of interlaboratory testing of EPDM, PVC, and APP and SBS modified bitumen membrane materials using three thermoanalytical methods: thermogravimetry (TG), dynamic mechanical analysis (DMA), and torsional pendulum analysis (TPA). Recommendations were made for developing standard procedures for applying these three analytical techniques to roofing membrane materials.

The Codes of Practice Task Group of the Joint RILEM 120-MRS/CIB W.83 Committee issued its report in 1996 [3]. The term, “Codes of Practice,” refers to written documents, which set forth requirements and/or guidelines for the design, application, and maintenance of membrane roof systems. These documents may or may not be mandated by law. The Codes of Practice Index was organized according to two categories: (1) agents and (2) requirements. “Agents” reflect the effects of climate, site, and occupancy on roof performance. “Requirements” reflect the expectations of building owners, occupants, and regulatory authorities, and relate to matters that effect safety, health, energy conservation, and the protection of people in and around buildings. The intent of the Index was to provide to those developing specifications and performance criteria for membrane roof systems an awareness of the design, application, and maintenance criteria that were in place worldwide. It was considered that the Index would be particularly useful to those whose countries had not developed such criteria for their roofing industry.

1.2 The current Committee

CIB W.83/RILEM 166-RMS Joint Committee on Roofing Materials and Systems was initiated in 1995, and has a core group of 21 members from 13 countries. This Joint Committee has two objectives: (1) to develop a methodology for assessing the condition of in-place (i.e., existing) flexible roofing membranes, and (2) to determine the state-of-the-art with regard to design, application, and maintenance of sustainable membrane roofing systems. These objectives were developed directly from the results of the previous Committee’s activities. For example, condition assessment of flexible membrane roof systems may involve, among other parameters, the use of thermal analysis techniques to characterize aged membranes. Additionally, a report on the design, application, and maintenance of sustainable membrane roofing systems was a natural extension of the work of the past Codes of Practice Task Group.

To meet the two objectives, the Committee initiated two task groups -- each of which conducted separate activities to meet the objectives. Task Group 1 focused on, and was entitled, "Condition Assessment of In-Place Membranes." Task Group 2 examined issues associated with sustainable roofing, and was entitled, “Towards Sustainable Roofing.” This latter title recognizes that the concept and practices of sustainable roofing will be evolving over the life of the Committee, if not well beyond.

Since its initiation in 1995, the Joint Committee has met six times:

- Brussels, Belgium; 14-15 May 1996,
- Haifa, Israel; 7-8 April 1997,
- Gaithersburg, Maryland USA; 14-16 April 1997,
- Copenhagen, Denmark; 7-9 June 1998,
- Vancouver, Canada; 3-4 June 1999,
- Florence, Italy; 2-3 October 2000, and

In addition to the activities of the Task Groups, the Committee was a co-sponsor of the Fourth International Symposium on Roofing Technology [4] that was held in Gaithersburg, Maryland, USA in 1997.

2. OBJECTIVE AND SCOPE OF THIS REPORT

The need to assess the condition of the roof system properly is critical from an environmental and monetary point of view. The visual and physical inspection of the roof is the first step in deciding whether to repair, replace or recover the system. This information is required to properly budget for various elements. Additionally, it would help the environment by reducing the amount of material sent to landfills.
Every country has its own standards and all practitioners have their own approach to the assessment. This report attempts to provide a guideline for the assessment of low-slope roof systems. A flowchart for the assessment is presented. Use of this flowchart to carry out inspections should help minimize inappropriate action, such as needlessly replacing roofs. Moreover, different test methods and standards are offered from various countries. This report is geared towards individuals who are involved in the roofing industry and who have a general understanding of condition assessment.

Committee members gathered information from their respective countries and the flowchart was developed based on the knowledge of the members. Obviously, other methods and approaches exist. The flowchart, standards, and test procedures mentioned in this document are presented as a resource for reference purposes. All decisions as to the use of the flowchart, test methods and interpretation of any data are to be based on professional knowledge and expertise.

3. INTRODUCTION

The envelope of a building is critical as it has both functional and aesthetic value. It must shelter its occupants from the effects of outside temperatures. It must allow them to stay warm in the winter, cool in the summer, dry when it rains and storms, and safe from wind and tornadoes.

One of the most important parts of any building envelope is the roof. The roof is the part of the building that is most exposed to outside conditions. But unfortunately, it is also the least exposed as far as visibility is concerned, and hence the part in which building owners generally try to invest as little as possible. The efforts to obtain optimal roof performance do not end once it has been constructed. Performance means the actual functioning of a building system or element in service, and is related to the fulfillment of the user’s requirements and the desired attributes of materials. Obviously, performance is considered the most important factor. Every roof cover, irrespective of the material or the manufacturer, must be capable, at a minimum, of doing the following:

- Remain waterproof.
- Withstand all weather factors (such as wind, rain, snow, hail, solar radiation, temperature extremes, and thermal shocks) during its intended service life.
- Resist various stresses from internal or external causes during manufacture, application and service.

Condition assessments and regular maintenance are essential to ensure that any roof will perform adequately for its expected service-life. Initiating timely remedial corrective actions will help maximize a roof's performance and its useful service life may be extended. Many roofs require replacement or extensive repair before the end of their design service life for a variety of reasons. Often, this is a result of mere neglect or failure to provide a minimum level of maintenance and care. Preventative maintenance must be recognized as a necessary component in the management of fixed assets. By implementing a carefully planned and comprehensive roof maintenance program, building owners can help to assure that they will receive the maximum return on their investment, and optimal roof performance.

Current economic and environmental conditions add stresses, such as low initial cost, and lower utilization of landfills and resources in general. This has forced organizations and individuals to do more with less and maximize the service lives of their fixed (capital) assets. As a result, preventative maintenance is being viewed as a practical tool in the effective management of assets through more planning. An important contributor for preventing a roof from failing is to inspect it visually twice per year and to perform non-destructive tests either when signs of problems appear or routinely every two to five years. If problems are detected early, prompt, effective action can be taken to extend the roof’s useful lifetime substantially.

Roofs represent a complex component of the larger building system, and are required to fulfill a variety of functions critical to the building's performance. Furthermore, most of today's roofing systems are an integral part in the control of the interior environment and are crucial to maintaining the comfort of the occupants and protection of the building contents. As roofs often represent a significant portion of the building's exterior surface area, and in the light of declining energy resources concurrent with escalating energy costs, their effect on energy consumption and environmental control is more important than ever. Consider the impact of a leaky roof on the efficiency of the thermal insulation and the increased load on heating and cooling equipment and the levels of fuel consumption.

Roofs, for the most part, have received very little attention from building owners and managers in terms of routine and preventative maintenance. Owners regularly enter long term agreements with respect to the maintenance of mechanical, electrical and other building systems and elements. However, roofs are largely ignored until they leak. Unfortunately, once leaks occur, they can signify extensive damage to the roofing system. If the response to, and elimination of the cause of the leakage is not immediate, moisture contamination of the components can promote rapid deterioration and result in premature replacement.

A roof, in many respects, can be considered a fixed asset. However, there are a number of important attributes of a roof that distinguish it from normal capital investments. First, it must be recognized that the satisfaction obtained from the roof investment is generally consumed over a very long time relative to other types of investment. Often, the life expectancy of roofs is expressed in terms of twenty years or more. Indeed, a cursory examination of promotional literature available regarding roofing products and materials will reveal that the theoretical life expectancy of commonly available roofing products far exceeds the normal twenty-year estimate. Secondly, roofs are subjected to the harshest influences of exposure to the exterior elements, over which the owner has little control. A roof cannot be switched off like a production machine when repairs or maintenance become necessary. Also, it is unlikely that a twenty-year roof life will be realized without proper maintenance.

It is clear that the roof of a building will have significant impact on the overall performance of a building. Its failure, or less than expected level of service, can result in serious adverse consequences on the value of the building, the cost of
operations and the comfort of the occupants. Given the importance of the roof as a component of any building, the implementation of a program of routine preventative and corrective maintenance can protect the roofing investment. This is achieved by ensuring full, uninterrupted service and obtaining financial benefits through extending its useful life.

All too often, building owners operate under the misconception that once a roof has been installed, no further action is required throughout its service life. This has been the result of the belief that warranties will provide remedy for any performance problems that may occur. Although the warranties offered by reputable manufacturers can be useful in protecting the building owner from loss due to defective materials and perhaps workmanship, the owner still has an obligation to properly maintain the roof. Almost all warranties available in the market today specify that they may be voided in the event of the failure to maintain the roof properly in accordance with the manufacturer's recommendations. The type of maintenance required is, of course, determined by the nature of the materials employed.

4. TERMINOLOGY USED IN THIS REPORT

Roof assembly: An assembly of interacting roof components (including structural roof deck) for weatherproofing and thermal insulation. Most low-slope roofing assemblies have five components: (1) deck (e.g., steel, wood, concrete, fibre and composite boards); (2) barrier (e.g., vapour barrier/retarder, air barrier, fire barrier); (3) insulation (e.g., extruded or expanded polystyrene, urethanes, polysiocyanurate, phenolics, cellulosic and mineral fibre); (4) membrane (e.g., BUR, EPDM, PVC, TPO, CSM, modified bituminous); and (5) attachment systems (e.g., spot fasteners, bar strap and anchors, adhesive, stone, heavy-weight pavers, light-weight interlocking pavers, ballast, concrete tiles with ship laps). Some assemblies also include interior finishes (below the deck) as a roofing component.

Roofing system: An assembly of interacting components designed to weatherproof, and normally to insulate, a building's top surface.

Repair: Re-active repair of problems after they have arisen.

Re-cover: Laying a new roof membrane over an entire roof, with or without removal of the old roof membrane.

Replacement: Complete removal of the old roofing system to roof deck level and replacement with a new roofing system.

Re-roofing: Includes both Roof Re-cover and Roof Replacement, but not Roof Repair. Re-roofing is a necessary part of building management and it should never be an isolated or unpredictable event. Re-roofing should occur after planned maintenance becomes ineffective or more expensive than the carrying cost of a new roof. A roof will last as long as the owner decides, and it will be re-roofed when the owner decides to re-roof his building. It may be appropriate to define some of the terms related to the performance of building materials or components in general.

Performance requirement is a qualitative statement describing what the system or element is to accomplish.

Performance criterion is a quantitative measure of the acceptable or adequate performance level.

Characterization method means a method for evaluating the compliance with performance criteria. The selection of a roof cover, like any other building component, must be based on its ability to meet the performance requirements for proper functioning throughout its life.

5. FLOWCHART

The flowchart is shown in Fig. 1. The first step consists of a general visual inspection of the building itself (inspect the wall, fascia, under roof, etc.). This is followed by a visual inspection of the roof system. At this stage, the roofing professional is looking for any signs of water leakage or extensive damage.

Pinpointing roof leaks is accomplished from the roof level. Experienced roofing contractor service crews are especially valuable when it comes to finding leaks. Non-destructive analysis such as infrared thermography, capacitance meters, neutron absorption gauges, or electronic leak detection methods can be employed.

Experience indicates that a great majority of roof leaks arise from poor flashing performance, through the ever-increasing number of roof penetrations. Leaks that only occur in winter are likely due to condensation within or below the roofing system. Roof leaks that only occur on warm days in winter may be due to ice damming causing water to back up, e.g., over poorly constructed roof flashings. Leaks that only occur when the wind is in a certain direction are usually related to poorly weatherproofed walls or roof-wall intersections.

Interior inspections are useful to locate the general area of roof leaks, and to verify that there is a roof leak as opposed to condensation or plumbing problems. Roof leaks over profiled steel deck can be misleading because the deck flutes act as gutters and water can flow a considerable distance before entering the interior. At least it is a one-dimensional search and a few drilled holes in deck flutes can usually help locate where the water is penetrating the air-vapour retarder.

If no leakage or damage is detected then regular maintenance is done. If minor leakage or local damage is observed then the repair is effected followed by routine maintenance.

If extensive leakage or damage is present and it is due to the failure of the roof system then one must determine if it is repairable. If the system is not repairable then the option is to re-cover or tear-off and replace. If the roof system is repairable then an emergency repair should be done to stop any further water ingress. At this point, if no remaining service-life assessment is required then a permanent repair and regular maintenance should be carried out.

The remaining service-life assessment would be performed if the roof is old or questionable (e.g., extensive damage) or if there are general concerns regarding the years of remaining service-life. During this assessment, samples are extracted and examined. The samples could be subjected to the tests listed in Table 1. If it is estimated that
less than two (2) years of service-life remains, then a plan (i.e., budget) should be put into place for replacing the roof system. A properly designed maintenance program is of great value in the budgeting process. Through a well functioning maintenance program, future replacement expenditures can be requested on an orderly basis by providing information about the condition of the roof.

When the roof system has finally reached the end of its service-life and is no longer economical to maintain, it can be scheduled for re-roofing or recovering, under conditions which best suit the owner. Good planning would allow this work to be done at a time where it will have least impact on operations, in the best possible weather and when prices are the most competitive.

* Note: 2 years is an approximate number
If it is estimated that more than two (2) years remains then one must consider whether or not a repair or upgrade is beneficial. If it would be beneficial and not too costly then the repair or upgrade is completed followed by regular maintenance. However, if either the repair or upgrade is too expensive then it would be best to complete the regular maintenance and plan for replacing the roof system.

6. PROTOCOL FOR REMAINING SERVICE LIFE ASSESSMENT

After roof leakage has been identified and emergency repairs have been made, it is necessary to determine if an assessment for remaining service life is needed. If the leakage was the result of an isolated anomaly such as a puncture caused by abuse, and the area of moisture within the roof system is small, then typically a service life assessment will not be necessary. Rather, the emergency repair can be replaced with an appropriate permanent repair. Prior to performing the permanent repair, a comprehensive visual inspection of the building and roof system should be conducted.

If the leakage was not caused by an isolated anomaly or if the area of moisture intrusion is not small, a service life assessment will be necessary. Rather, the emergency repair can be replaced with an appropriate permanent repair. Prior to performing the permanent repair, a comprehensive visual inspection of the building and roof system should be conducted.

If it is estimated that more than two (2) years remains then one must consider whether or not a repair or upgrade is beneficial. If it would be beneficial and not too costly then the repair or upgrade is completed followed by regular maintenance. However, if either the repair or upgrade is too expensive then it would be best to complete the regular maintenance and plan for replacing the roof system.

7. PROTOCOL FOR SERVICE LIFE ASSESSMENT

1. A comprehensive visual inspection of the building and roof system should be conducted. Confirm that the leakage was not caused by condensation or from infiltration from rooftop mechanical equipment or walls. Testing with water spray may be helpful in identifying water infiltration locations.

The following provide checklists that can be of assistance in evaluating existing roofs:


2. Test cuts should be taken down to the roof deck to determine system composition and condition. Fifty mm in diameter cuts can be taken with a roof-coring tool, or small cuts (about...
100 mm x 100 mm) can be made. At least one sample should be taken from each roof area where there is a possibility that a different system configuration or type occurs, or if different roof areas are believed to be of different ages. If the roof is still under warranty, obtain authorization from the warrantor before taking test cuts; otherwise, the warranty may be inadvertently voided.

3. Several large test cuts (600 mm x 600 mm minimum) should be taken to assess deck integrity in areas where there is wet insulation. The number of cuts will depend on several factors, including the deck type, roof size, leakage history and extent of wet insulation. Where possible the underside of the deck should also be evaluated.

4. Oftentimes the use of one or more nondestructive evaluation (NDE) techniques (e.g., electrical capacitance, infrared thermography, nuclear hydrogen detection) is extremely helpful in determining the extent of moisture accumulation within the roof system.

8. PERFORMANCE OF ROOFS

The performance of roofs is related to numerous variables concerning weather factors and stresses. Other variables are the chemical composition of materials, the quality control of the constituent materials and products during manufacture, storage, transportation, installation and, of course, maintenance. Most of these conditions vary from one situation to another, so that a large number of performance requirements and criteria are identifiable.

The performance of a membrane is often characterized by identifying the physical, chemical and mechanical properties essential for its performance and by quantifying them either arbitrarily on the basis of experience or by testing many products in the same generic class. Property values generated in this manner have constituted performance criteria for a specific class of products (e.g. BUR). These criteria may be projected with or without modifications to other generic types of membranes.

Table 1 lists the requirements for roofing membranes subjected to various stresses and strains in different stages of their life. Some of the requirements and common tests that are relevant to field performance are discussed here.

- **Tensile strength, elongation and strain energy and initial modulus.** These properties determine the ability of membranes to repeatedly withstand stresses imposed on them at joints and other places of concentrated movement as well as from shrinkage due to low temperature or membrane creep. The minimum strength requirement often applies to the weakest direction since some membranes exhibit anisotropic behaviour. Since strength and elongation properties can vary inversely, i.e., high strength membranes have low elongation and vice versa, the strain energy provides a better measure of the combined properties. Where cyclic loads are involved, as in the case of wind uplift pressure on mechanically fastened roofs, the modulus helps in the design of a fastening system for the load within elastic limits.

- **Lap joint integrity.** As prefabricated membranes have to be joined on site, the lap joint can be the weakest link because there is no continuity of the reinforcing medium. The lap joint strength and creep resistance are dependent upon the cohesive and adhesive characteristics of the joining matrix. Joint integrity is assessed by strength and creep testing in peel or shear. In addition, any voids left in the joint weaken its adhesive strength and reduce its creep resistance. Even if the strength is adequate, closely spaced voids can still promote water leakage.

- **Crack bridging ability.** Many shrinkage cracks are present in concrete roof decks. These cracks, which may be up to 3 mm wide, open and close cyclically with structural movements and thermal variations. A roofing membrane adhered to the substrate at those locations must be capable of bridging the gap. It is difficult for a well-adhered membrane to provide this capability because the percentage of elongation over the crack is very high. The crack-bridging test is applicable to both sheet and liquid-applied materials. For liquid-applied materials, this test is crucial; the results are related to the materials’ adhesion and elongation properties.

- **Tear resistance.** Initiation and propagation of a tear exists where an “oblique” stress occurs along the edges of the membrane, producing a torsional effect. This effect occurs due to an oblique pull during manufacture and construction. It occurs at the points of stress concentration along the edges due to structural movements and to pulls on the sheet during application. This property is important during installation with mechanical fasteners and where membranes support regular traffic, which could lead to mechanical damage.

- **UV resistance and heat aging.** Research and practical experience with the degradation of roofing membranes over a number of years have shown that UV and heat from the sun are among the most potent factors that affect durability. UV and heat-aging tests are intended to simulate the accelerated effects of solar heat that changes many properties. Generally, at present, the two effects are evaluated separately, but interactions between the two should also be considered. The results are compared with those of unexposed material to establish potential durability.

- **Granule embedment.** The exposure of bituminous surfaces to weather elements such as air, moisture, heat and ultraviolet (UV) radiation causes degradation of the bitumens that leads to cracking and loss of watertightness. Granules are embedded to help protect the bitumen. Embedment and adhesion of the protective granules or gravel is thus vital to the durability of the bituminous materials.

- **Static puncture resistance.** The puncture resistance test assesses the ability of a roofing membrane to resist any job-site damage caused by a rough or irregular substrate, traffic during construction or service, or a single human foot on a heated membrane during installation. High puncture resistance is needed for plaza decks.

- **Dynamic puncture resistance.** This is tested with a falling load with an indenter tip to determine if the membrane is damaged to such an extent as to lose waterproofness. It simulates impact from falling objects (e.g., a workman’s tool, hail, foot traffic).

- **Dimensional stability.** This important property estimates the dimensional change due to exposure to elevated temperatures, relaxation, loss of volatile components and incompatibility of materials. Dimensionally unstable materials can cause so much shrinkage as to pull the membrane off the flashing or to cause expansion resulting in wrinkles and subsequent failure due to cracking.

- **Permeability.** This property is related to the water vapour transmission (WVT) or permeation. When the substrate is wet
the membrane may not let water vapour pass through to dry out the other side. The rate of WVT is related to the vapour barrier in the system and affects the roof assembly design.

In general, the service life of a product is difficult to assess and measure. However, the above requirements must be quantified to establish performance criteria, thus allowing the user to evaluate a product. This leads to the development of test methods for evaluating materials that must meet the established criteria and satisfy certain requirements. These results indicate how the material should perform on the roof. In some products, there may be more than one grade. Since the criteria are generally more stringent for the higher grade, a longer service life may be expected.

Based on the above discussion, the committee members reviewed various properties used to characterize roof membranes in conjunction with condition assessment. The properties listed in Table 2 were found to be useful for all membranes. In discussing the relative importance of the various properties, the members developed a numerical ranking system (i.e., score) with the higher numbers being more often used in the member’s experience. The members also indicated that based on their experience the ranking order would possible vary for each membrane type (e.g., multi-ply vs. single ply). Also, they indicated tests performed to measure these properties would depend on a number of factors such as membrane type, reason for assessment and climate. The committee notes that a combination of tests is required to properly evaluate the membrane condition.

Regarding the testing methods for these properties, each standard writing organization of each country develops standard requirements, which will meet the environmental conditions and the preferred materials.

### 9. TO RE-ROOF OR NOT TO RE-ROOF

1. Generally, do not re-roof if the annual maintenance and repair costs do not exceed 5% of the cost of a new roof, and if minor roof leaks are tolerable. At 5% or below, it makes economic sense to maintain the roof. Maintenance costs for good roofs are typically 1 to 5% depending on roof size and labour costs. Costs can be higher in exceptional years, e.g., when roofs are resurfaced.

2. Do not entirely replace large roofs in a single operation unless absolutely warranted. Spread the work out, one area now, one area next year, etc. This usually minimizes disruptions of operations and evens out cash flow. It also provides a good way to assess whether the re-roofing was timely and to check whether the re-roofing schedule for other sections should be altered.

3. Do rigidly ensure that inspections and maintenance of the roof are carried out each spring and fall. The roof is out of sight and more visible items will take precedence unless roof maintenance is rigidly ensured. Simple cleaning of drains, recaulking flashings, etc., can prevent major future problems. The spring inspection catches problems that have arisen through the winter, and the fall inspection provides the opportunity to attend to the roof before winter commences (repairs in winter are difficult).

4. Do prepare a roof replacement plan when maintenance and repair costs exceed 6% a year. An odd year with maintenance and repair costs greater than 6% might be explainable. If such expenditures are made every year, the roof is near the end of it's useful life.

If re-roofing is the option then

a) Do employ the services of a reputable roof designer and a reputable roofing contractor. The roofing industry has its share of disreputable designers and contractors.

b) Do obtain a list of their recent projects and obtain references as to their quality of work. A half-day spent researching the reputations of designers and contractors via past projects is well spent. A poor design or poor application typically increases maintenance and repair costs and decreases the useful life of a roof by a factor of two. The combination of poor design and poor application can result in a disastrous roof.

c) Do not automatically take the lowest bid. Lowest bidders with good references are acceptable. As one quality roofing contractor said, "We only get jobs when we've made a mistake (in estimating)." Mindless acceptance of the lowest cost bid is a recipe for disaster. Many jurisdictions reject the high and low bids before making a selection.

d) Do comply with the building code, recommended good roofing practice, and any safety and insurance requirements. Compliance with the building code is a legal requirement, as is safety. Insurers may raise premiums if their requirements are not met, and good roofs result from good roofing practice. The building code and recommended good roofing practice are founded on years of experience and expertise.

e) Do re-roof in fine weather. With re-roofing, as opposed to new building, the owner has control over the roofing schedule. Surveys of roofing problems show that half of the problems that arise with roofing are attributable to workmanship. Successful application of roofing in inclement weather is difficult, and sometimes downright impossible.

<table>
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<tr>
<th>Property measured</th>
<th>Score</th>
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<tr>
<td>Lap joint integrity</td>
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<td>Elongation and tensile</td>
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I. Do not re-cover old roofs unless you are confident that all components left in place are in good condition. Remove many small areas of roof down to the deck, especially in areas where water entry has occurred. If any component of the roofing system (including the deck) is found to be unsound, increase the number of samples until you are confident that all unsound areas have been found. Repair or replace materials as necessary. Recent research has indicated that, under some conditions associated with the building environment, the design of the existing roof system, and its material properties, moisture trapped in a re-covered roof can dry inwards. Do not re-cover existing wet roofs with the intention that they will dry in an acceptable time period, unless it has been reliably determined that drying inward will occur.

II. Do remove and replace all membrane roof flashings. Flashings are a major source for water entry and they generally deteriorate faster than the membrane. The thickness increase of the re-covered roofing system normally requires new wood nails at roof edges to accommodate the new materials and to support counterflashings.

III. Do not adhere the new roofing membrane directly to the old roofing membrane. Always provide a separation layer. A fibrous board is preferred over a venting base sheet. Increased insulation should be considered. Mechanical fastening of the new insulations and/or the fibrous layer is preferred, as it does not rely on adhesion of the old roofing system. Slicing the old membrane prevents it acting as a secondary vapour retarder.

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REFERENCES

A1. BACKGROUND

An effective decision-support system is needed by asset managers to assist them in identifying optimal maintenance strategies that minimize life-cycle costs and risk of failure for a network of building systems and components. The development of such a system is the main objective of the Building Envelope Life Cycle Asset Management (BELCAM) project. BELCAM is a consortium co-founded by the National Research Council of Canada (NRC) and Public Works and Government Services Canada (PWGSC). The BELCAM project has identified two achievable goals that will assist asset managers in the course of their work:

1. To develop reliability-based methodologies to predict the performance and service life of building components;

2. To establish protocols to optimize the maintenance management of building systems.

The BELCAM project is initially concentrating on the life cycle maintenance management of low-slope roofs. The following synopsis describes the framework needed to collect and analyze data required to prioritize repair and replacement projects in a given roof portfolio.

The service life prediction techniques used in BELCAM rely on historical performance data, and condition information collected during inspections. This data is dependent upon several explanatory variables, including: age, environmental conditions, material type, quality of work executed as well as the amount and quality of maintenance.
A2. REGIONAL SURVEYS AND DATA COLLECTION

The development of the predictive framework to be used for the BELCAM project is based on historical performance data of roofing components and systems collected throughout Canada. The participating Canadian agencies in the BELCAM project are identified by the star symbol in Fig. 1. These sites represent a wide range of buildings in geographically diverse and hence, climatically different regions of the country. Each agency gathers information on roofs under their mandate and forwards the data for inclusion in a central database.

By gathering regional data, the project is generating performance profiles of sample roof sections that are representative of various climatic zones, construction techniques and maintenance practices and histories. Further data treatment will permit groupings relative to several explanatory variables. As additional performance data become available, the prediction model can be continuously improved using the Bayesian-updating method.

A3. STANDARDIZED DATA COLLECTION TOOLS

Following an evaluation of available roofing inspection and maintenance management software, “MicroROOFER vers.1.3” was chosen as the data acquisition software for the project. The software review examined four commercially-available packages relative to their ease of use, required minimum hardware configurations, operating platforms and database structure, their technical and reporting features as well as their ability to interface and link with other applications. MicroROOFER was considered to be the most comprehensive software package of the products studied, with respect to service life prediction.

The ROOFER methodology uses various quantified visual inspection indicators to determine a component condition rating for the roof flashing and membrane, whereas the condition rating of the insulation is determined from core sampling and evaluation of the percentage of wet insulation.

A review of existing data collection technologies lead to the expansion of the standard data collection framework to include the Fujitsu 1200 Stylistic™ pen-based computers running Microsoft Windows 95™ operating system. The utility of digital images was clearly recognized and, although not explicitly a component of the standardized data collection package, each agency participating in the regional survey is encouraged to use these visual recording techniques as part of their “survey kit”.

A4. ROOFING CONDITION ASSESSMENT INFORMATION REQUIREMENTS

An examination of the existing data fields of MicroROOFER and the BELCAM information requirements, relative to the identified explanatory variables, revealed numerous data gaps. In order to assure that adequate information was collected on all aspects of roofing performance (design and as-built conditions, material and workmanship quality, and condition of structural elements), additional requirements were mapped to appropriate storage locations within MicroROOFER. In all cases, the identified BELCAM protocol requirements can be recorded in existing “remarks” fields in MicroROOFER. The interaction between the explanatory variables, MicroROOFER data and BELCAM specific information is illustrated in Fig. 2. The Roofing Condition Assessment Survey (RCAS) methodology assists in obtaining consistent and easily interpreted information by detailing recommended methods of data collection and recording. A web-based On-line RCAS Manual provides a description of the MicroROOFER program requirements, as well as the data needed to fulfill requirements for the explanatory variable. An example of the recommended inspection procedures, rating scale and data input instructions for roof deck condition (as found in the on-line manual) is presented in Fig. 3.

Fig. 2 - Explanatory variable data requirements for BELCAM.
manuals, coupled with the pen-based systems and digital cameras, reduces learning time required to conduct inspections and minimizes the time between inspection and data entry. Over 500 roofs are being surveyed in the course of the project, with inspections recurring annually.

A5. INTEGRATION OF DECISION-MAKING TOOLS

As mentioned earlier, the main requirements of the BELCAM project are: (i) collection of in-field performance data (as described above); and (ii) development of performance and service life prediction models using these data. The improved performance prediction model will lead directly to the optimization of maintenance expenditures. The following steps are needed to accomplish these requirements:

1. Regional survey crews collect baseline building information, including drawings;

2. Crews collect electronic information on current condition using MicroROOFER, on-line RCAS Manuals and pen-based systems, including digital images of distresses;

3. Crews collect past maintenance information for individual roofs regarding repair actions and associated expenditures to assess life cycle costs and maintenance, repair and rehabilitation (MR&R) investment level;

4. New data are uploaded to a central server to update the probabilistic model and the MR&R and failure costs;

5. Operator queries the central database on issues regarding specific roofing components to establish the remaining service life;

6. The performance and service life data calculated above, in conjunction with risk and MR&R costs data, are used by the asset managers to optimize their maintenance expenditures using multi-objective and dynamic programming approaches.