THE U.S. ARMY'S IMPLEMENTATION OF THE ROOFER PROGRAM

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Engineers and facility managers within the federal government have long realized that the government is experiencing numerous and costly problems with its roofs. Many of the Army's roofing problems, regardless of roof type, are the result of not having a management system for properly inspecting, maintaining, repairing and, ultimately, replacing the roofs.

Recognizing that a standardized roof management program was tantamount to solving the government's roofing problems, a group of Department of Defense personnel, along with several civilian roofing consultants, undertook a concentrated effort to develop a uniform program for managing built-up roofs.

The combined team visited many military facilities, inspected numerous roofs, identified and categorized various roof defects (problems), classified the severity level of each defect, determined the individual and collective effects of the problems on the roof, determined how the evaluation of roofs could be standardized, and how the roof defects could be most effectively corrected.

The result of their efforts was the development of the ROOFER program. After testing at several Army installations, the Army began implementing the program at Fort George G. Meade, Maryland, in 1988. Since then, the Army has implemented the program at five other facilities. The analysis of the initial results shows that the ROOFER program not only works, it exceeds expectations.

KEYWORDS

Economic evaluation (EE), engineered management systems (EMS), five year budget plan, network analysis, project analysis, ROOFER.

THE ROOFER PROGRAM

ROOFER is an engineered management system (EMS) that is designed to provide the user with the data and procedures necessary to develop and maintain a cost-effective program for managing built-up roofs. The program was developed by U.S. Army Construction Engineering Research Laboratory (USACERL). Technical assistance was provided by the U.S. Army Cold Regions Research and Engineering Laboratories (USACRREL), the U.S. Navy, the U.S. Air Force, two civilian roofing consultants, and the U.S. Army Engineering and Housing Support Center (USAEHSC). The development of a ROOFER program for single-ply membrane roofs, including EPDM, PVC, PIB, CPE and CSPE is well underway. A program for steep roofs will follow.

The ROOFER program provides the user with an effective management tool that can be used on a periodic basis to access the overall condition of the roofs and to develop a program for bringing the roofs up to an acceptable level and keeping them there. The U.S. Army has decided that a detailed ROOFER inspection should be conducted every fifth year. During the interim years, the user should supplement the ROOFER program with a scheduled semiannual maintenance and repair program.

The ROOFER program is described in a paper that was presented at the 9th Conference on Roofing Technology, during May 1989,[4] as well as Volumes I and II of the ROOFER program.[1,2] The purpose of this paper is to show how the U.S. Army is implementing ROOFER and what benefits are being derived from its implementation.

IMPLEMENTATION OF THE ROOFER PROGRAM IN THE U.S. ARMY

It is estimated that the U.S. Army has over 21,000,000 square meters (225,000,000 square feet) of built-up and single-ply membrane roofs in its inventory. Managing such a large quantity of roof area is a very difficult task. To ensure that its roofs are inspected, maintained, repaired and replaced in a systematic manner, the Army has begun to implement the ROOFER program at its installations. As of this publication, ROOFER has been implemented at Fort George G. Meade, Maryland; Fort Sill, Oklahoma; Fort Riley, Kansas; Fort Leonard Wood, Missouri; Oakland Army Base, California, and West Point Military Academy, New York. Pending the availability of funds, the Army plans to implement the program at 15 to 20 installations per year.

Even at this rate, it will take eight to 10 years to implement the program Army-wide. Funding limitations will be a definite constraint on implementation, as the initial implementation of ROOFER costs from $.43-$1.60 per square meter ($.04-$.15 per square foot) of roof area; depending upon what inventory data and roof plans are available at the installation and who accomplishes the inspection of the flashing, membrane and insulation components of the roof. The most cost effective method of implementing ROOFER is for the installation to do the work. The most costly method is to have all the work done by contract. Most of the Army's implementation effort has been accomplished as a joint venture between a civilian contractors, installation personnel and members of USAEHSC.

Whatever method is used, ROOFER is still somewhat costly to implement. However, it is considered well worth the expense, as it provides the user with precise data on the condition of the roofs, the cost of correcting the problems, a determination of whether it is more cost-effective to repair the problems or to replace the roof, and how and when funds should be programmed to accomplish the work necessary to correct the problems.

THE BENEFITS OF THE ROOFER PROGRAM

Roofer provides the user with the following benefits:

- A complete inventory of roof area and its features.
- Development of roof plans.
- Detection of defects by:
  - A visual inspection to locate and identify problems in the membrane and flashing components of the roof
  - A nondestructive roof moisture survey to locate areas of wet roof insulation.
- Development of reports:
  - To cover flashing membrane, insulation and overall roof conditions.
  - To summarize the findings and to develop a long range budget program.
  - To determine whether repair or replacement is more cost effective.
  - To generate work requests to document the work requirements.
- Development of a final report.
- Training of personnel to use the ROOFER software program.

INVENTORY OF ROOF ASSETS AND DEVELOPMENT OF ROOF PLANS

For the most part, the development of the inventory for each roof section is a rather costly item associated with the implementation of the program at Army installations, as very little data is on file. Most of the inventory data is collected during the visual inspection phase by the inspector noting the physical makeup of the roof and entering the data on the inventory worksheet. A core sample is usually taken to determine the composition of the roofing system.

Roof plans are also difficult to find at Army installations. In some instances, the inspector had to sketch the roof plan on the inspection worksheet, prior to accomplishing the inspection. This is a rather costly way of developing plans. A more cost effective method is to use the installations's computerized site plan, which contains an outline of all the buildings at the installation. By using the building outline and a recent aerial photo of the roof, the computer operator can plot the roof plan on the inspection worksheet (see Figure 1). The rooftop features are added by the inspector during the visual inspection. This data is then entered into the computer, providing a permanent record of the roof plan.

DETECTION OF ROOF PROBLEMS DURING THE VISUAL INSPECTION

The primary purpose of the ROOFER program is the "detection" and eventual "correction" of roof defects. During the visual inspection of the roof surface, the inspector identifies and categorizes all defects noted in the membrane and flashing components. The location of each defect is plotted on the roof plan and its severity level, specific problem identifier, and quantity is noted in the tabulation column of the inspection worksheet (see Figure 1). Figure 2 shows an abbreviated list of flashing, membrane and insulation distresses that is used during the inspection. The abbreviated list correlates with the distresses, severity levels and problem identifiers contained in Volume II of the Roofer Inspection and Distress manual.[2] Severity levels of defects range from HIGH, (repair immediately), MEDIUM (repair during the next scheduled maintenance) and LOW (repair is not needed; however the defect would be monitored for further deterioration or corrected when the roof is replaced).

The proper coding of each defect establishes a standard identifier that is clearly understood by all personnel associated with the inspection, evaluation, repair and replacement of roof defects. The data from the inspection worksheet can be entered into the computer program for a rapid determination of condition of the membrane and flashings.

INSPECTION OF AREAS OF WET ROOF INSULATION

Many of the Army's built-up roofs contain a layer of insulation under the waterproofing membrane that can be altered by the infiltration of moisture, either from a defect in the waterproofing assembly or from the condensation of moisture from within the building. Moisture is detrimental to the insulating layer because it reduces thermal resistance capability, adds weight to the roofing system, reduces the attachment capability between the membrane and the deck, corrodes or rots the deck, etc. The condition of the roof's insulating layer is critical when evaluating the overall condition of the roof, therefore, it is an inherent element of the ROOFER process when evaluating insulated roofs.

Areas of wet roof insulation are best detected and plotted using either a nuclear moisture survey or an infrared (IR) scan. Because of the large number of insulated roofs at Army installations, an aerial infrared roof moisture scan is used to rapidly survey the entire facility. Potential areas of wet roof insulation are plotted on the roof plan. Sufficient core samples are taken in the suspect areas to verify the presence of moisture in the insulation and to obtain the moisture content of the insulation. Once verified, the location and quantity of wet insulation is entered on the roof inspection worksheet. The amount of wet insulation and its moisture content is then entered into the computer to determine the insulation condition.

ANALYSIS OF DATA

Once all the defects associated with the membrane, flashing and insulation components of each roof section have been identified and quantified, the data is analyzed and developed into a management program. The analysis can be done manually; however, this is a very time consuming process and, except in isolated instances, is too cumbersome to be used at most Army installations. The ROOFER software program provides an ideal vehicle for rapidly evaluating the inspection data. The results of the ROOFER program fall into two categories: Network analysis (which provides a general summary of the findings for all the roofs surveyed) and Project analysis (which covers the specific repair or replacement requirements for each roof).

NETWORK ANALYSIS DATA (GENERAL SUMMARY)

The development and meaning of the various condition ratings and the resulting summary reports were previously described in a paper and presentation given at the 9th Conference of Roofing Technology, May 1989.[4] Using the data developed during implementation, a five year budget pro-

gram can be developed for each installation. The five year program provides a clear and concise budget analysis that can be readily understood by all personnel involved in the management of roofs at the installation. At one exit briefing following the implementation of the ROOFER program, an individual associated with developing the installations's budget, stated that he did not understand some of the technical aspects of the briefing, but he clearly understood the significance of the five year program and its impact on the installation's roofs. At another briefing, the director of engineering for the installation told his staff that he would like to see similar plans developed for his other areas of responsibility.

The five year program that was developed for Fort "A" (an actual army facility) is shown in Figure 3. Basically the program shows the costs associated with the necessary repair, replacement, annual inspection and reinspection using ROOFER criteria that Fort "A" must fund for the next five years to bring their roofs to an acceptable condition and keep them there.

Three significant factors have become apparent from the five year programs that have been developed. First, a cost of about $4.84- $6.45 per square meter ($0.45-$0.60 per square foot) should be made for repairs on those roofs where repair was considered more economical than replacement. Secondly, if the user invests a minimal amount per year ($49,000 for Fort "A") for the semiannual inspection, maintenance and minor repair, he can expect the cost of the major repair and replacement projects to be greatly reduced. Finally, correcting the Army's roof problems will be expensive. However, the money spent is considered a sound investment, which will eventually provide much larger dividends by significantly extending the service life of the roofs and greatly reducing the amount of money that would have otherwise been spent on replacing the roofs.

PROJECT ANALYSIS (FOR EACH ROOF SURVEYED)

A major problem that confronts the Army's engineers is a determination of whether it is more economical to perform the repairs or to replace the entire roofing system. The ROOFER program now has the capability of providing an economic evaluation (EE) for each section surveyed. The ROOFER program generates a cost estimate for correcting defects, as well as the cost of replacing the entire roofing system. Figure 4 shows a sample economic evaluation worksheet for Section A, building 358, Fort "A." The costs associated with both repair and replacement are based upon the Washington, D.C. area. Actual cost estimates can be developed for other regions by applying the U.S. Army Corps of Engineering construction adjustment factors or by using cost values that are common to the local area. The economic evaluation (EE) ratio is developed using the following formula:

$$\frac{\text{Repair costs/year}}{\text{Replacement costs/year}} + \text{age factor} * = \text{EE ratio}$$

An economic evaluation (EE) ratio of a roof surveyed at installation "A" is shown below:

Function	Costs	Estimated Additional Service Life	Costs/year
Repair	$11,666	10 years **	$1,167
Replacement	$39,312	20 years **	$1,966

$$\frac{\$1,167}{\$1,966} + (0.01 \times 10) = 0.75 \text{ (repair is recommended)}$$

Ratio	Action
0 - 0.8	= Repair
►0.8 - 1.2	= Marginal
►1.2	= Replacement

*Reference #4 provides a basis for determination of the appropriate age factor.

**The estimated additional service life expected, if the necessary corrective action is taken and the required semiannual inspection, maintenance and minor repair is accomplished.

Note that the repair and replacement costs have been converted to yearly costs based upon the estimated additional service life that repairs of replacement will provide. With repair, the roof condition will be improved and the roof is then projected to last another 10 years, providing the semiannual inspection, maintenance and repair is accomplished. The resulting ratio provides the user with a recommended course of action, i.e., repair, replace or marginal (user's option). The user must still make the final decision and, because of local conditions and especially the availability of funds, may have to deviate from the recommended course of action.

WORK ORDERS

For the Army, the most important product of the ROOFER program is the development of a work order (work request) which documents the work requirements that need to be accomplished for each roof section surveyed. Once the work order is signed and approved, the requirements remain on the books until the work is accomplished. The work request for each section contains a copy of the completed inspection worksheet, the economic evaluation worksheet and a list of specific problems to be corrected.

THE FINAL REPORT

The user is provided with a final report that contains all the inspection results, including the network analysis summaries (i.e., roof condition lists, roof profiles and five year budget program) and project analysis data (i.e., completed inspection worksheet, economic evaluation sheets and work orders) is provided to the user as a permanent file that is readily available for reference. Additionally, the user is provided with the ROOFER software program which contains all the data used to develop the network reports and project analysis.

TRAINING

To ensure that the ROOFER program is properly used and maintained, training is provided to specific installation personnel on the contents of the ROOFER software program, how existing data can be extracted from the program, and how updated data can be entered into the program. When requested, training on how to inspect built-up roofs using ROOFER criteria is also provided to selected installation personnel, so they can reinspect specific roofs as conditions warrant.

SUMMARY

The implementation of the ROOFER program in the Army is already beginning to pay dividends. Those installations that have implemented the program now know the condition of their built-up roofs, know how their roofs measure up to an acceptable standard, have their requirements documented on work requests, and have a five year budget plan for correcting their roof problems. They also have specific facts to justify the need for additional funds to correct their roofing problems. These facts are going to be hard for managers and budgeters to ignore. The installations that have the ROOFER program appear to have a distinct advantage over those that do not. They simply have their act together, which gives them a distinct advantage on getting the funds necessary to correct their roof problems.

REFERENCES

[1] Shahin, M.Y., Bailey, D.M. and Brotherson, D.E., "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 (USACERL), September 1987.

[2] 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 (USACERL), September 1987.

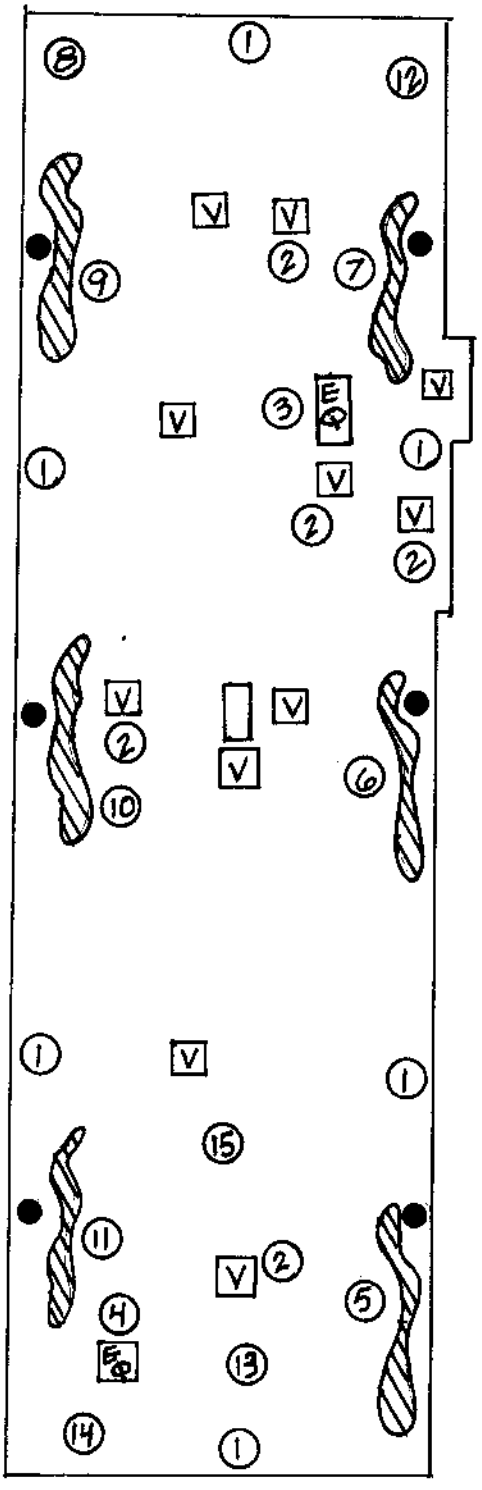
[3] Tobiasson, W. and Korhonen, C., "Roof Moisture Surveys: Yesterday, Today and Tomorrow," CRREL Miscellaneous Paper 2040, September 1985.

[4] Bailey, D.M., Brotherson, D.E. and Tobiasson, W., "ROOFER: A Management Tool for Maintaining Built-up Roofs," NIST/NRCA Paper, 9th Conference on Roofing Technology, May 1989.

ADDITIONAL INFORMATION

For information on ROOFER training courses contact the University of Illinois at Urbana/Champaign, Conferences and Institutes, at (217) 333-2882.

INSTALLATION: FORT "A" BLDG/SEC: 358 /A USE: ADMIN.
SURFACE: GRAVEL BIT: ASP. PLIES: 3 VAPOR RET: YES
INSULATION: 2" FIBERBOARD DECK: CONC. ROOF AGE(YRS): 16
AREA(SF): 7488 FLASHING(LF): 433 INSP: J.W.L. DATE: SEP. 89

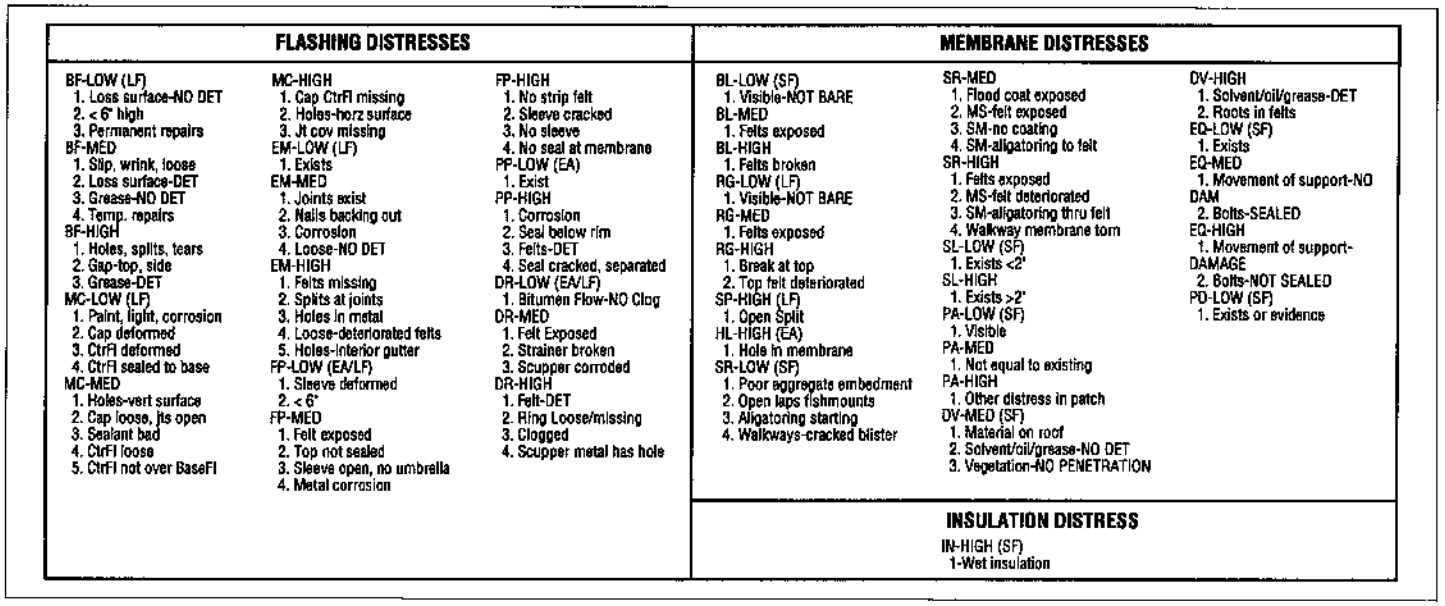


ITEM	DISTRESS	SEVERITY	DEFECT	QUANTITY
1	BF	H	1	413
2	BF	H	1	20
3	EQ	L	1	10
4	EQ	L	1	20
5	PD	L	1	50
6	PD	L	1	48
7	PD	L	1	24
8	DV	M	1	1
9	PD	L	1	24
10	PD	L	1	20
11	PD	L	1	40
12	SR	M	4	24
13	SR	M	2	2
14	SR	M	2	3
15	PA	M	1	1

NORTH

SLOPE: SCALE: 1"=20'-0"

Figure 1 ROOFER inspection worksheet.



FLASHING DISTRESSES

BF-LOW (LF)
1. Loss surface-NO DET
2. < 6" high
3. Permanent repairs

BF-MED
1. Slip, wrink, loose
2. Loss surface-DET
3. Grease-NO DET
4. Temp. repairs

BF-HIGH
1. Holes, splits, tears
2. Gap-top, side
3. Grease-DET

MC-LOW (LF)
1. Paint, light, corrosion
2. Cap deformed
3. CtrFl deformed
4. CtrFl sealed to base

MC-MED
1. Holes-vert surface
2. Cap loose, jts open
3. Sealant bad
4. CtrFl loose
5. CtrFl not over BaseFl

MC-HIGH
1. Cap CtrFl missing
2. Holes-horz surface
3. Jt cov missing

EM-LOW (LF)
1. Exists

EM-MED
1. Joints exist
2. Nails backing out
3. Corrosion
4. Loose-NO DET

EM-HIGH
1. Felts missing
2. Splits at joints
3. Holes in metal
4. Loose-deteriorated felts
5. Holes-interior gutter

FP-LOW (EA/LF)
1. Sleeve deformed
2. < 6"

FP-MED
1. Felt exposed
2. Top not sealed
3. Sleeve open, no umbrella
4. Metal corrosion

FP-HIGH
1. No strip felt
2. Sleeve cracked
3. No sleeve
4. No seal at membrane

PP-LOW (EA)
1. Exist

PP-HIGH
1. Corrosion
2. Seal below rim
3. Felts-DET
4. Seal cracked, separated

DR-LOW (EA/LF)
1. Bitumen Flow-NO Clog

DR-MED
1. Felt Exposed
2. Strainer broken
3. Scupper corroded

DR-HIGH
1. Felt-DET
2. Ring Loose/missing
3. Clogged
4. Scupper metal has hole

MEMBRANE DISTRESSES

BL-LOW (SF)
1. Visible-NOT BARE

BL-MED
1. Felts exposed

BL-HIGH
1. Felts broken

RG-LOW (LF)
1. Visible-NOT BARE

RG-MED
1. Felts exposed

RG-HIGH
1. Break at top
2. Top felt deteriorated

SP-HIGH (LF)
1. Open Split

HL-HIGH (EA)
1. Hole in membrane

SR-LOW (SF)
1. Poor aggregate embedment
2. Open laps fishmounts
3. Aligatoring starting
4. Walkways-cracked blister

SR-MED
1. Flood coat exposed
2. MS-felt exposed
3. SM-no coating
4. SM-aligatoring to felt

SR-HIGH
1. Felts exposed
2. MS-felt deteriorated
3. SM-aligatoring thru felt
4. Walkway membrane torn

SL-LOW (SF)
1. Exists <2'

SL-HIGH
1. Exists >2'

PA-LOW (SF)
1. Visible

PA-MED
1. Not equal to existing

PA-HIGH
1. Other distress in patch

OV-MED (SF)
1. Material on roof
2. Solvent/oil/grease-NO DET
3. Vegetation-NO PENETRATION

OV-HIGH
1. Solvent/oil/grease-DET
2. Roots in felts

EQ-LOW (SF)
1. Exists

EQ-MED
1. Movement of support-NO DAM
2. Bolts-SEALED

EQ-HIGH
1. Movement of support-DAMAGE
2. Bolts-NOT SEALED

PD-LOW (SF)
1. Exists or evidence

INSULATION DISTRESS

IN-HIGH (SF)
1-Wet insulation

Figure 2 Abbreviated list of flashing, membrane and insulation distresses.

ROOFER

FIVE YEAR BUDGET PROGRAM FOR BUILT-UP ROOFS

(COST = $000 IN FY90 FUNDS)

INSTALLATION: FORT "A," USA — INSPECTION DATES: AUG–OCT 1989
NO. OF BUILDINGS: 166 — NO. OF SECTIONS: 571 — AREA: 2,450,524 SF

FUNCTION	NOTES	FY90	FY91	FY92	FY93	FY94	LONG RANGE	TOTALS	COST/SF
IMMEDIATE REPAIRS	1	$255						$255	INCLUDED W/REPAIR
OTHER REPAIRS	2	$78	$632					$710	$0.56
REPLACEMENT PROJECTS	3	$771	$310	$316	$622	$555	$1,289	$3,865	$5.25
SEMI-ANNUAL IM&R	4	$49	$49	$49	$49			$196	$0.02/YR
ROOF MOISTURE SCAN	5					$27		$27	$0.011
VISUAL INSPECTION	6					$74		$74	$0.03
TOTALS:		$1,153	$991	$367	$671	$656	$1,289	$5,127	

NOTES.

1. Includes those immediate repairs that are required to prevent moisture from further damaging the roofing system, the building, or its contents.
2. Includes the repair of all other defects.
3. Includes all built-up roofing systems that need to be replaced.
4. Semi-annual inspection, maintenance, and minor repair (IM&R) should be accomplished between the formal ROOFER inspections.
5. An infrared (IR) roof moisture scan should be conducted every fifth year.
6. A visual inspection using ROOFER criteria should be conducted every fifth year.

Figure 3 Five year budget plan for Fort "A."

WORKSHEET FOR DETERMINING ECONOMIC EVALUATION OF A BUR ROOFING SYSTEM

Agcy/Ins: Fort "A" BLDG/SEC: 358 A AREA: 7488 SF AGE: 16

FLASHING

DIS-SL-DF	UNIT COST	QTY	TOTAL COST
BF-M-1	5.31		
BF-M-2	5.16		
BF-M-3	6.28		
BF-M-4	20.52		
BF-H-1	25.40	433	$ 10998
BF-H-2	11.20		
BF-H-3	33.16		
MC-M-1	17.35		
MC-M-2	19.60		
MC-M-3	8.74		
MC-M-4	4.26		
MC-M-5	7.29		
MC-H-1	10.89		
MC-H-2	10.80		
MC-H-3	6.19		
EM-M-2	7.07		
EM-M-3	7.81		
EM-M-4	7.43		
EM-H-1	7.20		
EM-H-2	9.45		
EM-H-3	16.15		
EM-H-4	8.51		
EM-H-5	25.13		
FP-M-1	5.33		
FP-M-2	6.43		
FP-M-3	38.32		
FP-M-4	21.43		
FP-H-1	18.57		
FP-H-2	56.28		
FP-H-3	93.95		
FP-H-4	24.67		
PP-H-1	21.43		
PP-H-2	46.52		
PP-H-3	23.74		
PP-H-4	61.58		
DR-M-1	23.45		
DR-M-2	44.90		
DR-M-3	21.43		
DR-H-1	29.13		
DR-H-2	62.65		
DR-H-3	50.23		
DR-H-4	111.44		

MEMBRANE

DIS-SL-DF	UNIT COST	QTY	TOTAL COST
BL-M-1	2.31		
BL-H-1	26.99		
RG-M-1	2.33		
RG-H-1	22.35		
RG-H-2	26.99		
SP-H-1	18.50		
HL-H-1	27.07		
SR-M-1	2.33		
SR-M-2	2.62	5	$ 13
SR-M-3	1.30		
SR-M-4	3.81	24	$ 91
SR-H-1	6.63		
SR-H-2	4.75		
SR-H-3	4.52		
SR-H-4	29.79		
SL-H-1	20.70		
PA-M-1	14.42	1	$ 14
PA-H-1	14.42		
DV-M-1	6.02	1	$ 6
DV-M-2	25.57		
DV-M-3	6.02		
DV-H-1	39.91		
EQ-M-1	337.74		
EQ-M-2	181.08		
EQ-H-1	105.90		
EQ-H-2	181.08		

INSULATION:

IN-H-1	8.00	NONE

REPAIR SETUP CHARGE = $ 544

TOTAL REPAIR COSTS = $ 11666

ADDITIONAL SERV. LIFE = 10 YRS

TOTAL REPAIR COSTS/ ADDITIONAL SERV. LIFE = $ 1167 $/YR

REPLACEMENT COST @ 5.25 SF = $ 39312

REPLACEMENT COST/ 20 YEARS = $ 1966 $/YR

COST ANALYSIS

$$\text{RATIO} = \frac{\text{REPAIR COST/YEAR}}{\text{REPLACE COST/YEAR}} = 0.59$$

$$\text{ADJUSTED RATIO} = \text{RATIO} + (0.01 \times \text{AGE}) = 0.75$$

ADJ. RATIO	RECOMMENDED ACTION
0 - 0.8	REPAIR
0.8 - 1.2	MARGINAL
> 1.2	REPLACE

Figure 4 Sample economic evaluation (EE) worksheet.