EFFECTIVE ROOF MANAGEMENT – UNDERSTANDING THE LIFE CYCLE OF YOUR ROOF SYSTEMS

Effective Roof Management

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Durability of Building Materials and Components 8. (1999) *Edited by M.A. Lacasse and D.J. Vanier*. Institute for Research in Construction, Ottawa ON, K1A 0R6, Canada, pp. 1213-1222.

Abstract

Roof system management can be an effective tool for keeping track of selection, maintenance, and long term performance of roof systems. The National Roofing Contractors Association currently lists over 1,300 different roof membrane products and systems that are available to building Owners. On any large facility, it would ***not*** be unusual to find dozens of different types of roof systems in use. Each roof system has its own maintenance requirements and life cycle performance characteristics. This presentation is oriented toward reviewing available roof life cycle data and management systems, and suggesting some key elements that should be included in a roof management system. An effective roof management system can also utilize past performance, material properties, and life expectancy databases to sort through and select the optimal systems for the next re-roofing project. This presentation will review available life expectancy data for different types of roof systems, and summarize key factors that have a large influence on life expectancy. Much of the data presented is derived form actual surveys and life-cycle predictions from several commercially available roof management software packages, and published studies on expected service life for many different types of roof systems.

Keywords: roof system management, life cycle, maintenance, material properties, inspection systems, prioritization

1 The roofing industry

The National Roofing Contractors Association (NRCA) closely tracks trends in the roofing industry. NRCA's 1997-98 Market Survey [1] predicted a $21 billion market for roofing in the United States in 1998. About 75% of the $21 billion was projected to be in the replacement of existing roof systems. The NRCA also publishes the "Commercial Materials Low-Slope Guide" on an annual basis. The purpose of the guide is to maintain a list of currently available low slope roof systems. The guide lists roof membrane systems by type, insulation types by manufacturer, and available warranties. Roof membrane systems are listed under the following categories:

- Built-up roofing Membranes
- Modified Bitumens
- Single-Ply Roof Membranes
  - Vulcanized Elastomers
  - Nonvulcanized Elastomers
  - Thermoplastics
- Spray-applied Polyurethane Foam Roof Systems
- Metal Roof Panels

The 1998 edition of the low-slope guide lists over 1300 available roof systems for new and replacement roof systems. This represents a seven-fold increase over the number of membrane systems listed in the first edition of the guide in 1983. In the chart below, the first series represents the number of roof systems available (by type) in 1983. The second series represents the number of available systems (by type) as listed in the 1998 edition of the guide.

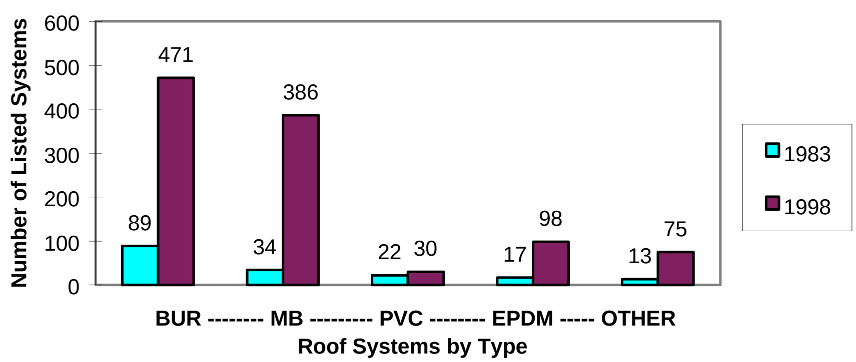


Fig. 1: Roof system availability – 1983 to 1998

Since the early 1990's the guide has been expanded to represent several new categories of roof systems that were not represented in 1983. Figure 1 does not include two of the guide's newest categories of roof system, spray applied polyurethane foam, and metal roof systems. The 1998 edition of the guide lists 131 spray applied polyurethane foam roof systems and 155 metal roof panel systems.

This tremendous rate of growth in the roofing industry has lead to the introduction of an unprecedented number of new products. The last 20 years in the roofing industry has been a time of new product development and implementation. Unfortunately, not all roof systems have passed the test of time. Along with significant growth, we have seen instances of product failure and inability of specific formulations of products to resist weathering. For example, some early formulations of unreinforced polyvinyl chloride (PVC) sheet material in loose-laid ballasted membranes were prone to shattering due to loss of plasticizer [2]. Degradation due to the exposure of chlorosulfonated polyethylene (CSPE) based single-ply roof membranes to ultraviolet (UV) has been documented [3]. Binder erosion in the CSPE membrane can lead to the development of cracking down to the level of the reinforcement, and the development of pinholes in the membrane.

Premature failure of roofing systems cannot always be attributed to product failure. C. W. Griffin, P.E., in the "Manual of Built-up Roof Systems" cites several causes of premature failure; the difficult environment in which a roof must perform, an abundance of new materials, complex roof system design, increasing roof dimensions, application issues, and trends toward more flexible buildings [4].

The issue of life expectancy of any given roof system is often debated and rarely agreed upon. We know that due to the forces of nature, a roof system will deteriorate. The stresses imposed on a roof system include thermal cycling, ultraviolet radiation, snow load, wind load, traffic, and a variety of other forces that vary by region. Each roof system will have a characteristic deterioration curve, such as the one shown in Figure 2.

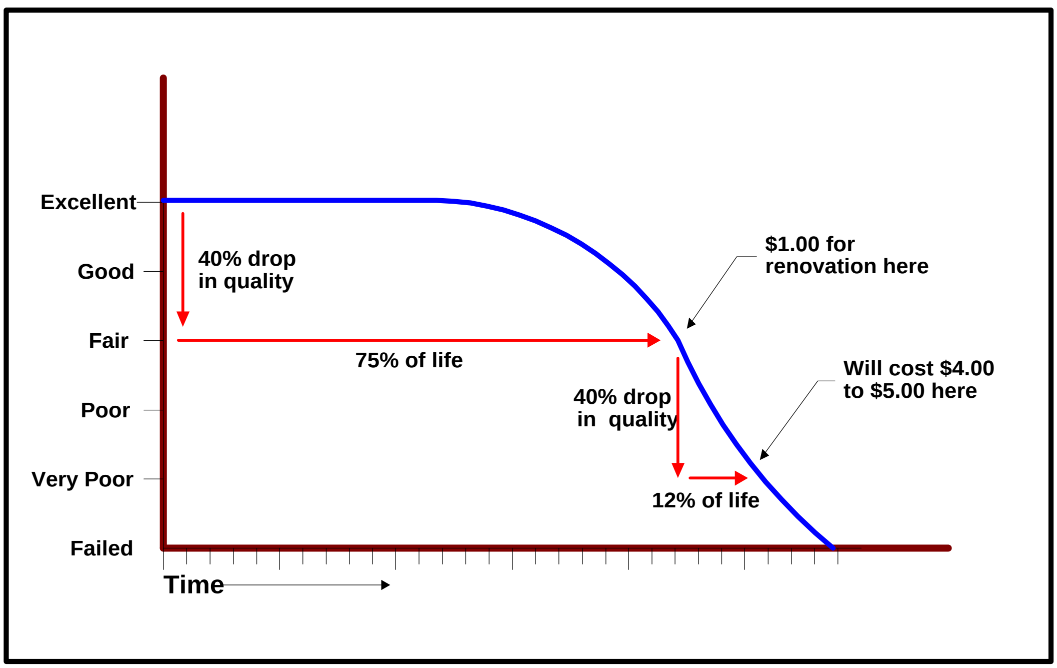


Fig. 2: Roof deterioration curve

Roof system failure is rarely a catastrophic event. The most common mode of failure is an increase in the occurrence of leaks. This is accompanied by an increase in the amount of annual maintenance dollars spent to maintain a roof in the last few years of its service life. In modeling the life cycle of a roof system, we generally assign a service life, then extend that service life by three to five years, assigning increasing annual maintenance costs during the extended period. This provides a more realistic economic forecast of true cost. The life cycle curve shown above is an illustration of the rapid decline in the condition of a roof system over the last few years of its life cycle.

2 Roof life cycle

With few exceptions, roofs fail over a period of time that usually lasts several years. As a roof nears the end of its life cycle, maintenance cost rises as owners respond to increasing instances of leaks. Failure of a roof system is usually defined as that time when replacement becomes necessary to protect the building. Until the past several years, there has been little published data regarding the life expectancy of a roof system. Factors such as the length of time required to conduct a study, and the dozens of variables that effect service life make life cycle prediction difficult.

In 1997, Cash [5] presented the results of a 1996 nationwide survey of durability, initial maintenance, and life cycle cost for frequently used low-slope roof systems. One of the results of the study is summarized in Table 1, Roof Life Cycle Costs. Cash notes in the study that durability is not represented by one value, rather a range of values. The mean durability of several roof systems is listed in the Table below.

Table. 1: Roof Life Cycle Costs for low-slope roof membrane (Cash (1997))

Membrane Type	Installed Cost $/ft^2	Disposal Cost $/ft^2	Mean Durability (Years)	Maintenance Cost $/(ft^2 x yr.)	Life Cycle Cost $/(ft^2 x yr.)
Coal tar-glass felt & pitch built-up	3.23	1.12	21.9	0.10	0.30
Asphalt-glass felt & asphalt built-up	2.28	0.81	16.7	0.12	0.31
Asphalt-glass felt & pitch built-up	2.87	1.07	17.7	0.09	0.31
Coal tar-organic felt & pitch built-up	2.97	1.10	23.0	0.14	0.32
EPDM (Rubber)	2.21	0.98	14.2	0.10	0.33
Asphalt-organic felt & asphalt built-up	2.27	0.86	14.7	0.12	0.33
SBS-Modified Bitumen	2.70	0.93	15.9	0.11	0.34
APP-Modified Bitumen	2.35	0.72	13.7	0.12	0.34
Polyvinyl Chloride (PVC)	2.54	0.84	13.8	0.11	0.36
Metal	4.94	1.27	25.0	0.11	0.36
Ethylene Propylene, Other	2.61	0.73	12.7	0.11	0.37
Reinforced Hypalon, CPE	2.69	0.75	12.8	0.11	0.38
Polyisobutylene (PIB)	2.76	0.76	10.6	0.09	0.42
Polyurethane Foam*	2.57	1.27	12.1	0.15	0.47

* Includes Insulation

Studies such as those by Cash have alluded to the fact that durability (life cycle) may be heavily dependent on heat aging (thermal load) of roof systems. Cash hypothesizes that roofs exposed to higher temperatures over their life cycle experience decreased durability over those that do not experience the same thermal loads. In other words, the mean time to failure decreases as the thermal load increases. Other factors which may have a significant effect on life cycle include slope, roof traffic, and maintenance.

Data presented by Kyle and Kalinger [6] at the Fourth International Symposium on Roofing Technology showed several examples of reductions in service life due to maintenance practices and roof traffic. In some cases, the reductions were over one-fourth of the service life between under-maintained roofs and highly maintained roofs. Reductions in service life of 18 to 20 percent were cited for heavily trafficked roofs versus those that sustained minimal roof traffic.

Most designers would recognize that roof slope plays a critical role in extending the service life of a roof system. However, there is very little published data available to compare roof system service life versus slope. Clearly, more study is needed to evaluate the effect of roof slope on service life.

Table 4 represents the results of a study of average roof life from a database of over 24,000 roof systems studied from 1982 to 1996. The study was conducted by Schneider and Keenan [7].

Table 2: Average life of roofing system by type (Schneider and Keenan (1997))

ROOF SYSTEM	1982 AVG LIFE	1994 AVG LIFE	1995 AVG LIFE	TO DATE AVG LIFE	TO DATE AVG LIFE
Asphalt BUR	13.3	13.6	13.6	13.6	13.64477
Coal Tar BUR	18.2	18.1	18.1	18.1	18.08732
Modified Bitumen	16.9	17.2	17.3	17.3	17.33041
Polyvinyl Chloride	9.1	9.4	9.4	9.5	9.48136
EPDM Adhered	17.7	17.9	17.9	17.9	17.94122
EPDM Ballasted	17.7	18.3	18.4	18.4	18.43481
EPDM Mech. Fast.	17.7	16.8	16.8	16.8	16.83660
Metal	17.9	22.4	22.4	22.4	22.44841
Shingles		12.2	12.2	12.2	12.23594

A comparison of the study by Cash to the study by Schneider & Keenan indicates that there is general agreement regarding the relative position of the service life of different types of roof systems in relation to each other. However, the service lives of several roof systems types is shorter in the Schneider & Keenan study, most notably in the case of built-up, PVC and metal roofing. The average service life of modified bitumen and EPDM roofs is longer in the Schneider & Keenan study.

The Schneider & Keenan study also appears to indicate that there has been no significant increase in service life for any of the roof systems in the study over the period of 1982 to 1995. This may be an indicator that although there may have been technological improvements in several of the newer types of roof systems since their first introduction, we have yet to see an increase in service life due to improved technology. Some data, such as that presented by Hoff [8] at the Fourth International Symposium on Roofing Technology, indicate that technological improvements in EPDM seaming, flashing, and application techniques have significantly reduced annual repair and maintenance expenditures on roofs constructed in the late 1980's as compared to those constructed in the early 1980's.

3 Managing roof systems

If a facility has more than four or five buildings, chances are there will be multiple types of roof systems present. In a campus setting of ten or more buildings, it would ***not*** be uncommon to have each major roof type represented in the inventory. Chances are also very good that at least one roof replacement is required in the next several years. The service life of a replacement roof system can vary from 10 to 25 years. At an average for removal and replacement of an existing roof system of $4.00 to $8.00 per square foot, the amount of money spent replacing roof systems can be significant. The expenditure of several hundred thousand dollars per year for roof replacement is not uncommon for large facilities.

Annual roof maintenance cost is also an important consideration. The level of roof maintenance has a significant impact on the annualized cost of installing and maintaining a roof system. The Cash data indicates that the average annual maintenance cost for the roofs reported in the study are typically one-third of the average annual life cycle cost. It has been the authors' observation that a lack of annual maintenance can lead to a shortening of expected service life. From a cost standpoint, the increase in annual life cycle cost for an under-maintained roof can far outweigh the cost savings from ***not*** performing the maintenance. The Kyle & Kalinger study presents data that supports the hypothesis that a well maintained roof may have a significantly increased service life over one that is poorly maintained.

With a significant amount of dollars at stake, it becomes cost effective to implement a roof management program. At the very least, roof system management can become an integral part of an overall facility management program.

4 Roof management systems

Many facilities are managed on a reactive basis where roof systems are concerned. When a roof leaks and becomes a constant drain on annual maintenance dollars, it is programmed for replacement. An effective roof management system can help quantify roofing assets, and program maintenance and replacement costs on an annual basis. A roof management program can help facility managers reduce annual maintenance cost. The savings is realized by programming the appropriate repairs at the right time in the life cycle, thus extending the life cycle curve shown in Figure 5.

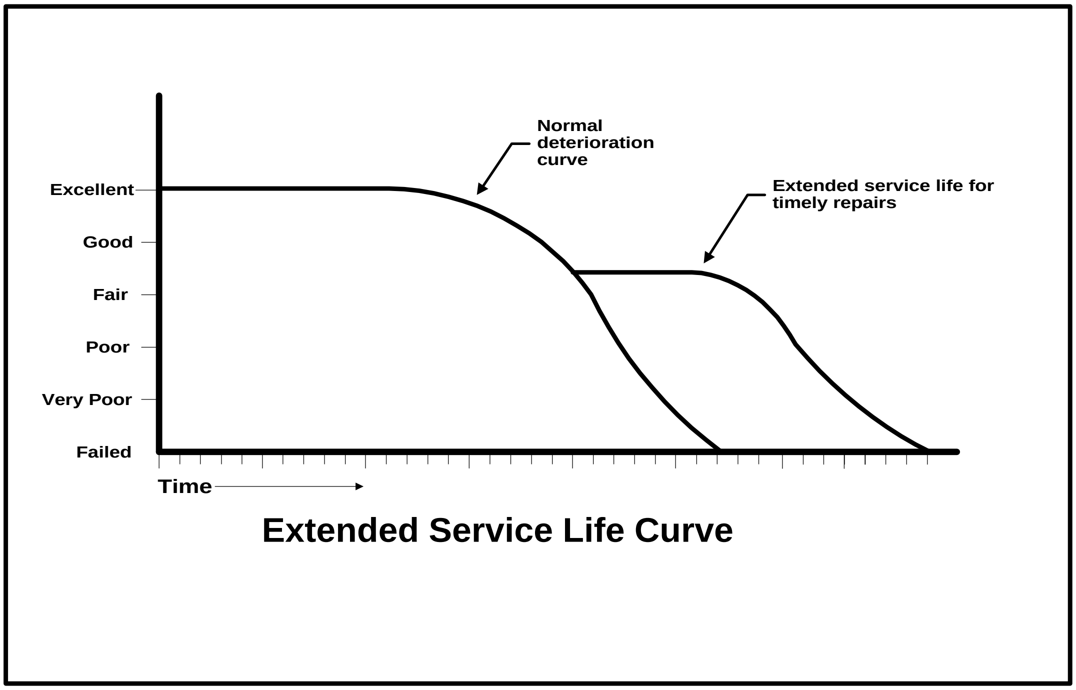


Fig. 5: Extension of life cycle

The first step in an effective roof management program is an accurate quantification of existing roof assets by periodic inspection. This includes gathering basic roof system information such as roof type, age, and maintenance history. This information can be entered into a simple database, or into a facility management program. More sophisticated roof management programs include quantification of roof defects and compilation of a roof rating. The rating can be used to compare to other roof systems in the database and help in the prioritization of repairs or replacement. The roof management system can also be linked to a construction repair and replacement cost database, to derive one-time or annualized repair costs. Several of the most detailed roof management programs include each of these elements, plus the ability to conduct life cycle cost analysis on various roof replacement options. A reasonable service life prediction can be made for each potential roof replacement type, and comparisons made to other types of roof systems. If the cost and potential service life is known, a reasonable life cycle cost analysis can be made. There are two critical elements in making this type of comparison worthwhile: (1) An accurate estimate of service life is made, and (2) Accurate replacement costs are used.

Unfortunately, there is very little empirical data regarding the expected service life of a given roof system. The data that is available in the industry is often proprietary to the interest of the manufacturer of the system, and varies widely within the industry.

The key elements of a roof management program include the following:

- An ***inspection system***
- A ***database*** to manage roof information and inspection data
- Repair and replacement ***cost data***
- Reasonable ***service life predictions*** for various roof systems
- ***Capability to prioritize*** repairs and replacements
- ***Reporting capabilities*** useful to the facility manager

Effective roof management can start with the implementation of a basic inspection system. This does not need to be a costly or time-consuming process. Collecting data on roof type, age, and general condition can be a useful first step.

The more sophisticated the management system, the more detailed the inspection information required. This information is input to a detailed database that makes retrieval and comparison to other roof systems of facilities easy. The most detailed management systems include cost data, service life prediction, prioritization, and reporting capabilities tailored to a Facility Manager's financial and capital needs programming requirements.

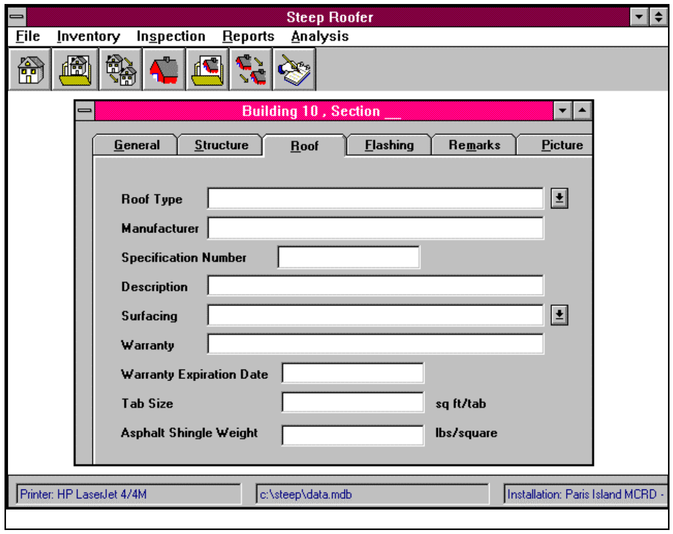
5 A roof management example

There are many commercially available roof management systems. Many are proprietary and can be costly to purchase or to implement. One of the most detailed and commonly used roof management tools is the U.S. Army Corps of Engineers ROOFER® Roof Management System (RMS). The basis of the ROOFER® RMS is the collection of detailed inspection information and development of a Roof Condition Index (RCI). The RCI is based on a sum of the quantity and density of defects found in a roof system. The RCI is derived as a composite of three separate indices developed for the roof membrane, flashing, and insulation.

The overall RCI is numerical value (from 0 to 100) which defines the roof condition. The numerical value can be used to compare to other roofs (to aid in prioritization), or can be used as a decision making tool as to when a roof requires replacement. The ROOFER® RMS has cost estimating capabilities for repairs or replacement. This allows for economic cost comparison of *repair vs. replacement* scenarios for any given roof, as well as comparison between roofs.

The ROOFER® RMS has been developed to include built-up, modified bitumen, and single-ply roof systems. One attractive feature of the ROOFER® RMS is that the cost of the system is extremely low since it was developed in the public domain. One drawback to the ROOFER® RMS is that since it utilizes detailed inspection information, the initial inspection cost may be significantly higher than other more basic systems.

Depending on facility type, it may also be useful to implement a roof management system on steep roofs. Steep roofs are generally those with slopes of at least two inches per foot, and include slate, tile, asphalt shingles, metal panels, and a variety of composite and man-made coverings. The following is an example of a data screen from a steep roof management program.



This program uses similar types of detailed roof inspection information as the ROOFER® RMS to develop a roof condition index. The implementation of these types of roof management programs can now be used for all of the major roof system types; built-up and modified bitumen roofs, single-ply roof coverings, and steep roof coverings.

6 Summary

Current roof life cycle data shows roof systems with effective service lives from about 10 to 25 years. Although there are many factors that influence life cycle, some of the more critical factors have been identified by research as heat aging, roof traffic, roof slope, and maintenance practices. Some of these factors have been shown to influence life cycle by reducing service life up to 25%. These factors should be considered in the design phase of new roof design, and in analyzing roof replacement alternatives. Clearly, more study is needed to analyze the effect of slope, maintenance practices, roof traffic, and the influence other factors on roof life cycle.

Regardless of the types of roof systems in the building inventory, few would argue against the cost savings features of an effective roof management system. Roof system management can be as simple and cost-effective as knowing the type, age, and area of each roof system on a campus or facility. This type of information is the least costly information to collect and maintain. It serves as the first step toward a more comprehensive and detailed management system.

The more detailed the inspection information and database management system, the more accurate the future maintenance and replacement cost predictions become. One of the benefits of a detailed roof management system is that an Owner can make better judgments as to which systems are working ***at their facility***. This leads to better decision making and longer service lives for each new or replacement roof system.

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