Roof Management Program for Multiple Systems

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INTRODUCTION

Roofing practitioners have long acknowledged that successful low-sloped roofing performance relies on a combination of four key elements; namely: sound design, suitable materials, good workmanship, and proper and timely maintenance.[1]

Historically, in spite of such acknowledgement, little attention has been paid to putting this tenet into practice, particularly with regard to maintenance. For example, almost 20 years ago, Firman chastised that, in general, the industry was geared toward new and reroof construction, with very little emphasis given to maintenance needs.[2] He further stated that owners were mainly responsible for this because they were not demanding an emphasis on maintenance. The result, in his opinion, was that owners contributed to most roof leaks due to lack of maintenance. Reasons for this attitude have not been explored, but these authors believe that it was associated with a shortsighted, outright unwillingness to allocate the funds necessary to perform the needed maintenance.

Fortunately, as time elapsed, many practitioners awoke to realize that the roof represents a sizeable investment that needs to be protected. They began to promote roof maintenance management programs as a formal mechanism for doing so. Bradford evidenced this shift in attitude clearly and succinctly in 1996 when he called the need for roof maintenance "indisputable."[3] To be sure, we can readily say in 2008 that widespread use of roof maintenance programs has been realized in the United States. Here we cite Bradford's 2004 writings that during the past several years, roofing contractors and roof consultants have seen substantial increases in requests for preventive maintenance services.[4] He also opines that almost everyone in the roofing business—from manufacturers to consultants to contractors of every size—has seemingly developed a program, system, or department to address owners' roof system maintenance needs. Today, any building owner in the U.S. can search the Internet for "roof maintenance management" and find Web sites for hundreds of firms that offer such services, ranging from limited inspections and repairs to full management.

The objective of a roof maintenance program is to extend the expected useful life (EUL) of a roof system.[5] The elements comprising such a program are periodic inspections, routine maintenance and repair, and correct application of quality roofing products.[6]

One of the first major organizations in the United States to adopt a formal roof maintenance management program was the U.S. Air Force (USAF).[7] Although controversial because of some of its requirements, a generally accepted feature of the USAF program was the assignment of a quantitative rating of the condition of a roof as determined through its inspection. In turn, the individual ratings for a number of roofs at a facility were used for ranking their relative conditions to establish priorities for completing necessary repairs.[8] Such prioritization is particularly important in the case of multibuilding complexes. Today, many maintenance programs incorporate roof-condition ranking systems for determining the allocation of maintenance funds.

In the United States, perhaps the most widely known maintenance management program is the ROOFER Program of the U.S. Army Corps of Engineers (USACOE).[9] This program, which incorporates relative ratings of roof condition among its many features, is not only used at Army facilities but also has been adopted by and adapted to the private sector. Such programs can be costly due to the amount of information needed to populate the database. Today's computer technology has aided in the development of maintenance programs, but at the same time, has increased the amount of information that is entered. The cost to obtain the data is sometimes the governing factor, exceeding the cost of the software itself.

This paper presents an overview of a newly developed roof maintenance management program for use on multibuilding complexes such as campuses, military bases, and office parks. Examples of its features are given from limited practical experiences in the field. The goals of this program are to prioritize roofs, train on-site personnel, and simplify the process. One key feature of this program–consistent with those developed, for example, by the USAF and the USACOE–is the inclusion of a quantitative ranking of a roof's conditions. Another key feature is the training of on-site personnel and the use of those trained personnel in conducting the inspections. Regarding this latter feature, we note with interest that Sinderman, in his article discussing roof maintenance management, quoted a U.S. consultant as saying that a lot of maintenance "is just having someone walk your roof who is competent, trained, and knows what to look for and how to evaluate repairs."[10]

ROOF PRIORITIZATION SCHEMA FACTORS

The foundation of the program presented here is the delineation of ten factors used in ranking the relative conditions of the roofs (entire buildings or roof sections at one building) inspected. These ten factors, referred to as the "Roof Prioritization Schema," are, in no particular order:

- **Age** (EUL of the existing roof system)
- **Importance factor** (use of the building under the roof area)
- **Susceptibility to damage** (roof traffic indicator)
- **Membrane condition** (existing membrane)
- **Flashing condition** (existing flashings)
- **Attachment** (type of attachment)
- **Slope and drainage** (slope to drains and general roof slope; size/amount of drains, gutters, scuppers, etc.; and function)
- **Constructability** (difficulty of repairs/replacements)
- **Leak history** (observed or reported leaks)
- **Durability** (existing membrane toughness)

These factors are scored on a relative scale of 1 to 10, based on a ranking system developed for this program. In general, a score of 1 for a factor is a poor rating, and a score of 10 is a good rating, except as noted in the descriptions that follow. The methodology behind the prioritization schema is to aid in development of recommendations and prioritization of maintenance needs and roof replacement scheduling. The documentation provided in AFI 32-1051[11] can serve as a primer for evaluations performed with these factors in mind. The technical basis for each of the factors in the ranking system is as follows:

Age Factor

While the age of a roof system may seem like a fair indicator by which to measure a roof's performance, not all systems age the same. Therefore, having a multibuilding complex with various different EPDM, single ply, gravel-surfaced built-up roof (GSBUR), metal, and other types of roof systems of varying ages presents the question, "How old is too old?" For the purpose of scoring on the basis of age, roofs are rated on the expected useful life of the existing membrane as compared to the current age. For example, the expected EUO of an EPDM membrane system is approximately 12-15 years;[12] therefore, a six-year-old roof would get a score of 5, while a one-year-old roof would result in a score of 9. A built-up roof has a EUL of about 25-30 years; therefore, a 12-year-old roof would receive a score of 5, while a 24-year-old roof would get a 1.

Based on the authors' experience, a minimal percentage of roofs fail extremely prematurely, within one to two years. Conversely, we have seen a similar minimal percentage of roofs fail after extremely long service lives of perhaps 30 years. The largest number of failures seen in practice tend to occur within one standard deviation of the average failure age. Using EPDM as an example and taking the average failure age to be 12 years with a three-year standard deviation, approximately 60% of EPDM roofs might be expected to fail within 9 to 15 years. Similar predictions based upon our experiences have been established for the other types of roofs. However, with the longer service lives of many roof types, the range of the statistical failure point (standard deviation) increases, resulting in larger ranges for the expected failures. *Table 1* summarizes the EULs of some typical roof systems based on the authors' field experiences and complemented by data from roofing literature.

Importance Factor

This ranking prioritizes roofs based upon the function of the building use or occupancy. That is, the level of importance is rated by how important the roof integrity is to the operation of the space below and how the occupants would be impacted by roofing damage or failure. For example, a building housing sensitive electronic gear would score a 1 (i.e., failure is worse here), while a building housing spare machine parts would score a 10 (i.e., failure results in little damage).

ROOFING SYSTEM	SURFACE TYPE	EUL*	SCORE FOR 10-YR-OLD ROOF
Built-up (3- or 4-ply)	Gravel	25-30 yrs	7 = ([30-10]/30) x 10
Modified bitumen (2-ply)	Granules	20-25 yrs	6 = ([25-10]/25) x 10
Single-ply (TPO, heat-welded PVC)	Unsurfaced/exposed membrane	15-20 yrs	5 = ([20-10]/20) x 10
Single-ply (EPDM, adhered)	Unsurfaced/exposed membrane	10-15 yrs	3 = ([15-10]/15) x 10
Metal (standing-seam)	Fluoropolymer paint	40 yrs	8 = ([40-10]/40) x 10

*Note: The EUL shown assumes a minimal roof slope of ¼ in per ft. Ranking Factor = ([Upper End of EUL-Age]/Upper End of EUL) x 10
Source: Author's experience, Cash[13], and Schneider[14]

Table 1 – Expected useful life (EUL) scoring.

			RELATIVE SCORE					
			FT		SC		ACCESS	
ROOF SYSTEM	SURFACING	TRAFFIC RESISTANCE	LOW	HIGH	LOW	HIGH	LOW	HIGH
Built-up (3- or 4-ply)	Gravel	High	10	8	10	8	10	8
	Smooth-surfaced	Moderate to high	9	6	9	6	9	6
Modified bitumen (2-ply)	Gravel	High	10	8	10	8	10	8
	Granular-surfaced	Moderate to high	9	7	9	7	9	7
	Smooth-surfaced	Moderate to high	9	6	9	6	9	6
Single-ply	Exposed membrane	Low to moderate	7	5	7	5	7	5
	Ballasted	Low to moderate	7	4	7	6	7	4
Metal	Fluoropolymer paint	Low to moderate	8	6	8	6	8	5
PMA	Ballasted	High	10	9	10	9	10	9

FT = Foot Traffic; SC = Surrounding Conditions; Access = Ability and/or need to access the roof.

Table 2 – Resistance to roof traffic.

Susceptibility to Damage

This factor addresses the probability of damage due to concerns such as foot traffic and surrounding conditions (overhanging trees, runways, taxiways, adjacent buildings, etc.). Are there multiple mechanical units on the roof that require access? Are there pavers or walkpads to protect the roof? Are traffic paths clearly identified? Each of these different types of traffic can cause undue stress on the roof system. *Table 2* is a general rating system of the resistance of a roof surface relative to roof traffic and a general guide to scoring roofs with respect to this factor. Note that the metal roof system is scored based on the possibility of paint scraping, denting of panels, the possibility of seams being bent, etc.

Membrane Condition

This is a subjective view of the membrane based on the inspection of each roof for defects. The number, type, and extent of defects are included in the rating. *Table 3* summarizes typical defects for roof systems.

A membrane in good condition could score "10," even if the membrane is 30 years old. A membrane in poor condition could receive "1," even if it were relatively new. The key in this factor is not to take extensive time to document each deficiency, but rather to use the general visual inspection to provide a relative magnitude of the defects. In our experience, with training, most facilities personnel can subjectively rate a membrane condition to a reasonable degree of consistency.

Flashing Condition

In general, the assessment of flashings is similar to the assessment of the membrane insofar as the number, type, and extent of defects are included in the rating. Two important concerns not associated with membranes but included in flashings are the vertical attachment method and the counterflashing. Vertical flashings should be attached with continuous terminations. Counterflashings should be provided. The lack of either of these may necessitate the assignment of a lower value in this category. Flashings that do not appear to be performing well are to be rated lower than those that appear to be watertight and performing well.

ROOF SYSTEM	TYPICAL DEFECTS
Built-up (3- or 4-ply)	Exposed felts, wind scour, blisters, asphalt migration (down slope), ply slippage (down slope), exposed embedded metal, inadequately filled pitch pockets, splits, or tears.
Modified bitumen (2-ply)	Open seams, inadequate bleedout, exposed bleedout, blisters, fishmouths, wrinkles, exposed reinforcing scrim, loss of granules, inadequately filled pitch pockets, punctures, tears, or splits.
Single-ply (heat-welded polymer)	Open-lap seams, short-lap seams, fishmouths, wrinkles, inadequately filled pitch pockets, punctures, tears, or splits.
Single-ply (adhered rubber)	Open-lap seams, short-lap seams, fishmouths, wrinkles, inadequately filled pitch pockets, punctures, tears, or splits.
Metal (standing-seam)	Open seams at standing seams, missing or backed-out fasteners, buckling of pans, scratches, dents, or corrosion.

Table 3 – Typical roof membrane defects.

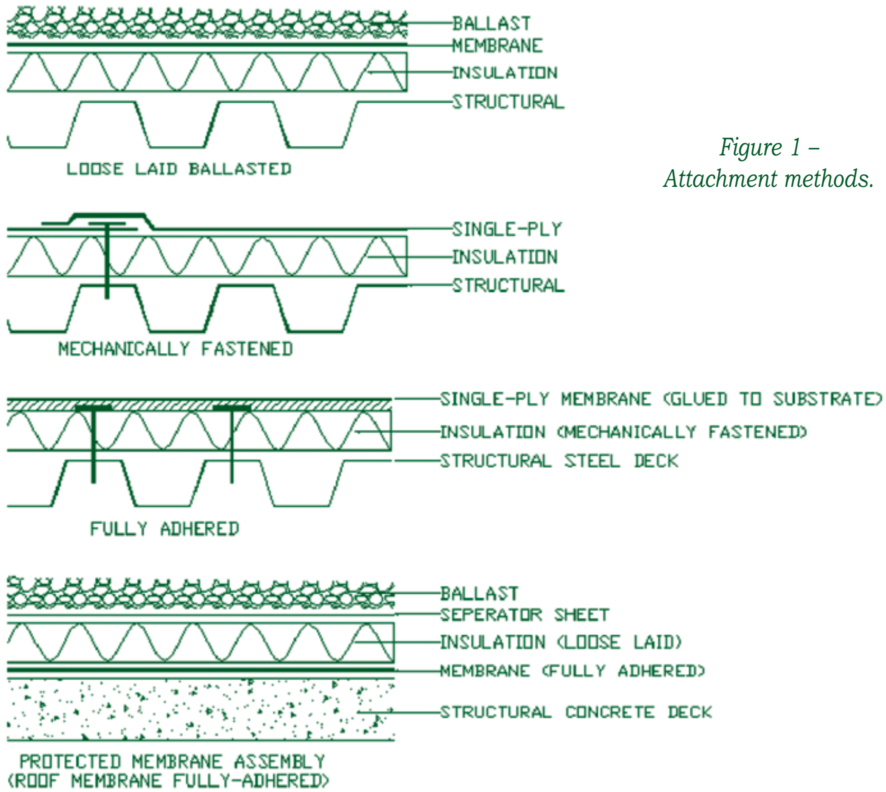

Figure 1 – Attachment methods.

Attachment

Attachment provides resistance to wind loads, and most design codes have very specific requirements for wind-uplift resistance. Attachment methods are at times compromised by force-fitting a particular attachment method to a roof deck that does not readily lend itself to the method. *Figure 1* shows the three most commonly used attachment methods. The fourth method shown, the protected membrane assembly, is a hybrid of the basic attachments in that while the membrane may or may not be fully adhered, the insulation clearly requires the ballast to keep it in place.

Deficiencies in attachment are a cause of roofing failures. Membrane blow-off causes failure of the weatherproofing system at the very least and can be accompanied by structural failure of the roof under certain circumstances.

Another example is failure of the attachments, causing failure of the waterproofing membrane. Examples include fasteners backing out through the membrane or fasteners penetrating the deck and causing condensation and water issues in the spaces below.

Either deficiency can have significant adverse effects on the long-term use of the existing roofing installation. Evaluating the appropriate attachment method for the specific type of deck and evaluating the condition of the attachment devices are critical to the long-term performance of the deck.

Attachment is evaluated by comparing an appropriately attached roof system with no apparent failures (score of 10) with an inadequately fastened but functional system (score of 5) with fastener backout puncturing the membrane (score of 1). Typically, fastener defects are difficult to detect in a surface visual review of the roof. For this reason, it becomes important that the personnel performing the rankings also perform review of the construction documents, looking for fastening requirements. He or she should also access the interior of the building to attempt to verify fastening type and pattern from the underside of the deck. In our experience, this factor is likely to be evaluated as either a 10, a 5, or a 1 by most assessors.

Slope and Drainage

Slope is an important factor in the proper function of a roof system. Adequate slope can compensate for inferior materials and construction quality; therefore, a roof with positive slope to drain (greater than ¼ in per ft) should receive a higher score than one with less slope. The waterproofing ability of the membrane is less likely to be compromised through draining of water quickly away from the roof surface. Roof drainage and slope are two distinctly different parameters. An adequately sloped roof can have inadequate drainage, and a flat roof deck can have adequate drainage. Inadequate drainage on a well-sloped roof can lead to slower water runoff, taxing the flashing systems and potentially leading to leaks. A relatively flat roof system can have adequate drainage, which becomes a requirement when designing protected membrane assemblies. Well-sloped roofs with minimal or no indications of ponding should score a 10, while no-slope roofs with extensive ponding should score a 1.

Drainage is an important factor in the proper functioning of a roof system. Drainage refers to the ability of the system to carry water away from the roof and the building. The building code usually dictates the minimum level of drainage required for a roof. Conventional design calls for at least four drains for larger roofs, a minimum of two drains for roofs under 10,000 square feet, and a maximum spacing of 75 feet in any direction for drains. Roofs that meet these criteria should receive a higher score; those not meeting the requirements should be scored lower. In addition, drainage covers the adequacy and function of the existing roof drains. Drains that are clogged, that inadequately carry water away from the roof and building, or that overflow during severe events, should be scored appropriately lower when drainage is evaluated. Those with good drainage adequate for the flow of water and well placed to divert water from the roof and building score a 10, while roofs with minimal drainage that retain water score a 1. Scoring within the slope and drainage category should be an average of the 1 to 10 recorded for slope and the 1 to 10 recorded for drainage.

Constructability

This factor is associated with the human element of postponing needed repair or renovation of failed roof systems only because they are difficult to access. In our experience with multibuilding complexes, the more difficult it is to reach a roof, the longer the replacement is avoided. To overcome this tendency toward procrastination, we rank relatively inaccessible roofs with lower values than those that are readily accessible. Constructability refers to the factors involved in maintaining or replacing a particular roof, taking into account building location, height, type, roof location and number, use, and occupancy. Roofs on taller buildings are more difficult to access than those on lower buildings. A building located in cramped conditions with inaccessible edges will be more difficult to replace. Roofs that can be easily and readily replaced or repaired due to their location, height, use, etc. should be scored at 10. Those that will be difficult to replace due to inaccessible locations or extensive restrictions should be scored at 1.

Leak History

Leak history can be quickly determined based upon interviews with building occupants or by visual inspection of the interiors. A roof that leaks extensively each time it rains scores a 1. A roof that never leaks would score a 10. Scores between 1 and 10 are based on a count of the number of leaks and a comparison of the total number of leaks at each building across the complex. It should be noted that the leaks need to be considered purely on number, not on what is damaged. Additionally, the determination of leak history scoring could be augmented with knowledge gained from nondestructive

ROOFING SYSTEM	SURFACE TYPE	RELATIVE DURABILITY	SCORE
Built-up (3- or 4-ply)	Gravel	High	10
Modified bitumen (2-ply)	Granules	Moderate to high	9
Single-ply (TPO, heat-welded PVC)	Unsurfaced/exposed membrane	Low to moderate	8
Single-ply (EPDM, adhered)	Unsurfaced/exposed membrane	Low to moderate	7
Metal (standing-seam)	Fluoropolymer paint	High	10

Table 4 – Durability scoring

evaluation (NDE) such as infrared or nuclear moisture scanning, if performed; however, NDE is not necessarily a requirement for completion of the ranking system.

Durability

Material durability refers to the roof's ability to resist weathering and natural or man-made impact without breaking down. Membrane type, thickness, and surface treatment have significant effects on system durability. The membrane and surface must have the capability to expand and contract to prevent splits and tears from extreme temperature changes. This capability must be present when a roof is constructed and remain at adequate levels throughout the EUL of the roof. Thus, in order for a system to perform adequately, it must have adequate material durability when it is constructed and not have a tendency to lose those characteristics as it ages.

For the most part, membrane materials today possess the material durability to resist weathering and building-related movement. However, some roofing materials may not be suitable for the climatic conditions of the site. A relatively thin, single-ply membrane that is suitable for the sunny, mostly dry climate of the southwestern United States is likely inadequate for a mid-Atlantic U.S. environment where large seasonal swings in temperature are experienced. A particular assembly that is used in environments where insulation is not needed or used may not be appropriate in a heavily insulated roof. Often, manufacturers have multiple products for numerous surfacing configurations. *Table 4* provides a summary of the authors' durability scoring methodology used in this prioritization schema. These scores are based on the authors' experience and relate similarly to the age-scoring EUL shown previously. It

BLDG. LETTER	AGE	CRIT.	MEM.	FLASH.	ATTACH.	SLOPE/ DRAINAGE	CONST.	LEAKS	SUSCEP.	DURA.
A	1	3	1	3	8	10	8	6	10	10
B	5	3	8	8	9	8	8	4	10	7
C	1	4	5	5	6	10	10	9	10	10
D	1	4	5	4	6	10	9	7	10	10

Note: Generic buildings considered to show how rankings would be tallied. Does not match those in *Table 6*.

Table 5 – Sample individual roof ranking scores

should be noted that scoring the age factor is based purely on the numerical age of the roof compared to its EUL, while scoring the durability factor is related more to the relative durability of one material to another.

USING THE FACTORS

Based upon the evaluations performed at a multibuilding complex in the northeastern-Atlantic region, each roof was given a ranking score in the categories as defined above. The scores were determined by minimally trained field personnel and compared to the opinions of two Registered Roof Consultants (RRCs) who had also accessed each roof. *Table 5* summarizes the scores for selected buildings at the complex to provide an idea of how the system works. *Table 6* summarizes the resultant scores for the selected roofs and ranks them in order of priority. It should be noted that the complex surveyed consisted of approximately 130 buildings, with a total gross building area of approximately 1.4 million sq ft. In this phase of the work, 30 buildings were surveyed, totaling approximately 512,000 sq ft in area, or an approximate 33% sampling.

Typically, scores below 60 would be considered a priority for replacement, while scores above 80 would indicate roofs that were recently installed or were in good condition. As can be seen from this ranking, the complex has many systems that score between 50 and 70, indicating a great need at the facility both for maintenance activities to keep the roofs from deteriorating further and for funding to begin to replace those with scores below 50, which indicates a system that is on the verge of failure.

SUMMARY

In summary, these ten items can be subjectively rated by minimally trained individuals to obtain a roof rating. This rating can then be tracked in a database to obtain information on the relative degradation of the roof, and from this information, projected deterioration rates and replacement time frames can be determined. In addition, the rating can be used to rank multiple roofs across one or more multibuilding complexes in order to more efficiently spend limited budgets.

KEYWORDS

Durability, Management Program, Prioritization, Roof.

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BUILDING NUMBER	ROOF SIZE	WHEN BUILT	ROOF TYPE	RANKING SCORE
1	107300	1988	EPDM	42
2	5640	1991	EPDM	44
3	5640	1991	EPDM	44
4	5640	1991	EPDM	45
5	5640	1991	EPDM	45
6	5640	1991	EPDM	48
7	5640	1991	EPDM	49
8	5640	1991	EPDM	49
9	5640	1991	EPDM	50
10	51400	1994	Hypalon	52
11	2350	1940	Metal	52
12	5640	1991	EPDM	53
13	2350	1940	Metal	53
14	2350	1940	Metal	53
15	2350	1940	Metal	53
16	2350	1940	Metal	53
17	5640	1991	EPDM	54
18	2350	1940	Metal	54
19	2350	1940	Metal	54
20	2350	1940	Metal	54
21	51400	1994	Hypalon	55
22	51400	1994	Hypalon	55
23	25185	1987	EPDM	56
24	2350	1940	Metal	56
25	2350	1940	Metal	56
26	51400	1994	Hypalon	58
27	14760	1994	EPDM	59
28	6550	1978	Built-up	60
29	51400	1994	Hypalon	63
30	8515	1979	Built-up	66
31	10270	1956	Built-up	70
32	2680	2002	EPDM	70

NEEDS REPLACEMENT (buildings 1–10)
WATCH LIST (buildings 11–27)
FAIR CONDITION (buildings 28–32)

Table 6 – Roof prioritization.

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Walter Rossiter retired in 2006 from the National Institute of Standards and Technology, where he was a research chemist with the Building and Fire Research Laboratory with over 35 years experience in the performance of organic building materials. In this position, he directed numerous studies on the characterization and performance of roofing materials and systems. Walt joined RCI, Inc. in 2007 as its director of technical services. He is a past chairman of ASTM Committee D08 on Roofing and Waterproofing, and past chairman of the Joint International CIB/RILEM Committee on Membrane Roofing Systems.