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Efficient Management of Inspection and Monitoring Data for a Better Maintenance of Infrastructure

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ABSTRACT

In North America, Europe and Japan, government agencies and large private owners are now facing the challenge of maintaining, with limited resources, large stocks of vital structures like traditional and nuclear power plants, Cooling towers but also highways, railways, bridges, dams, harbors, industrial facilities etc… These structures are representing a large amount of money, have not been designed to be easily repaired or replaced, and are getting older and more vulnerable.

People involved in structure management have developed extensive technical methods and tools to monitor the condition of the structure and establish the diagnosis. Each authority has been developing is own inspection maintenance procedures, taking into account their specificity, their different priorities, safety requirements, resources and range of competence.

In most cases visual inspections are used to detect deteriorations, to rank structures, define priorities, estimate repair costs, etc… These visual inspections require to record, report, analyze and store for years large quantities of data (inspection records, drawings, photos…) and it is easy to get lost in the clerical work. Moreover a number of decision steps (inspection record, ranking of defects, long-term analysis) are still highly subjective and can greatly affect the quality of the final diagnosis.

An inspection-based management software system has been developed to optimize this process and provide decision-makers with objective information on the condition of the infrastructure. The system is a comprehensive management system which integrates: database of structural defects, on-site computerized record, analysis, maintenance, diagnosis, repair and budgetary functionalities.

This paper describes the basic functions and benefits of the system.

1. LIMITATIONS OF CONVENTIONAL INFRASTRUCTURE MANAGEMENT PROCESS

The characteristics and limitations of, still widely used conventional structure management process are listed below:

- Design data (drawings), inspection data, detailed investigation data and repair data are not stored in a single system.
- Inspection frequency for a given structure is based on the type and age of the structure. It is rare that the date of inspection is based on the results of the previous inspection.
- Before inspection, inspectors must prepare inspection drawings – very often original design drawings are not available and inspectors must spend time to make new drawings.
- During inspection: the inspectors take hand-written notes of the defects. Inspectors usually do not bring with them the heavy reference manuals.
- Back in office the inspectors copy the deterioration onto the structural drawings, along with their dimensions and characteristics. Sometimes these data are stored electronically (excel sheets and CAD drawings).
- In accordance with the inspection manual, a ranking indicator or a comment is affected to each deterioration. The inspectors then establish reports that are transmitted to the engineers in charge of the analysis.
- The engineers receive several reports from different inspectors. They may have difficulties with inconsistent data, inhomogeneous ranking systems, unreadable handwriting or confusing dimensions. However on the basis of these reports the engineers must estimate the condition of the structures and recommend actions for maintenance or repairs.
- When needed, detailed investigations are performed by specialized consultants and specialized contractors propose repair solutions.
- Maintenance and repair costs are then presented to decision makers.

After reviewing the above points, it becomes clear that even with a clear inspection manual and an efficient organization, conventional infrastructure management process allows too much room for subjectivity and conventional infrastructure management is expensive.

2. OBJECTIVES OF THE INSPECTION-BASED MANAGEMENT SOFTWARE

The inspection-based management software has been developed with the following objectives:

- improve the overall efficiency of the maintenance process,
- reduce the cost of maintenance process at all steps,
- build a comprehensive database system which integrates all steps of the maintenance process (inspection preparation – inspection – reporting – analysis – repair – budget),
- facilitate the task of inspectors,
- assist engineers in the compilation and analysis of large quantities of data,
- allow easy access to all data at any step of the engineering and decision process,
- provide decision makers with valuable and objective information on the condition of the infrastructure, on which they can base and justify their decisions.

3. BASIC DESCRIPTION OF THE INSPECTION-BASED MANAGEMENT SOFTWARE

The inspection-based management software consists of several components specifically designed to handle the tasks of each people involved in the maintenance process (Table 1).

Software components	Tasks	Designed for
Infrastructure Management	- database of detailed information on structures (drawings, design-construction-inspection-repair data), - ranking of structures according to preset rules, - management of the database, - budgetary tools, - scheduling of tasks, - management of repair works	- operators of structure, - consultants, - specialized inspection companies
Inspection Management	- preparation of inspections, - transfer of data from mainframe to mobile inspection units	- inspectors, - specialized inspection companies, - consultants
Inspection	- on site recording of deterioration (on pen-touch light computers) - reference available	
Photo-based inspection	- time-effective survey of deterioration based on photos	
Report	- reporting of site-records, - automated standard report	
Analysis	- advanced analysis functions, - detailed investigation, - detailed repair definition	- engineers, - consultants, - contractors

Table 1: Components of the inspection-based management software

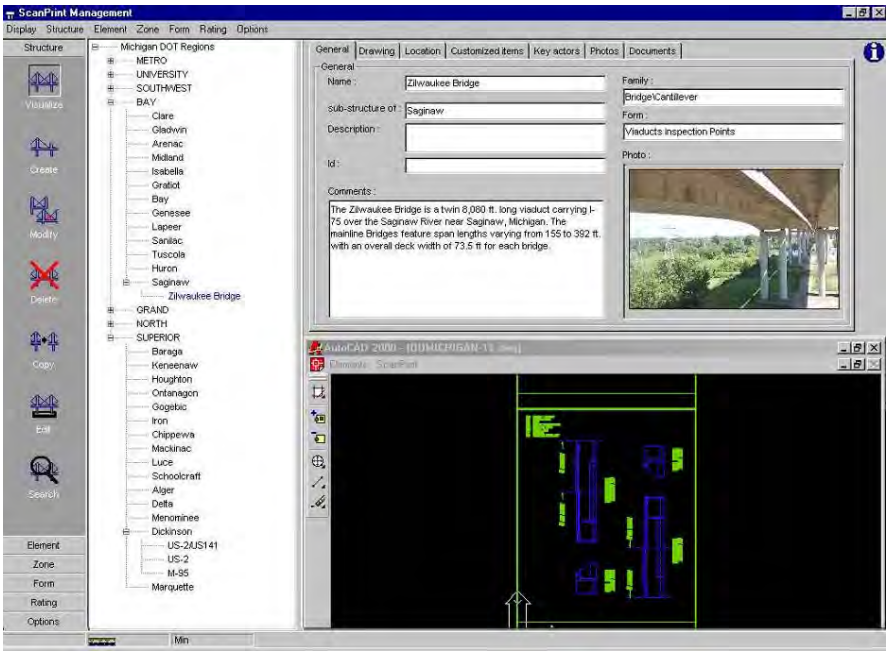

Fig.1: General information tab

3.1 Infrastructure management software

With the infrastructure management software, operators can organize their inventory of structures. The system allows to build a database including:

- general information about each structure (design, construction, location, pictures, drawings – see Fig.1),
- detailed check-lists for each structural component (see on Fig.2 an example for expansion joints),
- damage criteria for ranking of deteriorations (see Fig.2 where limit values for joint opening are defined),
- catalogue of repair solutions and corresponding costs and durations (see Fig.3).

The software has been built so that all parameters can be changed and adjusted to the specific usage of each industry/administration/operator. For example: the limit criteria for crack opening is smaller in nuclear containment vessels than in highway tunnels. Such a limit criteria can be set in accordance with the corresponding regulations.

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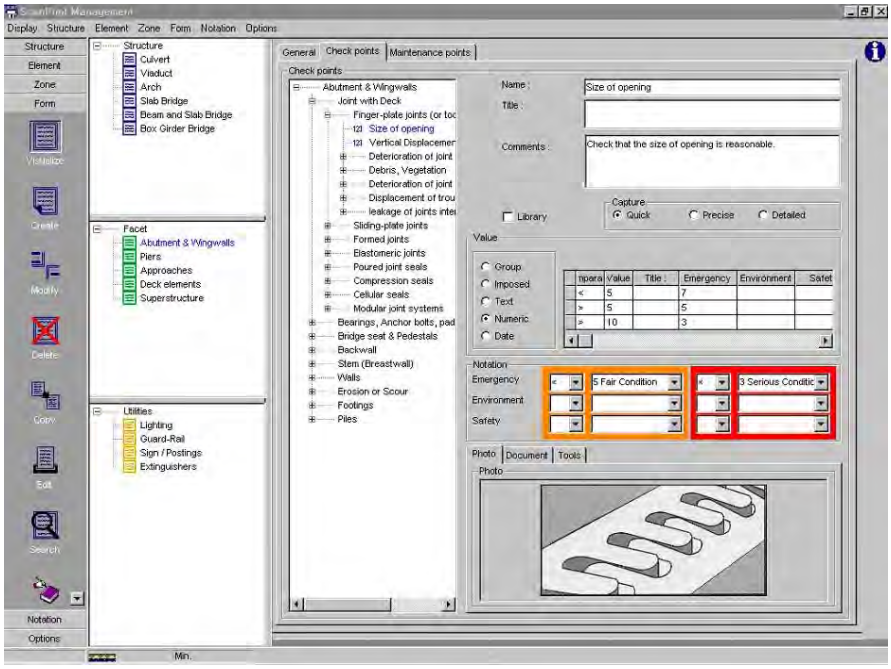

Fig.2: Definition of check-points and damage criteria for expansion joints

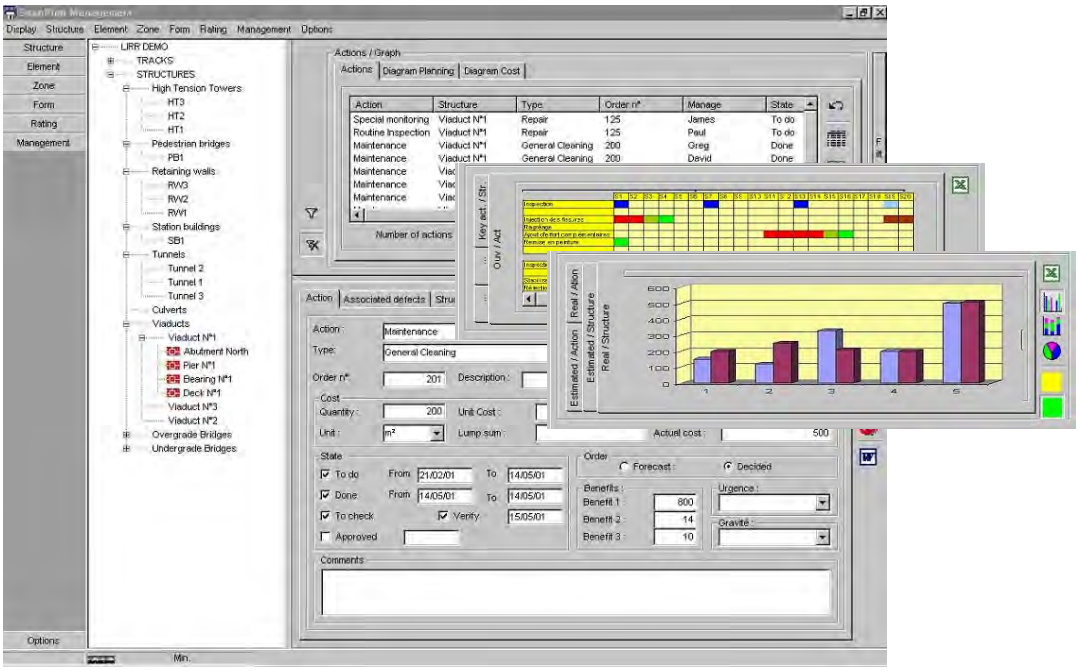

Fig.3: definition of tasks, with corresponding costs and scheduling

3.2 Inspection software

The inspection software is designed to simplify the task of inspectors and ensure coherent and regular deterioration surveys and maintenance records (Fig.4). Running on pen-touch computers (Fig.5), the inspector can access at any time:

- the inspection reference manual,
- the drawing of the inspected structure,
- the history of the deterioration that was recorded in past inspections,
- the maintenance check-list for each structural component.

When the inspector detects a deterioration, he draws with the pen directly on the computer screen the shape of the deterioration. He can use a reference of more than 200 deterioration types classified in families. In accordance with the inspection manual, the software then requests the inspector to measure and record a certain number of parameters to describe the deterioration (dimensions, color, humidity level…). He may also want to take pictures of the deterioration. The software saves all this information in the database:

- the deterioration type,
- its graphical representation in the CAD drawing,
- its dimensions and other specific parameters,
- any picture of the deterioration.

Because these data are linked together in the database, it will be easy to access and sort such information at any step of the maintenance process, even years after the inspection.

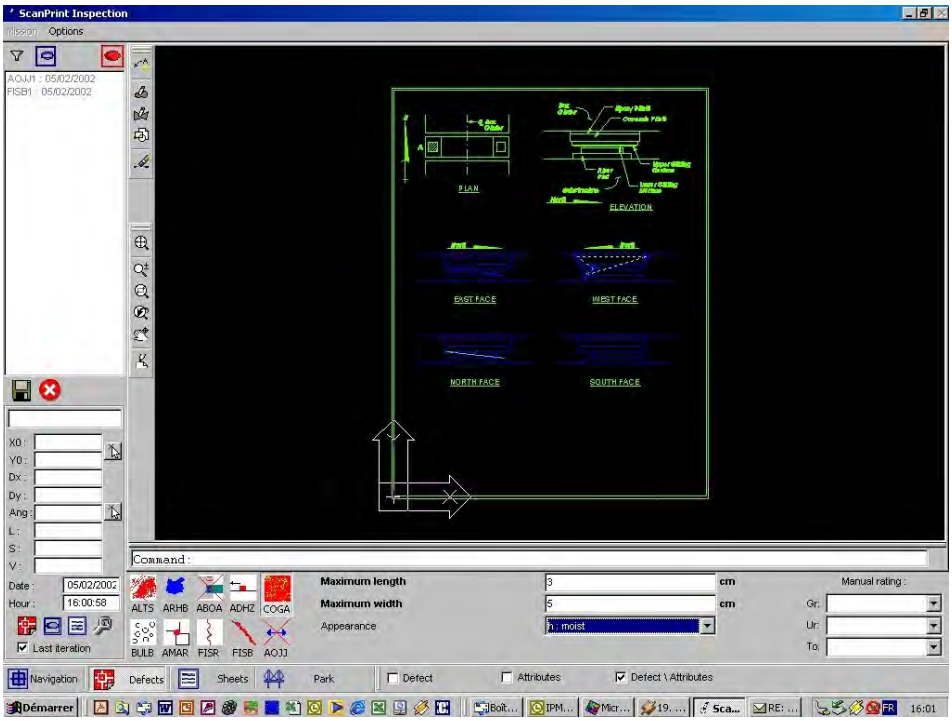

Fig.4: Site inspection software running on pen-touch computers

3.3 Photo-based inspection software

In some cases when access is difficult, survey of deterioration can be done using high quality digital pictures. The photo-based inspection software has the following functions:

- correction of the lens deformation of the picture,
- deformation/scaling of image,
- on-scale insertion of image data into CAD drawing,
- highlighting of typical deteriorations (rebar, cracks…)

Photo-based inspection is often a cost-efficient alternative for the inspection of large structures (dams, cooling towers, etc…)

Fig.5: Site inspection using pen-touch computers

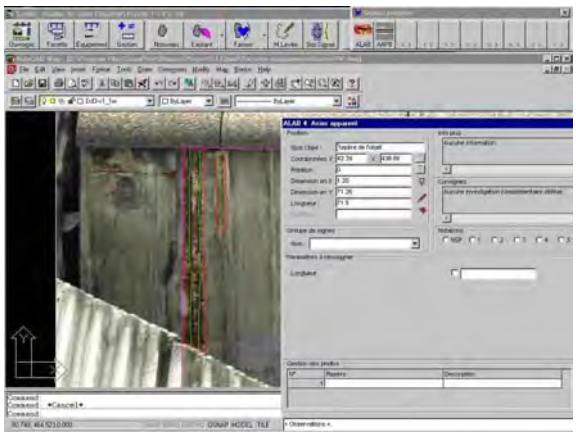

Fig.6: Photo-based deterioration survey

3.4 Reporting software

Immediately after an inspection has been performed, the inspectors can edit standard reports with the reporting software:

- output of drawings with deteriorations (Fig.7),
- tables,
- pictures.

The process is automated and the output format can be adapted.

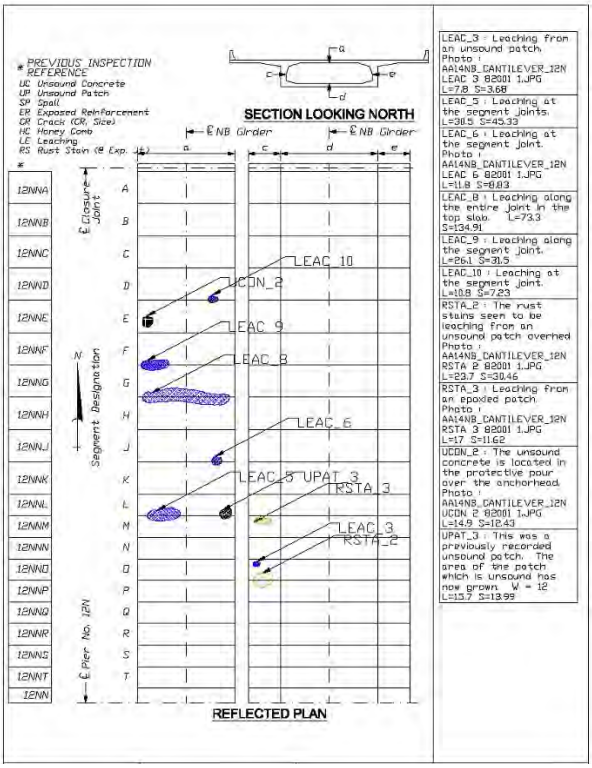

Fig.7: Standard output

3.5 Analysis software

Designed for engineers in charge of the analysis of data, the analysis software consists of a set of tools for:

- browsing and sorting of data,
- evolution of one deterioration or a group of deteriorations,
- comparison of similar structural components,
- evolution of the condition of one structure, evolution of the stock of structures,
- identification of deterioration to be repaired in priority,
- bill of quantities for repairs,
- assistance in the diagnosis.

4. BENEFITS AND DIFFICULTIES

The direct benefits are cost reduction and improved efficiency due to:

- organized database of consistent data (structural, inspection, maintenance and repair data),
- easier access and sharing of information,
- time savings for preparation of drawings, reporting and analysis of data,
- long-term management.

Whereas the main difficulties in implementing the system are:

- staff need to be computer literate,
- drawings that exists only on paper must be digitalized (scanner) or redrawn with CAD,
- older data should be input in the new system.

The system is therefore easier to implement on recent structures because CAD drawings are available and older data is smaller: the system has been used from the beginning on the Tagus estuary crossing in Portugal (Vasco de Gama Bridge).

However, the extra work required to input paper-based drawings and older data can be recovered through cost and time savings at all steps of the process. During the inspection and analysis of the Zilwaukee bridge (a twin 2.5 km-long precast segmental viaduct carrying I-75 over the Saginaw River, Michigan, USA), the system proved to be very cost-effective. Every day the inspectors sent the data by email for review by the Project Manager and the analysis team, located 3,000km from the bridge. Data from previous inspections was later inputted electronically so that it can be compared, sorted and visually displayed along with new data.

5. CONCLUSION

Structure management is an increasingly important concept for structure owning authorities or private companies around the world today. Each owner has been developing its specific health condition indicator system, allowing to express the structural condition of a structure by some quantitative measure, to monitor durability, safety and to decide at what point action needs to be taken.

A management software that would integrate all the steps of this maintenance process can dramatically optimize its efficiency through easier management, storage, sharing and analysis of the structural information. While such a concept is not new, this paper presented in detail the capabilities and benefits as they were observed in actual large scale implementation of the inspection-based management software.

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