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A COMPARISON OF THE ROOF MAINTENANCE MANAGEMENT SYSTEMS OF TWO PUBLIC SECTOR ORGANIZATIONS

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ABSTRACT: Roof maintenance management systems were studied for two public sector organizations based on a framework using five factors. These factors were analyzed in detail in order to compare the roof maintenance management systems of the two public sector organizations. The effectiveness of a roof maintenance management system is influenced by the degree to which these five factors are implemented. The roof maintenance management systems of the two public sector organizations were therefore assessed on the present condition of the roofs versus their age. The study focused solely on flat and low-slope roofs. It was determined that the more a roof maintenance management system is utilized, the better the overall condition of the roofs will be and the rate of deterioration of the roofs will be slower.

1. INTRODUCTION

Roofs are a critical component of the building envelope. Roofs ensure water tightness, energy efficiency, and structural support. Many factors can lead to the early deterioration and failure of roofing systems if care, inspection, and maintenance are not carried out throughout the service life of the roof. These factors include environmental degradation factors (high and low temperatures, solar radiation, water, wind), traffic loading, inadequate maintenance, and poor workmanship in the construction and in the repairing of roofing systems**.** Consequently, if inspections are not made and care is not taken, unforeseen, expensive repair or replacement costs arise. To extend the service lives of roofing systems and to reduce unforeseen costs, a roof maintenance management system (RMMS) is essential.

2. ROOF MAINTENANCE MANAGEMENT SYSTEMS (RMMS)

What roofs should be repaired, what roofs should be replaced, and when should this happen in order to maximize the service lives of the roofs? There are no exact answers to these questions because there are so many factors involved in the deterioration of roofing systems. It is possible, however, to develop a "best" solution to these questions, for particular situations, with the help of a roof maintenance management system.

What is a roof maintenance management system and how can it be achieved? A RMMS allows facility managers to better manage roofing assets and determine the condition of these assets in order to plan for maintenance and operation. This can lead to longer service lives and reduced repair and replacement costs. The framework of a roof maintenance management system consists of five main factors: idententification of roofing system components requiring assessment; identification of roofing system performance requirements; identification of performance assessment methods; roofing system maintenance planning; and roofing system maintenance operations management (Froese et al. 1999).

As previously noted by the authors (2001), identification of roofing system components requires obtaining information such as the top cover type (if any), membrane type (built-up, modified bitumen, or single-ply), insulation type and thickness, vapour/air barrier type (if any), roof deck type (steel, concrete, etc.), and flashing types (s). Other information that is useful when identifying the roof components includes, but is not limited to, the year of roof construction (original and/or replacement), building identification (unique identification number, building use, etc.), repair history, roof warranties, manufacturer information, and roof drawings. This data can then be used to form a detailed inventory of roofing assets.

After identifying the roofing system components, it is necessary to identify their purpose. That is, how does each component contribute to the overall performance requirements of the roof (water tightness, energy efficiency, and structural support)?

Performance assessment methods are ways in which the performance requirements of roofing components are evaluated. This is done by periodically inspecting roofs using two techniques, external (visual) and internal (empirical testing) inspections. External inspection of roof components is done visually from the top of the roof, while internal inspection can be done using destructive and/or nondestructive testing. Internal inspections can be done by: Destructive Moisture Tests, including Roof Cut Tests and Moisture Meter Tests; and Nondestructive Moisture Tests, including Infrared Thermography (IF), Nuclear Moisture Detection and Capacitance Radio Frequency Scanning (CRF) (Froese et al. 1999).

Maintenance, repair, and replacement planning can be undertaken more effectively if the current condition of roofing assets are known. If the condition is not known and leaks occur, immediate remedial work is both disruptive and is an inefficient use of resources. Projects can be prioritized and roofing budgets can be more optimally allocated when planning and inspection is properly programmed.

Operations management is best carried out by a qualified individual. Being certified by, or being a member of, organizations such as the CRCA (Canadian Roofing Contractors' Association), IRWC (Institute of Roofing and Waterproofing Consultants International), or the RCI (Roof Consultants Institute) assures that the individual has the knowledge to monitor the quality in design, construction, and workmanship of both repair and replacement projects (Christian et al. 2001).

The extent to which the five factors of a RMMS are implemented influences the effectiveness of a RMMS and ultimately will affect the remaining service lives of the roofing systems.

3. ESTABLISHING THE CONDITION OF ROOFING ASSETS

Visual inspections of flat and low-slope roofs were performed at two public sector organizations as part of a collaborative research project with the Institute for Research in Construction (IRC). The inspection procedure used was developed with the help of the United States Army Construction Engineering Research Laboratory (USACERL) as part of the Building Envelope Life Cycle Asset Management (BELCAM) project. This project is attempting to address growing problems faced by Canadian asset and building managers regarding when and how to repair or replace their building stock and components (Vanier et al. 1996).

A series of inspection and distress manuals (Shahin et al. 1987, Bailey et al. 1990, Bailey et al. 1993) were developed and then modified (Lounis et al. 1998) to standardize roof inspection procedures for this project. Flat and low-slope roof inspection procedures for built-up roofs (BUR), modified bitumen roofs, and single-ply membrane (SPM) roofs are identified and distresses are also identified for both the flashings and the membrane in these inspection and distress manuals. Names, descriptions, severity levels, and photographs of specific defects along with measurement criteria are presented for each distress in the manuals.

Data from the visual inspections are recorded on roof inspection worksheets and then entered into a computerized maintenance management system (CMMS) called MicroROOFER (USACERL 1995). This computerized maintenance management system is used to maintain a roof inventory database, to provide a roof repair history and to calculate roof condition indices (RCI). Condition indices are used to establish the technical condition of an asset, in this case, a roof. The RCI is broken down into an index for each of the three main roof components namely, a membrane condition index (MCI), a flashing condition index (FCI), and an insulation condition index (ICI). Each individual index reflects the component's ability to provide its intended service. The computerized maintenance management system calculates the individual indices based upon the type, quantity, and severity of the defects found in the roof inspection. ICI's are based on nondestructive moisture tests or internal methods of inspection, such as Infrared Thermography (IF), which were not undertaken in this research. This paper is restricted to roof condition indices for two organizations based on only flashing condition indices and membrane condition indices (i.e. external or visual inspections). The roof condition index is a number from 0 - 100 where "0" indicates a failed roof and "100" represents a roof with no distresses or defects.

4. CASE STUDIES: TWO ORGANIZATIONS, TWO APPROACHES TO RMMS

Two public sector organizations, with very different approaches to RMMS were studied. The findings are presented as case studies.

4.1 Case 1: An Educational Campus

The University of New Brunswick (UNB) has 35 buildings, totalling 150 flat and low-slope roof sections on its Fredericton campus encompassing over 420 000 ft^2 (39 000 m^2) of roof area. In Case 1, a roof maintenance management system is not currently utilized although, to some extent, some of the principles behind it are used.

This organization relies mostly on hard copy documentation, in the form of specifications and roof plans, to identify its roofing assets. Much of this documentation, because there is usually only one copy, has been lost over time due in part to the age of the documents and also possibly the staff turnover. For this reason, many gaps exist in the body of knowledge when attempting to identify roofing system components (membrane type, insulation type, etc.). These hard copy documents are difficult to manage. Specifications, which are used to identify the roofing system components of a particular roof, are found in one room. Roof plans which are used to identify roof areas, location, and type of roof-top equipment are found in another room. A general roof inventory (building identification, membrane type, etc.) and roof history (repairs, etc.) is compiled in several binders in yet another location. It may be necessary to look in several different places to seek the information that is required only to discover that this information has been lost. The vast amount of hard copy documentation occupies a considerable amount of space and requires a sound filing system. Updating the documentation also poses problems as there is no system in place to ensure information is accurately updated.

Routine inspections are not undertaken in Case 1. A roof may be inspected by in-house roofers if they have reason to believe it is leaking (i.e. a phone call from a building occupant). Since the roofs are not inspected, it is difficult to determine which roofs need repairs or need to be replaced. The organization may have a very general idea of what roofs have priority for repairs or replacement based on the age of roofing assets and the leak history of the roofs. However, if the organization only has enough money to repair or replace one roof out of this group of "priority" roofs and if a decision is based solely on the age and leak history of the roofs, the organization will not be able to make a logical decision on what has actual priority. A lack of programming for roofing system projects (repairs or replacement) can lead to problems in the future when more roofs are in need of repairs or replacement than there is money available to fund and implement the repairs.

All major repair or replacement project work is contracted out in this case. An in-house project coordinator has the responsibility of overseeing the roofing work even though he/she may have little knowledge of roof construction. The contractor is required to be certified by the supplier of the roofing membrane but the supplier is only on site periodically and upon completion of the project. This allows the contractor significant latitude in what is provided and how it is provided (materials and methods) (Bailey et al. 1999).

4.2 Case 2: A Department of National Defence Installation

The Combat Training Centre (CTC) Gagetown, located in Oromocto, New Brunswick, has a flat and low-slope roof inventory located on 156 buildings, covering over 1.43 million square feet (133 000 m^2) of roof area. In this study, only 101 roof sections on 15 buildings were investigated, totalling over 510 000 ft^2 (47 000 m^2) of roof area. A RMMS is fully utilized in this case.

Roofing system components are identified in a more convenient and centralized manner. Buildings are identified on spreadsheets along with information pertaining to the roofs of each building. Substantial amounts of information can be stored or collated on a spreadsheet, which does not involve the manual filing that is required for hard copy documentation. Not all relevant information to roofs can be stored in spreadsheets, consequentially, the organization has a large room dedicated to the filing of hard copies of as-built roof plans. It takes some effort to find a particular roof plan and then copy it without damaging the original. To address this problem, the organization is currently in the process of scanning most of their plans into computer files to make them more readily available if required.

Inspections, both external (visual) and internal (Capacitance Radio Frequency Scanning and Infrared Thermography), are regularly undertaken by the organization. Based on a combination of the age of roofing systems, their leak history, and regular inspections, the organization develops future plans for their roofing assets. It decides what needs to be repaired, what needs to be replaced, and when these plans need to be executed while keeping in mind that the objective is to maximize the service lives of the roofing systems and minimize costs.

Roofing repair and replacement projects are contracted out by the organization. It is mandated that the contractor be certified by the supplier of the roofing membrane. A qualified individual, separate from the in-house project coordinator and experienced in roofing system construction, oversees the construction of the roof. For this reason, the organization is assured that it is getting a quality roofing system.

5. DISCUSSION

The impact of using a RMMS was evident when the roof data were analyzed. The condition of the roofing assets of the organizations of Case 1 and Case 2 are very different. Figure 1 illustrates the deterioration curve, for the organization who uses a minimal RMMS (Case 1), based on visual inspections in 2000. As shown in the deterioration curve, for roofs greater than 14 years of age, there is a decrease in the roof condition indices (RCI) as age increases. This is what would be expected, that is, roofs deteriorate over time. However, when looking at roofs less than 15 years of age, the RCI is actually lower than that of older roofs. In other words, the condition of the “newer” roofing assets is worse than that of “older” roofing assets. This may indicate a change in the roof maintenance management strategies (or principles thereof) or a lack of quality management in design and construction (Christian et al. 2001). Linear approximation of this model (used for comparative purposes only), including only roofs greater than 14 years of age, suggests rapid deterioration of roofing assets, as indicated by the steepness of the slope. The actual deterioration curve implies that as roofs get older their rate of deterioration increases.

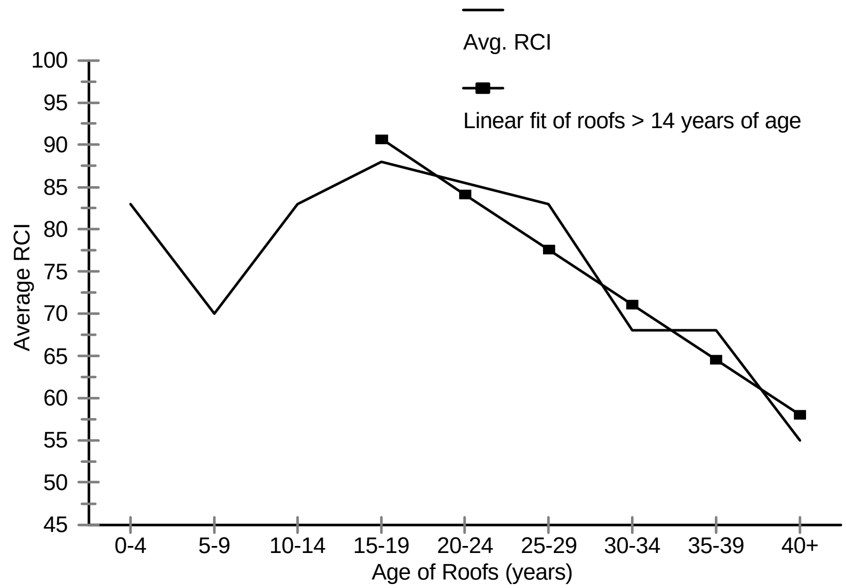

Figure 1. Deterioration curve for Case 1 roofs based on year 2000 visual inspections.

Figure 2 illustrates the change in RCI for Case 1 roofs over a one-year time frame. It can be observed that there is little change in the RCI of roofs less than 15 years of age. Since roofs will deteriorate at a faster rate as they increase in age, the little change in RCI for newer roofs is anticipated. The higher degree of deterioration or drop in RCI for older roofs can also be expected as depicted by the 2001 deterioration curve of Case 1 roofs. The RCI for roofs greater than 14 years of age decreases between 2% and 13% over a one-year period depending upon the age of the roof. It is hypothesized that the average percentage decrease in RCI would be smaller for newer roofs and larger for older roofs over a one-year period. If more inspection data, from subsequent years, were available, an average yearly percentage decrease in RCI could be determined for all ages of roofs. This information could then be used to predict the actual service life of roofs. The percentage decreases in RCI would vary depending on the level of maintenance that the organization undertakes.

The deterioration curve based on visual roof inspections in 2001 of the organization with a well established RMMS (Case 2) is markedly different from Case 1. As shown in Figure 3, the deterioration of roofs in Case 2 occurs at a much slower rate. The conditions of the roofs, both newer and older, are much better than those in Case 1, as illustrated by the higher RCI values.

From the examination of Figure 4, it can be seen that the present overall condition of Case 2 roofs are much better than those of Case 1. It is suggested that the variances in both the overall condition of roofs and the rate of deterioration of roofs is due largely to the differences in the roof maintenance management systems of the two organizations.

The linear approximation of the deterioration curves of Case 1 and Case 2 roofs are compared in Figure 5. The rate of deterioration is much slower for Case 2 roofs than Case 1 roofs. Since the condition of the roofing assets in Case 1 are not known, required repairs are not undertaken; thus, the roofs will not last as long and will deteriorate faster than if the repairs had been done. This leads to unforeseen, early, and expensive replacement costs. In Case 2, the condition of the roofing assets are known and repairs are made as required. Consequently, the roofs last longer thus, avoiding unforeseen, expensive replacement costs.

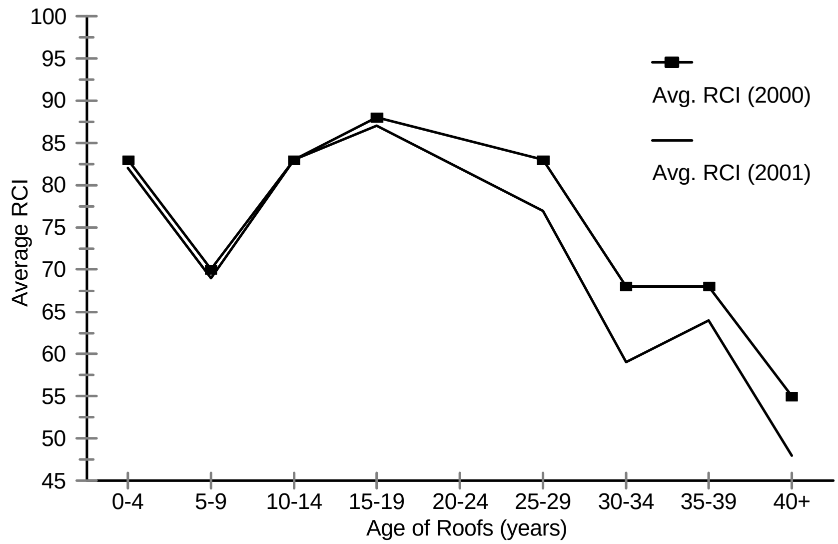

Figure 2. Deterioration curves for Case 1 roofs based on year 2000 and 2001 visual inspections.

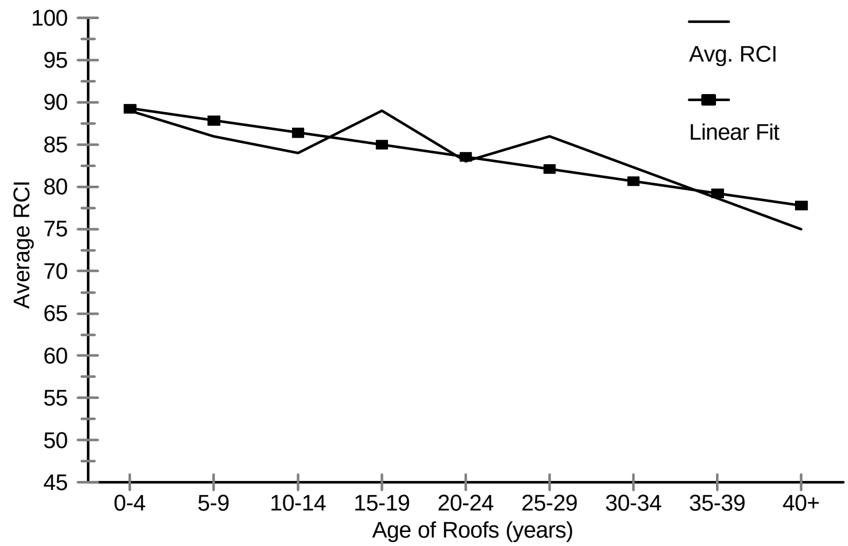

Figure 3. Deterioration curve for Case 2 roofs based on year 2001 visual inspections.

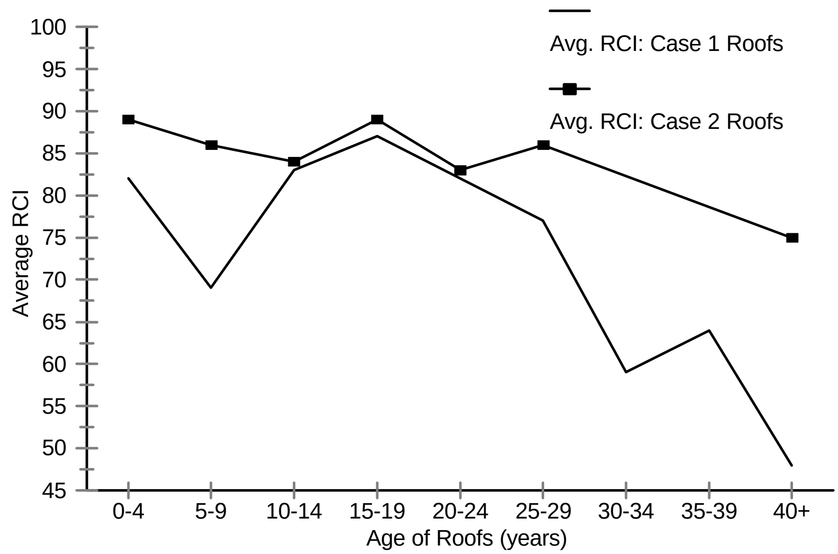

Figure 4. Present deterioration curves for Case 1 and Case 2 roofs.

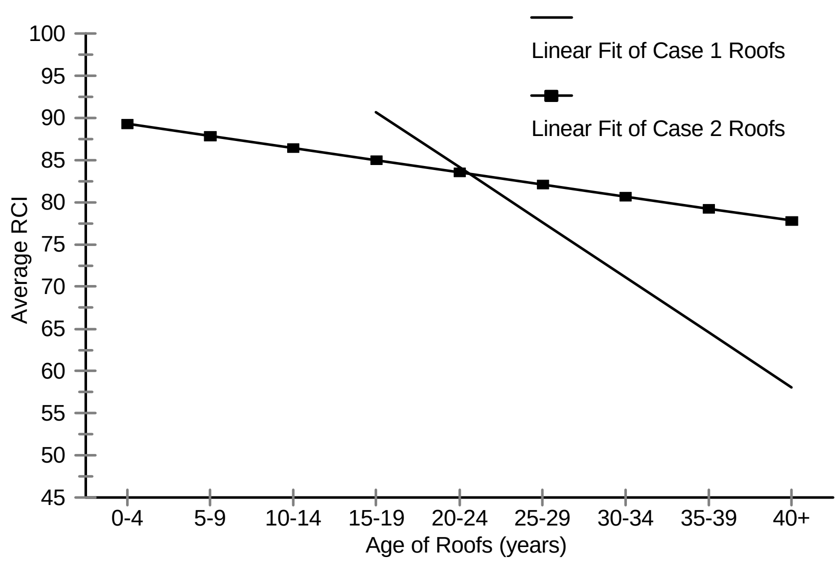

Figure 5. Linear approximation of the deterioration curves for Case 1 and Case 2 roofs.

6. CONCLUSION

The roof maintenance management systems (RMMS) of two public sector organizations were compared based on five factors which constitute the framework for a roof maintenance management system namely: identification of roofing system components requiring assessment; identification of roofing system performance requirements; identification of performance assessment methods; roofing system maintenance planning; and roofing system maintenance operations management. The two organizations studied in this research have radically different approaches to RMMS.

The condition of the flat and low-slope roofs of the two organizations were contrasted with the support of visual inspections and the use of a computerized maintenance management system (CMMS) to determine a roof condition index (RCI) for each roof section. It was determined that the condition of roofing systems is a function of the degree to which an organization implements the use of a roof maintenance management system. The greater extent to which a roof maintenance management system is utilized, the better the overall condition of the roofs will be and the slower the rate of deterioration will be. By comparing the condition of the roofing assets of the two organizations, the need to implement a roof maintenance management system is very clearly shown. With the implementation of a roof maintenance management system, the overall condition of roofing assets can be improved, the rate of deterioration of roofing assets can be reduced, and cost for both repairs and replacement of roofing systems can be minimized.

7. ACKNOWLEDGEMENTS

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