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ROOFER: A Management Tool For Maintaining Built-Up Roofs

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FOREWORD

This article is reprinted with permission from the Proceedings of the 9th Conference on Roofing Technology, "Putting Roofing Technology to Work," May 4-5, 1989, Gaithersburg, Maryland.

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ROOFER: A MANAGEMENT TOOL FOR MAINTAINING BUILT-UP ROOFS

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The U.S. armed services have a very large inventory of buildings with bituminous built-up roof membranes. Millions of dollars are being spent annually to repair or replace these roofs. In the past this has been done using inconsistent management schemes. There was a need for a systematic procedure to evaluate these roofs, to determine priorities and to select repair strategies that would insure the maximum return on investment.

To respond to this need, the U.S. Army Construction Engineering Research Laboratory (USA-CERL), with the assistance of the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) and the U.S. Army Engineering and Housing Support Center (USAEHSC), is developing ROOFER, a roofing maintenance management system for built-up roofs. This work has been a team effort involving roofing experts from industry as well as from other branches of the military in an "on the roof" dynamic process involving more than 50 buildings at seven locations.[1] ROOFER provides building managers with a practical decision-making procedure that will identify problem roofs and select maintenance and repair strategies for roofs with bituminous membranes.

ROOFER comprises procedures for dividing the building roof into manageable sections, collecting and managing inventory information, inspection and condition evaluation, network management and project management. It utilizes many of the highly successful concepts developed by USA-CERL for the PAVER pavement maintenance management system.[2,3]

NETWORK vs. PROJECT

Network management is defined as the process of making decisions regarding the management of a group of roof sections, such as all roof sections on a military installation or all roof sections on a specific building type such as barracks. Project management is the process of making decisions regarding the maintenance and repair of individual roof sections. When there are just a few roofs to manage, they can be kept track of on a project basis. When there are hundreds or thousands of roofs to manage, initial decisions should not be made on a project-by-project basis but on a network basis. ROOFER provides the tool for network decisions as well as the information needed to initiate projects. Network-level management includes managing all of the roofs on an installation, in a geographic area or even service-wide. Management decisions are made in a general way and do not require the same amount of information that a project-level decision requires. What is needed is a way of comparing the condition of all of the roofs in the network using a consistent evaluation technique. Network-level information is used to develop a rational means of repairing or replacing problem roofs within the network to meet specific performance levels. Short- and long-term plans can be developed that will respond to actual or anticipated needs rather than employing crisis management or spending money on roofs in less need than others.

DIVIDING A ROOF INTO SECTIONS

Building roofs are divided into identifiable sections in order to increase management efficiency. Managing roofs at the section level provides a better means of evaluating condition and determining maintenance and repair needs. For example: A roof section that is in poor condition will not detract from the condition of a roof section in good condition on the same building, and conditions indicating replacement of one section would not necessarily indicate replacement of the entire building roof.

Roof sections are generally delineated by firewalls, expansion joints or area dividers. Areas having different roofing systems, different amounts of roof traffic and/or rooftop equipment or significantly different occupancies below the roof are designated into separate sections.

INVENTORY AND DATA MANAGEMENT

The roof inventory is the foundation of ROOFER. It provides the information needed by engineering personnel to select repair techniques and to determine the suitability of replacement systems. A well maintained inventory will provide a history of each roof section and a record of roof performance that can be used to determine which built-up roof systems are the most suitable for use on a particular building type or occupancy.

For each building, general information concerning building name, number, location and occupancy are collected. A building roof plan is developed that shows overall dimensions and identifies each roof section. This information, along with contract drawings, specifications, submittals and as-built drawings, is also collected and stored in a building folder.

For each roof section, data are collected on the type of structural frame, deck, vapor retarder, insulation, membrane and flashing. Worksheets with checklists are used to ensure uniformity in reporting. A roof section plan is drawn to scale on the roof inspection worksheet, showing all physical features, including perimeter conditions, rooftop equipment

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and projections, drains, scuppers, walkways, etc. This information is then stored in a section folder.

Collecting the inventory data can be a frustrating experience. The inventory information is obtained from a variety of sources such as as-built drawings, specifications and an inspection of the roof itself. The core cuts that are made to determine the moisture content of the insulation should also be used to verify the components of the roofing system. However tedious, the effort is needed and important since it establishes the foundation of the ROOFER system.

INSPECTION AND CONDITION EVALUATION

Condition Rating

The condition rating is the key component of any maintenance management system. The ROOFER system uses three separate condition indexes:

- MCI—the membrane condition index
- FCI—the flashing condition index
- ICI—the insulation condition index

Each of these indexes provides a measure of that component's ability to perform its function, the needed level of repair and the potential for leaks. Numerical indexes range from 0 to 100, with 100 representing excellent condition. Treating each component separately provides a more accurate assessment of component condition and needed maintenance and repair. The MCI and FCI are determined by visual inspection, and the ICI is determined by evaluation techniques such as infrared, electrical capacitance or nuclear.

Visual Inspection

The MCI and FCI indexes for a roof section are based on the quantity, severity and type of distresses present on the roof section.

The visual inspection technique, a distress manual and computation procedures are described in detail in USA-CERL Technical Report M-87/13, "Membrane and Flashing Condition Indexes for Built-Up Roofs, Volume II: Inspection and Distress Manual."[4]

Five steps are followed in the procedure:

1. **Determine type, severity and quantity of distress.** The type, severity and particular defect for each distress is defined in the "Inspection and Distress Manual." Six flashing distresses and 10 membrane distresses are identified (Table 1), and low, medium and high severity levels of distress are described. For a typical distress such as blisters, low, medium and high levels are described (Figure 1), and eight color photographs are used to illustrate the descriptions. The method of measuring the distress density is also defined. Color photographs are used throughout the manual to illustrate the other 15 distresses.
2. **Determine deduct values for each distress.** Deduct values for each distress and severity level are determined from a series of charts similar to Figure 2.
3. **Determine corrected total deduct value.** The deduct values are entered on the roof section rating form, and a corrected deduct value is determined using a correction chart that takes into account the effect of multiple distresses (Figure 3).
4. **Determine component condition index.** The condition index is calculated by subtracting the corrected deduct value from 100.
5. **Determine component condition rating.** The condition rating is determined from Table 2.

NON-DESTRUCTIVE MOISTURE EVALUATION

A complete evaluation of an insulated roofing system requires that the insulation be inspected to determine if excessive moisture is present. Moisture reduces the thermal value of the insulation and may also reduce the bond between it and the membrane or deck. Water in insulation adds to the weight the structural system must support and may cause corrosion of fasteners and deterioration of the roofing system.

By using non-destructive moisture evaluation techniques such as infrared (IR), nuclear or capacitance, areas of probable wet insulation can be determined.[5] Core samples must be taken to verify the probable wet areas and to determine the moisture content of the insulation. Knowing the type and amount of wet insulation and its moisture content, the insulation condition index (ICI) for a section can be calculated.

ROOF CONDITION INDEX

The membrane, flashing and insulation condition indexes are combined to determine the roof condition index (RCI). This provides a useful method of evaluating the overall condition of a roof section and a method of comparing conditions between roof sections. The RCI allows the user to rank individual roof sections according to their ability to perform.

The three component indexes (MCI, FCI and ICI) have a direct relationship to determining the needs for maintenance and repair (M&R) of a roof section. Similarly, the RCI provides an overall indication of M&R needs.

Like the component indexes, the RCI is based on the same scale of 0 to 100, with 100 indicating that only routine maintenance is needed. It is calculated by giving the greatest weight to the component with the lowest condition index and a lesser weight to the remaining indexes. For a roof section with insulation, the lowest of the three indexes has 70 percent of the weighting and the other two indexes each have 15 percent of the weighting. Table 3 lists the qualitative condition ratings associated with the RCI.

NETWORK MANAGEMENT

Network management uses the collected information to develop long-range budget projections and work requirements for the network.

The ROOFER program can generate a series of reports for making network management decisions. These reports include:

Section Inventory List

The section inventory list report (Figure 4) provides a list of the surveyed roof sections. For each section, the type of membrane insulation, and deck as well as roof slope and area are provided.

Inspection Scheduling

The inspection schedule report is used to prepare a plan for scheduling future ROOFER inspections for roof sections based on the RCI. The report produces a plot and list of the roof sections to be inspected during the next three years for all of the roof sections of a particular building use, membrane type or section area.

Condition Frequency

The condition frequency report informs management of the current condition of the roof network and helps plan for future maintenance and repair. The roof sections included in the report can be selected by building use, membrane, insulation and/or deck type, roof slope, section area or age. The report lists, by section and area, the number and percentages for the different RCI ranges and provides a graphical plot of the frequency of occurrences. Figure 5 is a typical report for a group of buildings at a military installation.

Using the different selection options, the effects of conditions such as deck type, insulation type or slope on overall condition can be examined.

Roof Condition Index

The roof condition index report (Figure 6) lists roof sections and component indexes in order of increasing RCI. The report can be sorted based on building use, membrane, insulation, deck type, roof slope, section area or age to provide management with the background information needed to select and prioritize roof sections for maintenance and repair. The RCI, building use and age, as well as available budget, provide the criteria for project selection.

Project Management

Project management uses the three component condition indexes and distress data that were determined for a section to provide valuable information regarding the condition of the roof section and required maintenance and repair. This information when combined with life-cycle predictions can be used to identify M&R alternatives.

Field Tests

Field tests of the ROOFER program were performed at Ft. Meade last year, and preliminary findings indicate that the system works well. The forms used for data collection and the microcomputer program for analyzing the data provided the planning for long-range repair and replacement of the built-up roof network at Ft. Meade. They did not present any problems to the contractor performing the work.

CONCLUSIONS

This paper has described a comprehensive management system for built-up roof systems. The procedures presented are being programmed for microcomputer use as part of the ROOFER program. Inventory, inspection, condition evaluation and network management techniques have been developed, and the system has been designed to enable the incorporation of other low-slope roofing systems in the future. ROOFER will be available to private industry through a nongovernment distribution agency.

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[1] Shahin, M.Y., Bailey, D.M., Brotherson, D.E. and "Membrane and Flashing Condition Indexes for Built-Up Roofs, Volume I: Development of the Procedure," Technical Report M-87/13, U.S. Army Construction Engineering Research Laboratory (USA-CERL), September 1987.

[2] Shahin, M.Y. and Kohn, S.D., "Pavement Maintenance Management for Roads and Parking Lots," Technical Report M-294, U.S. Army Construction Engineering Research Laboratory (USA-CERL), October 1981.

[3] Shahin, M.Y., Cation, K.A. and Broten, M.R., "Micro PAVER Concept and Development, Airport Pavement Management System," Report No. DOT/FAA/PM-87/7, Federal Aviation Administration (FAA), July 1987.

[4] Shahin, M.Y., Bailey, D.M. and Brotherson, D.E., "Membrane and Flashing Condition Indexes for Built-Up Roofs, Volume II: Inspection and Distress Manual," Technical Report M-87/13, U.S. Army Construction Engineering Research Laboratory (USA-CERL), September 1987.

[5] Tobiasson, W. and Korhonen, C., "Roof Moisture Surveys: Yesterday, Today and Tomorrow," CRREL Miscellaneous Paper 2040, September 1985.

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Flashing	Membrane
Base Flashing	Blisters
Metal Cap Flashing	Ridges
Embedded Edge Metal	Splits
Flashed Penetrations	Holes
Pitch Pans	Surface Deterioration
Drains and Scuppers	Slippage
	Patching
	Debris and Vegetation
	Equipment Supports
	Ponding

Table 1 Built-up roofing distresses

Condition Index	Rating
86 - 100	Excellent
71 - 85	Very Good
56 - 70	Good
41 - 55	Fair
26 - 40	Poor
11 - 25	Very Poor
0 - 10	Failed

Table 2 Condition ratings

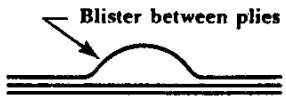
RCI	Roof Condition Rating
86 - 100	Routine Maintenance
71 - 85	Minor Repairs Needed
56 - 70	Moderate Repairs Needed
41 - 55	Major Repairs Needed
26 - 40	Replacement Probable
11 - 25	Replacement Needed
0 - 10	Replacement Critical

Table 3 Maintenance and repair recommendations

BLISTERS

Description: Blisters are round or elongated raised areas of the membrane that are filled with air.

Note: Blisters and ridges are difficult to differentiate at the low and medium severity levels. The rating error will be insignificant because of the similarity in the deduct curves. At high severity, however, it is important to distinguish between the two distresses due to their different leak potentials.



Graphic Representation of Blister

Severity Levels:

Low:
1. The raised areas are noticeable by vision or feel. The surfacing is still in place and the felts are not exposed.

Medium:
1. The felts are exposed or show deterioration.

High:
1. The blisters are broken.

Measurement:
1. Measure the length and width of the blister in lineal feet and calculate the area (length times width). If the distance between individual blisters is less than 5 feet, measure the entire affected area in square feet.
2. When large quantities of this problem are present (especially on large roofs), the representative sampling technique can be used.

Density:

$$\frac{A}{B} \times 100 = \text{Problem Density}$$

where A = total area of membrane blisters (sq ft)
B = total area of roof section being rated (sq ft)

Note: The problem density is calculated for each existing severity level.

Figure 1 Distress description and severity levels for blisters

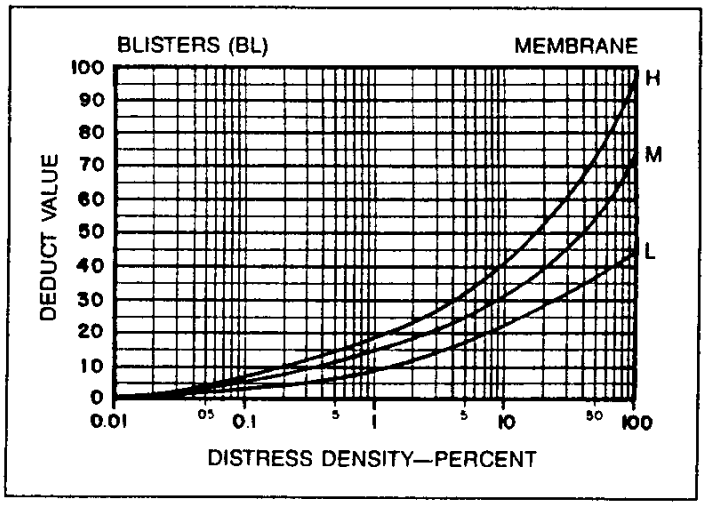


Figure 2 Deduct value curve for blisters

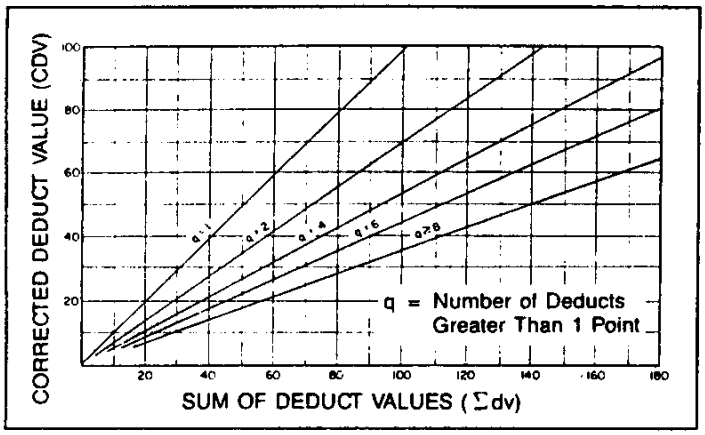


Figure 3 Corrected deduct values for membranes

DATE: SEP/21/1988 | SECTION INVENTORY REPORT | PAGE: 1

INSTALLATION: 00000 FT. XXXXX

BLDG NUMBER/NAME FACILITY CLASS	SEC ID	MEMBRANE TYPE	INSULATION TYPE	DECK TYPE	SLOPE	AREA (SqFt)
393 CAREER CENTER HOUSING & COMM	A	BUR: Asphalt	GLASS FIBER	STEEL	1/2	10368
4407 TELEPHONE EXCHANGE OPER & TRAIN	A	BUR: Asphalt	WOOD FIBERBD	GYPSUM: Gypsum Form	1/8	7028
	B	BUR: Asphalt	PERLITE	CONCRETE STD Cast-In-Pl	1/8	258
6600 OFFICERS CLUB HOUSING & COMM	A	BUR: Asphalt	PERLITE POLYURETHANE	STEEL	1/4	22800
	B	BUR: Bit. Unk.	UNKNOWN	STEEL	1/8	2003
8478 ENLISTED MEN'S BARRACKS HOUSING & COMM	A	BUR: Asphalt	FILL-Lt Conc	CONCRETE STD Cast-In-Pl	1/8	10374
	B	BUR: Asphalt	FILL-Lt Conc	CONCRETE STD Cast-In-Pl	1/8	5195
8501 REGIMENTAL HEADQUARTERS OPER & TRAIN	A	BUR: Bit. Unk.	WOOD FIBERBD	CONCRETE STD Cast-In-Pl	1/2	3100

TOTALS: Sections = 8 Area = 61126

Figure 4 Section inventory report

DATE: SEP/21/1988 | RCI FREQUENCY PLOT | PAGE: 1

INSTALLATION: 00000 FT. XXXXX

SELECTION CRITERIA:

Condition Index -- RCI	: ALL
Building Number	: ALL
Facility Class	: ALL
Membrane Type	: ALL
Insulation Type	: ALL
Deck Type	: ALL
Roof Slope	: ALL
Section Area	: ALL
Last Construction Year	: ALL
Last Inspection Year	: ALL

PLOT OF RCI FREQUENCY REPORT

NO. SEC.	%	CONDITION	
0	0	FAILED	
3	5	VERY POOR	*****
1	2	POOR	**
8	15	FAIR	***************
15	27	GOOD	**************************
26	47	VERY GOOD	**
2	4	EXCELLENT	****
55			0 3 6 9 12 15 18 21 24 27

NO. OF SECTIONS

TOTAL NUMBER OF SECTIONS: 55

AVERAGE RCI : 66

NUMBER OF MISSING VALUES: 0

Figure 5 RCI frequency plot

DATE: SEP/21/1988 | RCI REPORT | PAGE: 1

INSTALLATION: 00000 FT. XXXXX

BLDG NUMBER/NAME FACILITY CLASS	SECTION ID/SLOPE/MEMBRANE INSULATION TYPE(S) DECK TYPE	SECT AREA (SqFt)	LAST CONS YEAR	LAST INSP YEAR	RCI/FCI/ICI RCI
8501 REGIMENTAL HEADQUARTERS OPER & TRAIN	A 1/2 BUR: Bit. Unk. WOOD FIBERBD CONCRETE STD Cast-In-Pl	3100	1961	1986	82/ 60/ 27 41
4407 TELEPHONE EXCHANGE OPER & TRAIN	A 1/8 BUR: Asphalt WOOD FIBERBD GYPSUM: Gypsum Form	7028	1955	1987	96/ 26/ 60 42
8478 ENLISTED MEN'S BARRACKS HOUSING & COMM	B 1/8 BUR: Asphalt FILL-Lt Conc CONCRETE STD Cast-In-Pl	5195	1955	1987	78/ 59/100 68
393 CAREER CENTER HOUSING & COMM	A 1/2 BUR: Asphalt GLASS FIBER STEEL	10368	1986	1987	78/ 63/100 71
6600 OFFICERS CLUB HOUSING & COMM	B 1/8 BUR: Bit. Unk. UNKNOWN STEEL	2003	1982	1987	70/ 90/--- 74
4407 TELEPHONE EXCHANGE OPER & TRAIN	B 1/8 BUR: Asphalt PERLITE CONCRETE STD Cast-In-Pl	258	1955	1987	94/ 86/100 77
8478 ENLISTED MEN'S BARRACKS HOUSING & COMM	A 1/8 BUR: Asphalt FILL-Lt Conc CONCRETE STD Cast-In-Pl	10374	1955	1987	87/ 70/100 77
6600 OFFICERS CLUB HOUSING & COMM	A 1/4 BUR: Asphalt PERLITE POLYURETHANE STEEL	22800	1982	1987	96/ 76/100 83

Figure 6 RCI report

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