PICTORIAL DATABASE FOR BUILDING DIAGNOSIS

Shipra Singh Ahluwalia[1] and Tarek Hegazy[2]

ABSTRACT

Frequent maintenance and repair programs are crucial to sustain the safety and operability of building facilities. Planning for repairs, however, is a time-consuming and costly task that requires frequent assessment of the condition of all building components. Among the various condition assessment methods that are currently being used, visual inspection can be considered as the most suitable approach for the majority of building components. Visual inspection, however, is highly subjective and requires experienced professionals. As such, the process is time consuming and expensive. There is a need for efficient tools to support the visual inspection process of building components so that it becomes fast, economical, and suitable for less-experienced inspectors.

To support the visual inspection process, this paper first identifies the most frequently deteriorated building components and their possible deficiencies. For each of the identified components, a pictorial database is to be developed from a large number of components at different severity levels for the various deficiencies. The pictorial database will then be used to provide guidance for supporting the visual inspection of components, thus making the process faster, less costly, less subjective, and suitable for inexperienced personnel at the individual facility location. The proposed research would aid condition assessment professionals and organizations, such as municipalities and government agencies, to accurately assess the condition of their building facilities to support the repair and fund allocation decisions.

KEYWORDS: Condition Assessment; Visual Inspection; Buildings; Maintenance and Repair; Asset Management; and Pictorial Database.

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INTRODUCTION

Currently in North America, a large percentage of infrastructure assets are deteriorating rapidly due to age, environmental factors, and overuse (Bordogna 1995). Maintaining these assets is a complex task due to budget constraints on municipalities and public agencies. In Canada, the environmental, social, and transportation infrastructure systems alone require huge investments that amount to approximately $10 billion (US) annually for 10 years (Federation of Canadian Municipalities 1999). Despite the large need for repairs, the Infrastructure Canada Program allocated only $2 billion (US) for the year 2000 among all infrastructure sectors (Federation of Canadian Municipalities 2001). With the non-residential buildings being approximately 40% (largest sector) of the infrastructure in Canada, such sector is expected to suffer the largest shortfall in expenditures on rehabilitation and repair. In addition, in the year 2005, the American Society of Civil Engineers (ASCE) released a set of report cards on infrastructures in the USA that gave failing grades to many infrastructure systems, and identified a need of $1.6 trillion (US) funds to bring the current infrastructure to an acceptable level (ASCE 2006). In view of the stringent shortfall of infrastructure expenditures, it is essential to establish an effective maintenance/repair strategy to keep infrastructure facilities safe and serviceable with least expenditures.

In response to infrastructure challenges, several asset management systems have evolved. The main functions of an asset management system include: (1) assessment of current condition; (2) prediction of future deterioration; (3) selection of maintenance and repair strategies; (4) condition improvement after repair; and (5) prioritization of building components for repair purposes under budget constraints. Asset management system, as such, involves strategic decisions for the repair, replace or up-grade of certain components/systems within the building asset. These decisions largely depend on the current physical condition of such components/systems. Thus, it is the condition assessment of the building that governs all the subsequent asset maintenance decisions.

Rugless (1993) defined condition assessment as “a process of systematically evaluating an organization’s capital assets in order to project repair, renewal, or replacement needs that will preserve their ability to support the mission or activities they were assigned to serve”. As such, the key benefit of a condition assessment system is to facilitate the ranking of all the components of all assets according to their need for repair. To do that, a condition assessment system may involve four main functions (Figure 1):

1. An asset hierarchy, which is a database of all components, organized in different levels;
2. A systematic approach for evaluating the condition of various components;
3. A mechanism for visual inspection in the field; and
4. Calculation of components’ conditions, then aggregating them to different levels.

The asset hierarchy determines the main components of an asset. The lowest level in the asset hierarchy represents the individual instances (e.g., Boiler no. 1) that will be visually inspected and given condition ratings so that a repair budget can be allocated to them.

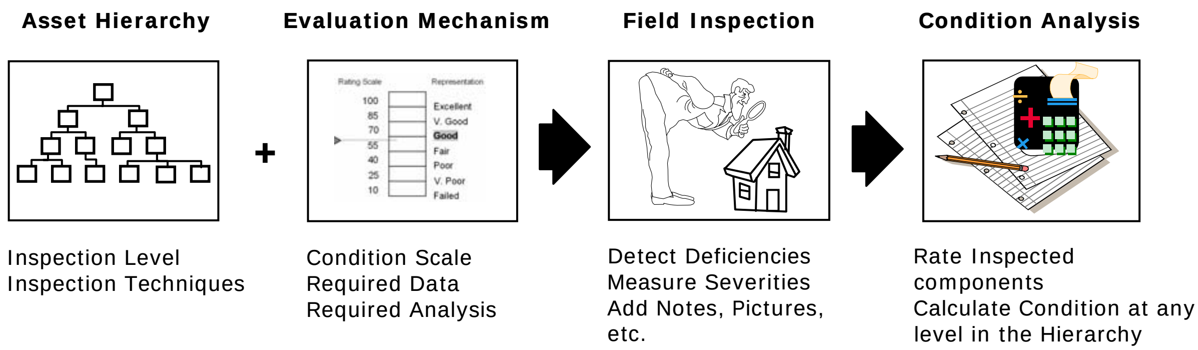

Figure 1: Main functions in a condition assessment system.

Two common approaches are possible for evaluating the condition of any instance of a building component (Uzarski 2002): 1) direct condition rating; and 2) rating based on a distress survey. Direct condition rating is a simple but subjective process of giving the component a global rating to represent its overall condition (e.g., good, fair, poor, or critical). This, however, does not represent the specific problems that need to be repaired. A distress survey, on the other hand, is a more accurate procedure that provides a record of what's wrong with the inspected instance of a component (Uzarski 2002). This approach requires more details regarding the possible deficiencies that can affect the component and how to evaluate them.

Generally field inspection can be done by hiring an outside consultant, or using in-house staff. In deciding who performs the field inspection, cost is a major constraint. Small owner organizations may not be able to afford a specialist whereas larger organizations might employ several. It is important, however, that the inspection team possesses a thorough understanding of facility maintenance and operation, and has enough time to perform the task properly. Literature (e.g., Lewis and Payant 2000; NCES 2003; DfES 2003) suggests that all inspection team members should be well-trained on the inspection procedures and must be qualified to conduct the inspection. In addition, National Centre for Education Statistics (NCES 2003) suggests that regardless of the size of the facility, inspection is best carried out by teams of two or more people rather than by an individual. The inspector is generally accompanied by someone who is intimately familiar with the facility being assessed (e.g., a custodian or a maintenance staff member who works in the facility on a regular basis).

Much research has been directed to the evaluation criteria used to assess the performance of buildings (Assaf et al. 1995; Ashworth 1996; Chew and De Silva 2003). Many systems have also become available in the market and include modules for condition assessment. While these systems are comprehensive in allowing either a direct rating or a distress survey approach to evaluate asset components, still their results are much dependant on the accuracy of the subjective visual inspection process. Such systems require as experienced user to judge the condition of an asset during the inspection process itself. Such experts are, therefore, costly and require a long time in the process.

EXISTING CONDITION ASSESSMENT SYSTEMS

Since the 1980s, various asset management systems have incorporated condition assessment functions for specific types of infrastructure assets (Vanier et al. 1998; BUILDER 2002; Uzarski 2002). For example, the Center of Expertise for Engineered Management Systems (EMS) of the U. S. Army Corps of Engineer Research Laboratory (USACERL) has developed several applications such as PAVER for pavement management; RAILER for railroad tracks; BRIDGER for bridges; GRIPPER for underground gas pipes; ROOFER for roofs; and BUILDER for buildings (USACERL 2006). Other commercial asset management software with condition assessment functions specifically for buildings include RECAPP (PPTI 2006) and TOBUS (Brandt and Rasmussen 2002).

Regardless of the software used, the existing condition assessment process is highly subjective due to the varied perceptions of field inspectors. Recent improvements in this area have provided electronic deficiency-lists to facilitate the field inspection. Often times, however, deficiency-lists (which need detailed analysis of their relative importance) are bypassed to a quick subjective assessments, to save time. Existing systems, as such, can be described as good databases that provide enough spaces to add notes or pictures (for documentation purposes) during the inspection process, however, do not provide adequate improvement to the subjective assessments.

In an effort to reduce subjectivity, one of the recently developed condition assessment system, TOBUS (Tool for Office Building Upgrading Solutions), developed by the European Commission (Brandt and Rasmussen 2002) uses pictures as a visual guidance during field inspection. For each condition category, the system has one or more example photo(s) illustrating this condition. In this system, it is claimed that the photos (Figure 2) assist in doing a more homogeneous diagnosis of an object, independent of the surveyor or his professional background (Brandt and Rasmussen 2002). However, TOBUS, uses the direct-condition rating approach to evaluate the condition of building components, which is less accurate than distress surveys.

Due to the rapid technological developments in information technologies, storage devices, and digital imaging, the use of visual data has recently experienced an unparalleled growth (Brilakis and Soibelman 2003). This is because images provide an accurate and compact method for providing information. Brilakis and Soibelman (2003) provide the following benefits of images:

- Easily understandable view of activities, processes and methods;
- Used for communicating complex engineering work and in marketing projects to local communities;
- Used to save time and money during monitoring and visual inspections through the use of the internet;
- Used to develop trends to support estimating and resource planning functions; and
- Provide permanent documentation of situations and events.

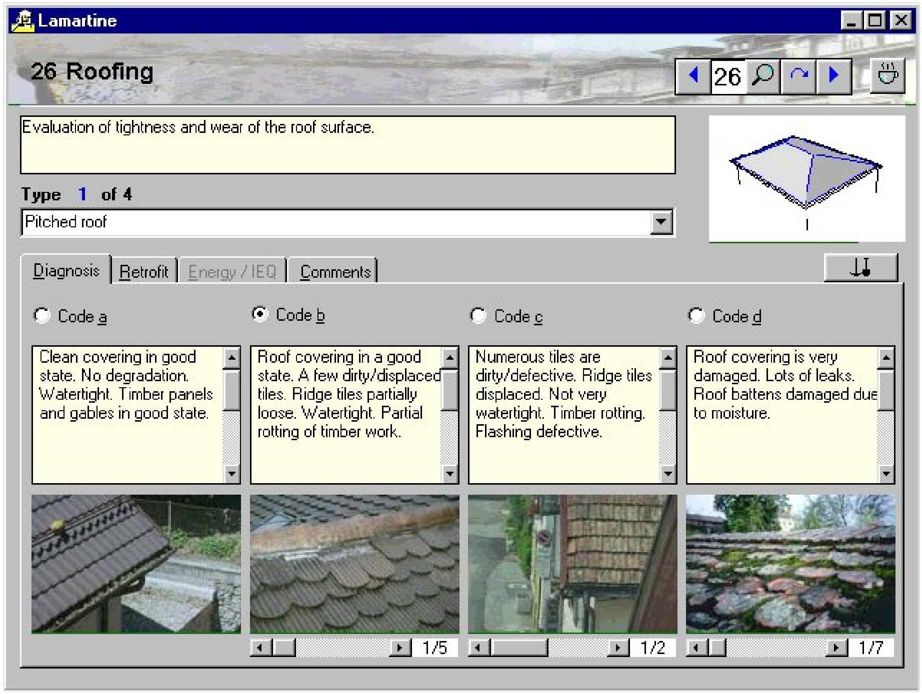

Figure 2: TOBUS inspection guide

In the asset management domain, limited efforts have been done involving images to facilitate field inspection. Yau and Liao (2005) developed an automated visual-aid system (AVAS) for field inspection of bridge components has been developed. Among the limited efforts, another effort related to visual guidance was presented by Elhakeem and Hegazy (2005) which involves collecting images of building windows (e.g. Figure 3) to facilitate condition assessment. While the two above efforts are useful, both conduct the condition assessment during the field inspection. As such, they can be time consuming and their reliance on experienced professionals is still high. Both studies, however, have confirmed the usefulness of images to support the condition assessment process.

PICTORIAL DATABASE TO SUPPORT CONDITION ASSESSMENT

Although images are useful for providing information to be used for assessing the current condition of the asset, yet the accurate identification of the deterioration levels of various building components still remains highly subjective. It is often difficult to specify the exact level of deterioration by just viewing a photograph of the building component. Therefore, the need arises for guidance and support to reduce the subjectivity of the process.

Building upon the earlier effort by Elhakeem and Hegazy (2005), this study presents a simple approach for providing adequate guidance for deciding the condition of a component through a pictorial database of similar components at different condition states. This makes the process less subjective. Due to the extensive nature of this task and for practicality purposes, the present study focuses on the most frequently deteriorated building components and their possible deficiencies.

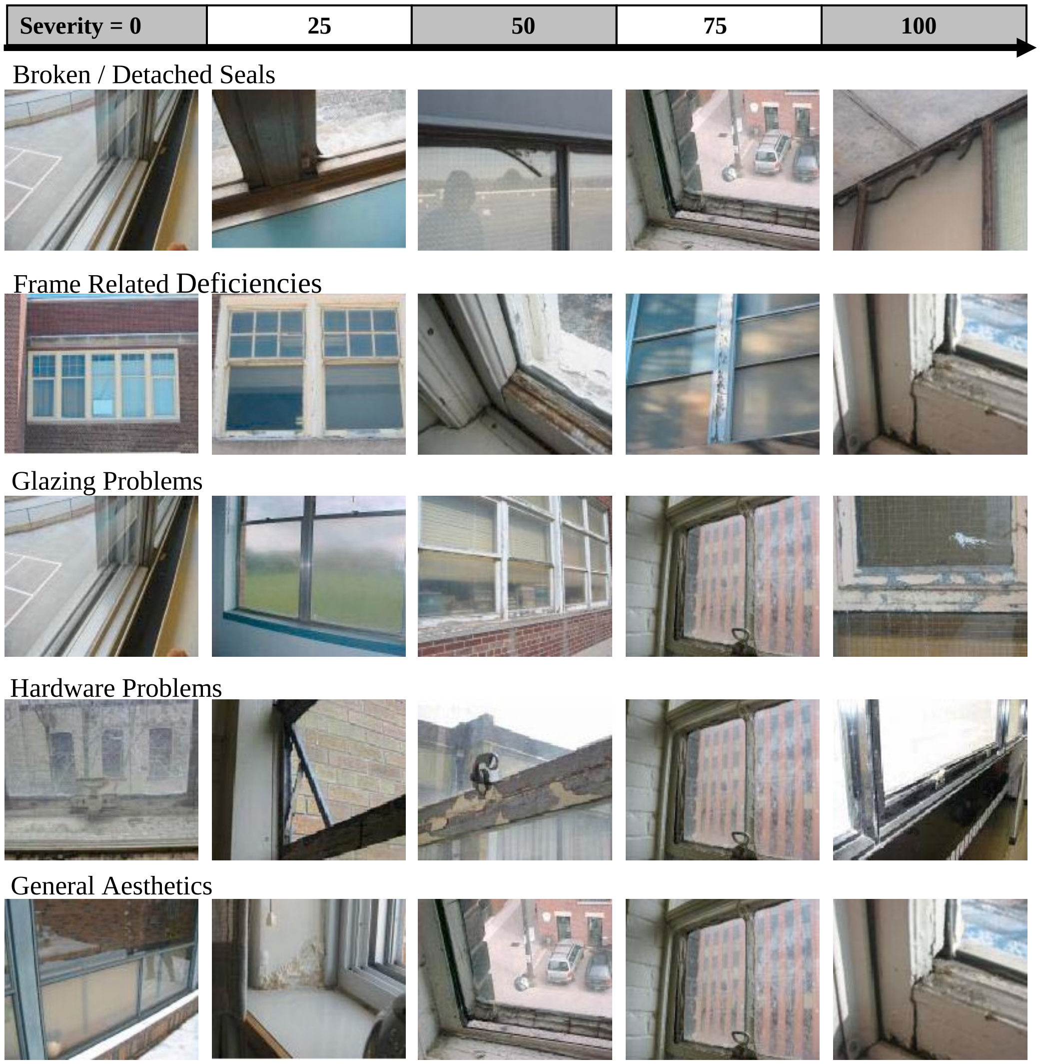

Figure 3: Ranked pictures at different deterioration levels

An earlier study in the United Kingdom of building costs over 5 years (1999-2000) by the Department of Education and Skills (DfES 2003) identified the cost percentage of the main twelve building components (Table 1). As shown in the Table, the top-five building components account for almost 80% of the total cost. Further analysis of the top building components is presented in Table 2, highlighting their critical sub-components that this research will focus upon. Similar to the United Kingdom, the important components defined in North American studies (e.g., ADOE 1997; NCES 2003) are almost the same. In the Toronto area also, these five components are actually the ones that consume the largest proportion of repair and maintenance budget for most school boards, as in the case of the Toronto District School Board (TDSB).

Table 1: Cost Percentage of the Building Components (DfES 2003)

No.	Building Components	Percentage of Total
1	External Walls, Windows and Doors	20
2	Mechanical Services	19
3	Roofs	15
4	Electrical Services	14
5	External Areas	9
6	Decoration	8
7	Floors and Stairs	5
8	Sanitary Services	3
9	Ceilings	2
10	Internal Walls and Doors	2
11	Fixed Furniture and Equipment	2
12	Playing Fields	1

Table 2: Five Top-Most Building Components and their Sub-components

No.	Building Components	Sub-component
1	External Walls, Windows and Doors	Windows
2	Mechanical Services	Boiler Replacement
3	Roofs	Roof Coverings
4	Electrical Services	Rewiring
5	External Areas	Playground Resurfacing

For each of the components considered in this study, a pictorial database is currently being developed from a large number of components at different severity levels for the various deficiencies. The pictorial database is being created by collecting pictures from previous condition assessment reports. Once various pictures are collected, they will be ranked according to their deterioration levels. The pictorial database will assist the expert in the office to make accurate assessment of the component's condition by matching a 3D view of the inspected components with pictures at different conditions in the database (Figure 4).

Currently, the Toronto District School Board (TDSB) has provided the present research with a large amount of past condition assessment reports that contain many pictures and text descriptions of various components at various conditions. For the purpose of identifying the deficiencies associated with the selected five components and the development of visual guidance, these reports will be carefully studied.

One of the key concepts introduced in the present research, besides creating a pictorial database, is the separation between field inspection and office assessment of condition. In the field, building caretakers need only to make a video capture of the building, using a digital video camera. A more advanced system, would also allow caretakers to associate images, video clips, text, and sound to a 3-D computer CAD model of their building. Using either system, the field inspection process can be fast and parallel, thus less costly. On the other hand, when the inspection information is received at the main office, the team of experts can assess components' condition with the support of the visual guidance system that uses the pictorial database. Such a system is currently being developed and tested with the support of the Toronto District School Board.

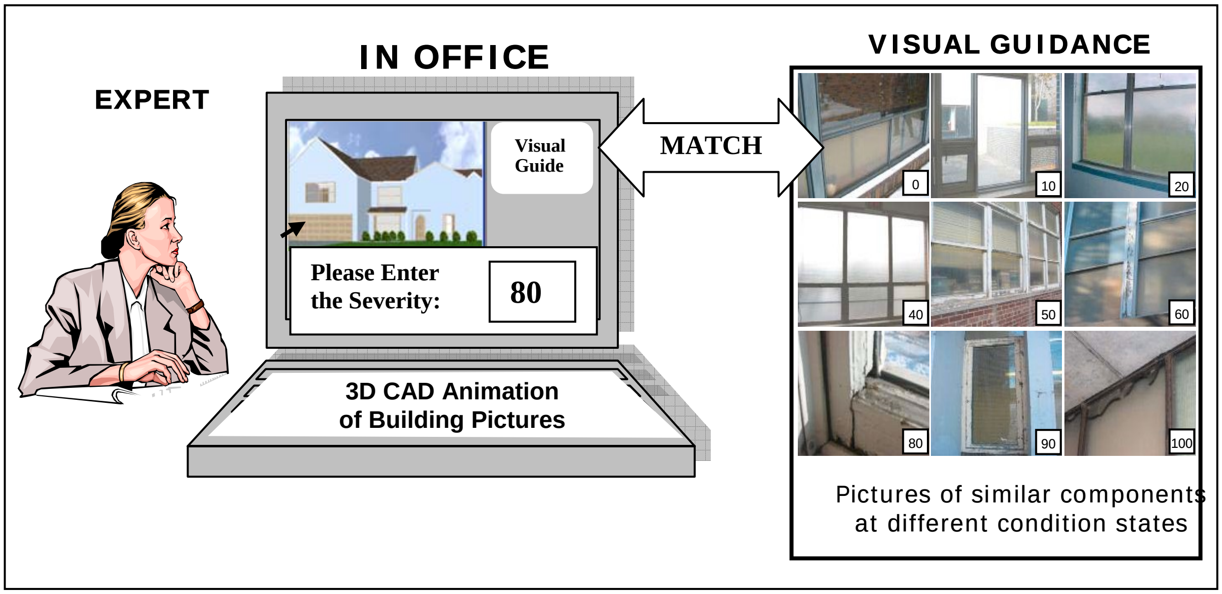

Figure 4: Proposed Support for Condition Assessment

CONCLUSIONS

In this paper, an effort is made to support the costly maintenance decisions of building owners by suggesting improvements to the current condition assessment process. First, literature related to condition assessment techniques has been reviewed and the concept of a pictorial database has been presented as a visual guidance system to enhance condition assessment. The development of the visual guidance system involves collecting images of components at different condition states, in addition to detailed analysis of the deficiencies associated with the top five building components. The collected images will be sorted according to severity levels, in consultation with expert inspectors at the Toronto District School Board (TDSB).

One of the key aspects of the present research is to separate the field inspection process from the condition assessment process. As such, field inspection becomes less costly, fast, and suitable for less-experienced individuals (local caretakers of each building). Thus, the inspection can be done simultaneously at various buildings and then sent to the central office for assessment. At the office, the visual guidance system will then be used to support a less subjective assessment of components' conditions. In addition, the visual guidance system will facilitate the planning of any additional field tests (destructive and non-destructive) that may be needed for some building components. The research is beneficial to large owners of educational, health care, and other building infrastructure, and will assist managers in decisions that ensure cost effective maintenance and uninterrupted operations of buildings.

REFERENCES

Alaska Department of Education (ADOE 1997). "Guide for School Facility Condition Surveys", State of Alaska, USA.

ASCE (2006). 2005 Progress Report Card for America's Infrastructure, "http://sections.asce.org/ louisiana/directory.htm" Accessed Feb. 20, 2006

Ashworth, A. (1996). "Estimating the life expectancies of building components in life-cycle costing calculations". *Stuct Surv.*, 14(2): 4-8.

Assaf. S., Al-Hammad, A., and Al-Shihah. M. (1995). "The effect of faulty construction on building maintenance". *Build Res. Info.*, 23(3):175-181.

Bordogna, J. (1995). "Civil Infrastructure Systems: Ensuring their Civility". *Journal of Infrastructure Systems*, ASCE, 1(1): 3–5.

Brandt, E. and Rasmussen, M.H. (2002) "Assessment of Building Conditions", *Energy and Buildings*, 34(2), pp. 121-125.

Brilakis, I. and Soibelman, L. (2003). "Blind Relevance Feedback for CIVR in the Construction Industry", CKDD Internal Report 003/2003, Department of Civil and Environmental Engineering, University of Urbana Champaign, USA.

BUILDER (2002). "BUILDER User Guide".

Chew, M. Y. L., and De Silva. N. (2003). "Maintainability problems of wet areas in high-rise residential buildings". *Build Res. Info*., 31(1): 60-69.

Department for Education and Skills (DfES, 2003) "Assessment Management Plans - Condition Assessments, Section 3a: Getting into the Condition", DfES/0175/2003, Sherwood Park, Annesley, Nottingham.

Elhakeem, A. and Hegazy, T. (2005) "Towards a Visual Guidance System for Condition Assessment of the Building Infrastructure", CD-ROM, CSCE Specialty Conference on Infrastructure Technologies, 2-4 Jun, Toronto, Ontario, Canada.

Federation of Canadian Municipalities (1999). Quality of life infrastructure program. Ottawa, Ontario, Canada.

Federation of Canadian Municipalities (2001). Early warning: will Canadian cities compete?, FCM, Ottawa, Ontario, Canada.

Lewis, B.T. and Payant, R.P. (2000). "Facility Inspection Field Manual: A Complete Condition Assessment Guide", McGraw –Hill.

National Centre for Education Statistics (NCES July 2003). "Facilities Information Management: A Guide for State and Local Education", US Department of Education, NCES 2003-400, USA.

PPTI (2006). "http://www.recapp.com/" Physical Planning Technologies Inc., Accessed Feb.20, 2006.

Rugless, J. (1993). Condition Assessment Surveys, *Facilities Engineering Journal*, 21(3): 11-13.

USACERL (2006). "http://www.usace.army.mil/civilworks/cecwe/coexpert/doe/emscenter.htm" Accessed Feb. 20, 2006.

Uzarski, D. R. (2002). Condition assessment Manual for Building Components for Use with BUILDER Version 2.1.

Vanier, D.J, Doshi, H, Kyle, B.R. (1998). "Roofing Maintenance Software Review: The Art of Roofing Conditions Inspections" (First Report), National Research Council Canada; Ryerson Polytechnic University; Public Works and Government Services Canada, C.M.E.L. Engineering.

Yau, N.J. and Liao, H.K. (2005). "An Automated Visual-Aid System for Inspecting Concrete Bridges", Proc. of the Tenth Int. Conference on Civil, Structural and Environmental Engineering Computing, Civil-Computing Press, Stirling, Scotland.