Learning from damage of masonry structures, expert systems can help!

Koenraad E.P. Van Balen
K.U.Leuven, Department of Civil Engineering and R. Lemaire International Centre for Conservation, Leuven, Belgium

ABSTRACT: Only a limited number of expert systems are used in the field of architectural conservation and the Masonry Damage Diagnostic System (MDDS) is positioned between them. The development of MDDS is explained and its features that make it interesting to the users are described. Expert systems as MDDS are the demonstration of the change of attitude towards the approach of architectural conservation. The interest for minimum intervention, maintenance and continuous attention as a means for integration of heritage in the life of tomorrow are in fact the basis of the development of such instruments. In this way they can help to use proper conservation strategies, learning from damage.

1 INTRODUCTION

Treatment options for conservation and restoration of historic structures depend on various factors and include aspects related to different disciplines. For architectural historians involved in decision taking processes for the conservation of historic buildings the decay problem is often evaluated in a different way as by engineers or material scientists. From the other hand historical information (e.g., severe damage that occurred in the past by an accident) is a very valuable source of information if existing damage is to be evaluated.

Multi-disciplinary approach and possibility of exchange of information between different partners are hence crucial when choices between treatment options have to be made. Diagnostic tools to evaluate the condition of historic structures as to arrive at suitable treatments should take this into account.

A research group co-ordinated by the author developed an expert system (Masonry Damage Diagnostic System (MDDS)) and an Atlas of Damages of historic brick structures aiming at improving the diagnosis of masonry structures. This expert system and Damage Atlas are used to evaluate type and cause of damage before intervention but can be used to evaluate previous interventions and monitor changes in the state of preservation.

This monitoring fits within the loop-approach: analysis - diagnosis - therapy - control (-> analysis) (Lemaire et.al. 1988). This approach is also proposed in the Principles developed by the International Scientific Committee for the Analysis and the Restoration of structures of the architectural heritage (ISCARSAH), the Scientific Committee of ICOMOS dealing with the problems of structural preservation.

It seems more and more accepted that conservation of historic buildings is better served with regular control and regular maintenance of buildings than by a “heavy” intervention every 50 years. The group of professionals dealing with monuments’ conservation is widening to technicians dealing with small gradual interventions and regular control as is happening with the creation of “monument watch organisations” (Monumentenwacht) in Flanders and The Netherlands. This interest in monitoring and follow-up of the state of conservation of historic structures and more ordinary buildings in historic towns and villages is increasing also in Southern Europe and

in earthquake prone regions. This fact demonstrates the change in attitude toward maintenance versus restoration.

The maintenance concept for intervention is based on the minimum intervention principle (Van Balen et.al. 1999a) and considers actions (interventions, controls) for small time steps. The monitoring could serve as guiding tools towards a proper calibration of the next step to take. It means that we can learn from damage and damage progress to develop the best conservation strategies and expert systems can help to do so!

2 EXPERTS SYSTEMS IN THE FIELD OF ARCHITECTURAL HERITAGE

2.1 How many expert systems are there in the field?

There are only few expert systems developed for the field of conservation although expert systems seem to become of increasing importance for decision taking in different fields. Management, design and monitoring complex processes that requires knowledge on different fields and taking into account different variables make use of those knowledge based systems.

Bibliographic search in the scientific literature (International Scientific Information) revealed that since 1972 10.017 articles have been written on expert systems of which 446 were related to building, 428 referred to architecture (in the broad sense including e.g. software architecture), 8 matched with archaeology and 3 matched with heritage. In a more specialised bibliographic database (BCIN) dealing with heritage we found 31 references to expert systems and heritage between 1985 and now.

Expert systems or knowledge based systems seem appropriate for disseminating information in a way that its is useful to different types of end users in the field and for learning processes. Their use stimulates a wider perspective (a more holistic approach) and promotes transparency and consistency in the assessment of damage and development of strategies. In the field of management of architectural and archaeological heritage expert systems seem to be of interest but not developed sufficiently.

2.2 Masonry Damage Diagnostic System

Different bibliographic references refer the mentioned EC-research project that has been dealing with damage assessment in historic brickwork "Expert system for evaluation of deterioration of ancient brick masonry structures: Masonry Damage Diagnostic System (MDDS)". This project has received a lot of attention in the conservation field as it aimed at bridging the gap between scientific information and application of it in the field of architectural conservation. Different authorities, educators and professionals have expressed the interest in progressing further in this way: promote scientific research that contributes to the development of similar expert systems or knowledge base systems.

Since the Masonry Damage diagnostic system has evolved and is being further developed within the Pointing EC-project the system. Modifications are now made to reply to the demand of different possible end-users.

2.3 The first MDDS and the damage atlas for brick masonry

The objective of the project was to improve the knowledge on the effects of environmental factors on damage to Europe's cultural heritage and to guarantee better treatment and protection by providing the professionals who work on the analysis of ancient buildings with an expert system including a damage atlas.

The research was based on a scientific inter-disciplinary approach, accepting as a starting point the complexity of the problem (see later on the change of attitude). The scope of the project was limited to the evaluation and interpretation of damage including understanding of damaging mechanisms. The approach started from the assumption that understanding damage serves the conservation. The relation between damage definition (type) and damage cause (process) is based on a thermo-dynamical approach: resistance against stress defines the damage. In that respect approaching from visible damage, the process of decay is the right way to make tools that can be

used for monitoring. It was at the time the EC-project was set-up (in 1991) very innovative to try to develop through scientific research a useful tool directed to possible end-users. The selection later on of the project as a success story before the fifth framework programme has been launched is in my opinion recognising the innovative character of this project. This success however has not really stimulated the further development of user directed research on expert systems. Extensive information on this project can be found in the report published in 1999 (Van Balen et.al., 1999b)

2.3.1 Objectives as defined at the start of the project.

The aim of the project was to create an instrument bases on scientific information that could increase the number of persons to execute general monitoring of historic buildings. By increasing their number there should be a shift toward maintenance type interventions on historic buildings instead of more "heavy" restoration interventions. Therefore groups of technicians, architects, engineers should be helped in executing correct analysis of the major part of (more simple) damage cases, leaving the more difficult and special cases to the smaller group of leading professionals. The latter will be thus only involved in those cases where very specialists' information is required. It has also been noticed that even for specialists those instruments could be a helping guide when they have to deal with fields in which they do not have very specialised knowledge. To define the group of less research oriented professionals the profile of the "Monumentenwachters" (Monument Watchers) of the Netherlands or in Flanders has been taken as a reference.

2.3.2 Methodology

The methodology used is based on the scientific principles of research. In the problem stated, damage to historic brick structures, and the development of the Masonry Damage Diagnostic System defined the scientific description and deductions of the physical mechanisms causing the damage. Inherent choices have been made in relation to the order of input taken into account for the deduction: it started with the most easy way of identification which is visual analysis (this also explains the usefulness of the damage atlas) and then included in order the in situ and laboratory tests. A thermo-dynamical model of decay of materials as developed in the project defines damage as a result of stresses and resistance allowed damage types and damage causes to be linked. This was then developed in terms of processes within the Masonry Damage Diagnostic System. The development of the Masonry Damage Diagnostic System allowed in many cases to limit the problem only to those parameters that are described really necessary (goal oriented), thus omitting irrelevant elements while the link with the practice remains guaranteed.

This approach is unique in this field and the experience of the project demonstrated the scientific interest of this engineering approach for the evaluation of deterioration of ancient brick structures. It is an applied scientific approach producing practical results for the conservation of historic brick monuments.

2.3.3 Research results.

2.3.3.1 Terminology.

In the first stage of the work common definitions had to be set up which should be useful within the different instruments of the project. A first set of damage types has therefore been defined which is useful for the questionnaire but could be developed within the Masonry Damage Diagnostic System. The hierarchic concept allows the user to narrow his definitions gradually. This approach was based on the assumption in the project that defining goes hand in hand with increasing knowledge. Vague knowledge needs broader terms while added information has to narrow the set of terms. In the questionnaire the group of damage types is given with the subset of more precise terms. The logic in the definition was based on the visual discrimination. It has been defined so that in the order of the analysis the visual appreciation was the first "instrument" used. As the questionnaire and the related damage atlas are related to this first analysis, it was logical that the definition of damage types should use visual criteria. Within the Masonry Damage Diagnostic System the same terminology has been used while the "instrument" itself allows the user to check his interpretation of the terminology by answering questions defined by the conditions contained in the definition of the term.

2.3.3.2 Questionnaire.
For the development of the system and to allow the checking of the system with case studies a questionnaire covering the analysis of damage to historic brick structures was developed. Its first development stemmed from the collaboration of the experts of the NATO-CCMS pilot study on Conservation of Historic Brick Structures and it has been modified considerably during the project (Van Balen 1998).
The main reasons for this development are found in the interaction with the set-up of the terminology which was developed in relation to the Masonry Damage Diagnostic System.
It was experienced that even experts contacted by purpose were reluctant to formalise the collection of information into a questionnaire if they see no direct interest or reply leading them to the diagnosis. As an instrument to monitor, the questionnaire had the disadvantage to be to lengthy, not precise and synthetic enough.

2.3.3.3 Damage atlas.
A classification of damage patterns found in brick masonry has been set up (Franke et.al. 1998). The terminology used follows the same structure and set-up as the questionnaire and the Masonry Damage Diagnostic System. The definitions are more extensive than the definitions presented in decision table form in the Masonry Damage Diagnostic System and possible damage causes are also given. A complete set of illustrations of the different damage types is provided in the atlas with an explanation about the possible causes of the damage. Consistency with the Masonry Damage Diagnostic System was guaranteed as they were developed to be used together. The publication is used by students and professionals in the field and is recognised to be useful for its purpose to help making a diagnosis of historic masonry structures.

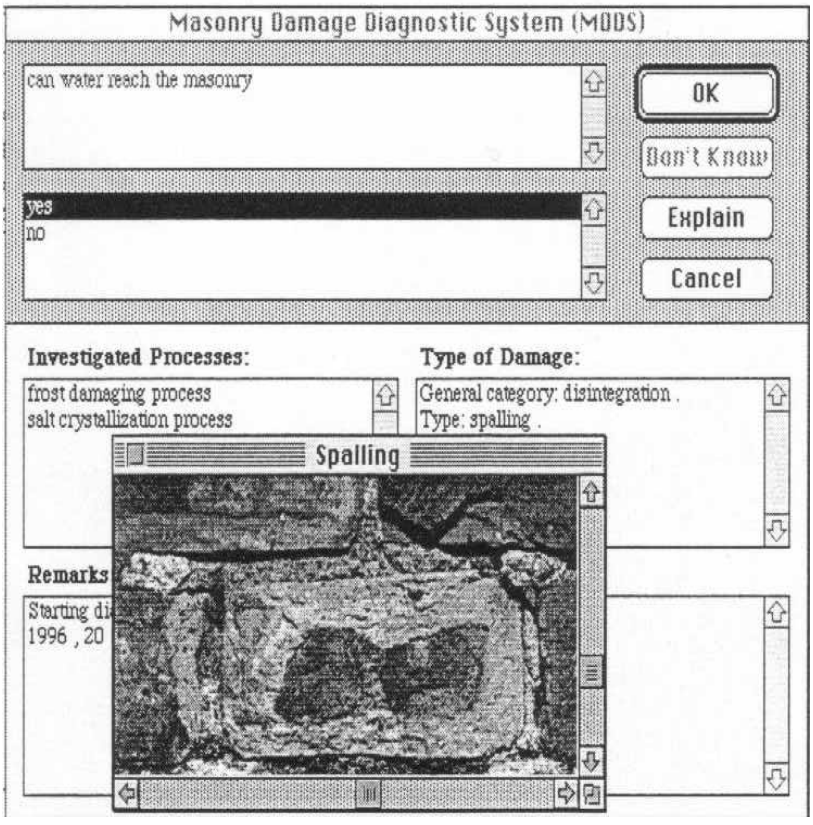

Figure 1: Typical screen picture of the first MDDS programme, showing an example of a damage type and the start of the damaging mechanism investigation.

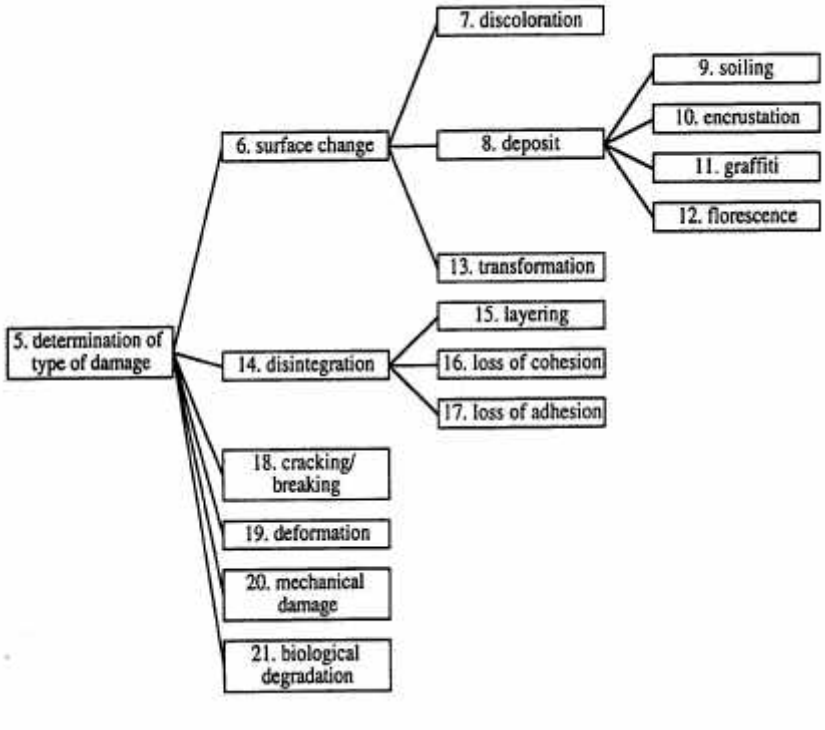

Figure 2: Decision tables tree with the different definitions of damage types, using an hierarchical approach.

2.3.4 The first Masonry Damage Diagnostic System

2.3.4.1 Structure and concept.

The Masonry Damage diagnostic System (MDDS) (Van Hees et.al.1995) is a Knowledge-based System (KBS). It is a database with information and additional knowledge to create relations according to given answers and questions. It is the translation of expertise into a computer system. The knowledge is structured and can be consulted using a Decision Table System Shell (DTSS) developed by TNO-Bouw. It was a programme running on Macintosh computers and later a Windows version has been made. The Masonry Damage Diagnostic System was and still is a prototype and is not for sale. It is the aim of the partners of the project to create links with organisations that would like to develop the existing system for their use and co-finance in this way the updating and extension of the system.

The knowledge is translated into a large set of decision tables themselves containing sets of conditions and actions. The set of condition tables is structured in a hierarchic way and can be presented as a decision table tree. (Van Hees et.al. 1995)

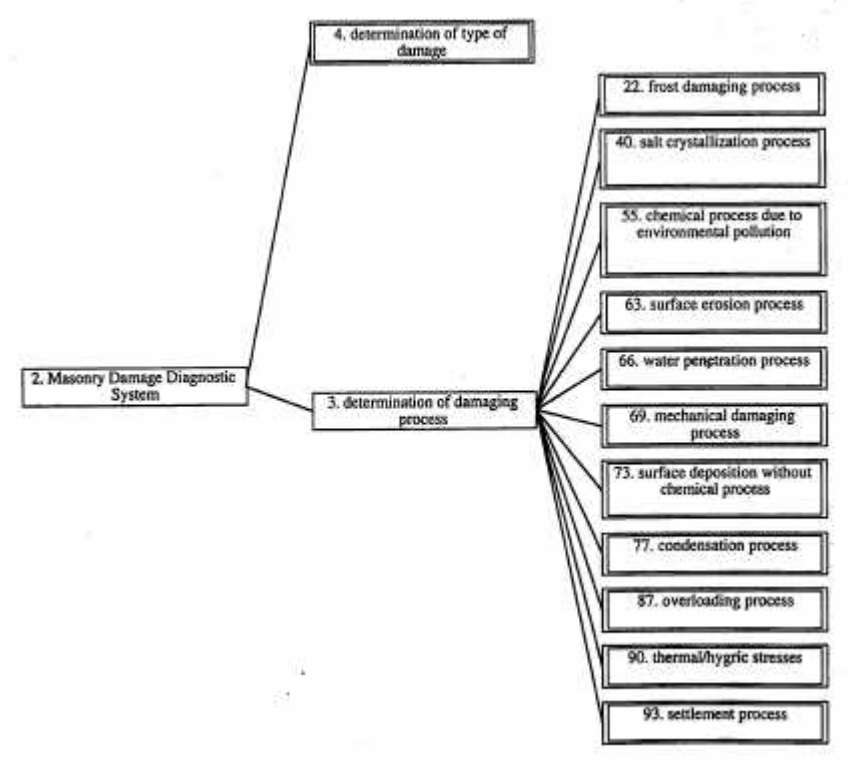

Figure 3: Decision tables tree with the damaging processes to be checked.

2.3.4.2 Consultation procedure:
The computer programme aims to make the consultation of the Masonry Damage Diagnostic System user-friendly. In contrast to the questionnaire the Masonry Damage Diagnostic System will adapt its questioning according to previous answers given. Comparative data as pictures and comparative results of test trends are also given so that if there is uncertainty or when the answer to be given is not clear, additional information can be consulted. A typical screen picture is given in Figure 1.

2.3.4.3 Consultation output.
The output of the Masonry Damage Diagnostic System is given immediately on the screen, but a printed report of the consultation is also generated. The user can use this document as a report. The results of a consultation can be stored in a file that allows progressive and step-by-step consultation in different stages. During the progress of the project it has been shown that it is very useful to create, using the Masonry Damage Diagnostic System, an interesting collection of examples of damage. The structure of the KBS within the Masonry Damage Diagnostic System obliged the users to work in a very systematic way while developing the system and using it afterwards.

2.3.5 Important features of the first MDDS
The MDDS had contributed considerably to the description of damage types on historic brick structures. The link between terminology, questionnaire, damage atlas and Masonry Damage Diagnostic System was guaranteed by accurate definitions and the hierarchic concept of the damage types descriptions. In the same way the description of possible damage causes and the processes leading toward the above-mentioned damage types have been improved. The increase in systematisation that was sought by the project is a necessary and interesting by-product of the creation of Knowledge Base systems (KBS).

The Decision Table System Shell (DTSS) has proved to be a very interesting tool for the development of the KBS.

The collection of different types of information using the questionnaire and other related summary sheets allowed the research team to make an interesting collection of degradations of different types. Those examples are useful for the elaboration of the damage atlas.

Reactions on the complexity of the questionnaire and uncertainty on the part of the user about which information should be mentioned in this document prove the advantage of the Masonry Damage Diagnostic System. It is certain that in the dialogue between the expert system and the user the latter will feel more comfortable as he will think that the questions which are asked are relevant to the problem. On the other hand the expert system will limit his questioning only to that information it can consider in its reasoning. It was at that stage expected that further development of the Masonry Damage Diagnostic System could be guaranteed by the integration of research results from other projects.

2.4 Latest developments of the MDDS

Further development of the mentioned expert system was first made at a voluntary basis in the contacts between the Dutch and Belgian partners and the local Monument Watch organisations. It was felt that a translation into a Windows environment was necessary and that a certain type of modifications had to be made.

2.4.1 Consultations for improvement

In March 1996 a workshop with Monumentenwacht Nederland and Monumentenwacht Vlaanderen was organised and a systematic feed-back was collected. At the occasion of the EC-project "POINTING" co-ordinated by R. Van Hees from TNO-Bouw it was tested in which way new information could be added and the use for end-users could be improved. Different workshops were organised in The Netherlands, Belgium and Italy. The feed-back given by National authorities (+ regional consultants), Government building agency, Monument Watch (NL, B.), Bishop's Building agencies, Municipal authorities of important monument cities, scientists and conservation technicians was given through a questionnaire.

It was evaluating the general interest for the MDDS concept, it asked for the missing parts and checked if the organisations represented would be willing to use it and to contribute to the development.

The participants expressed that there is an important interest in use of such a system. It seems promising but needs further completion to be useful on site. Organisations as Monument Watch would require information about advice to give to the owner and last but not least local language versions were definitively requested.

Collaboration for further development seems present and some of them are willing to collaborative to the development through membership in a "users group". It was clear that also new research is needed to develop the scientific information that the "concept" of such a shareable knowledge requests (e.g. background information, …).

2.4.2 An outline of the new system.

The most striking differences of the new systems are the "on-line" Web environment including the features the previous system had. The extensive on-line documentation with articles and recommendations on techniques of repointing are related to the consultation context.

The advantage of the on-line version is the ease of keeping the information updated and to solve all possible bugs in the system. The disadvantage however is that access from on site is more difficult.

3 MDDS-LIKE EXPERT SYSTEMS ANSWER TO NEW APPROACHES IN CONSERVATION.

3.1 The importance of maintenance and small step approaches

The concept of instruments as the Masonry Damage Diagnostic System is particularly of interest for the conservation of monuments if it is related to a concept of gradual, small time step approach and with a merely continuous following up, this is monitoring. It allows using "evolution of damage" as an element of evaluation as objective criteria (terminology and testing procedures) are available for its description. The same description is the communication tool between different specialists dealing with the conservation of a particular building or with the authorities responsible for the conservation policy. Let's not forget also the owner who requires an objective idea of the state of his building and is willing to plan his future interventions.

Although it seems rather obvious, it seems that those concepts differ considerably from the (sometimes hidden) concepts guiding the way of conserving historical buildings the last decades. Speaking with the situation of Belgium in mind, which does not significantly seem to differ from the situation in other countries, we can see a change in attitude coming up. It is in demonstrated by the fact that organisations dealing with monuments' maintenance have been set-up and interest for them is increasing in Europe.

Nowadays inter-disciplinarity seems to be of importance in an increasing number of research fields. It results from the post-modern attitude that opposes simplicity against complexity, determinism against probability, order against chaos, structure against fragmentation. If we accept this complexity and know that the information should be treated as probabilistic, this inherently means that we can -from an ethical viewpoint- only limit our intervention to a small one. It will be only one in the long chain of history which obliged us continuing watching at the monument as to understand how its reacts on the intervention. This reaction, e.g. damage will guide us towards the next step to take. This approach also avoids over-done restorations.

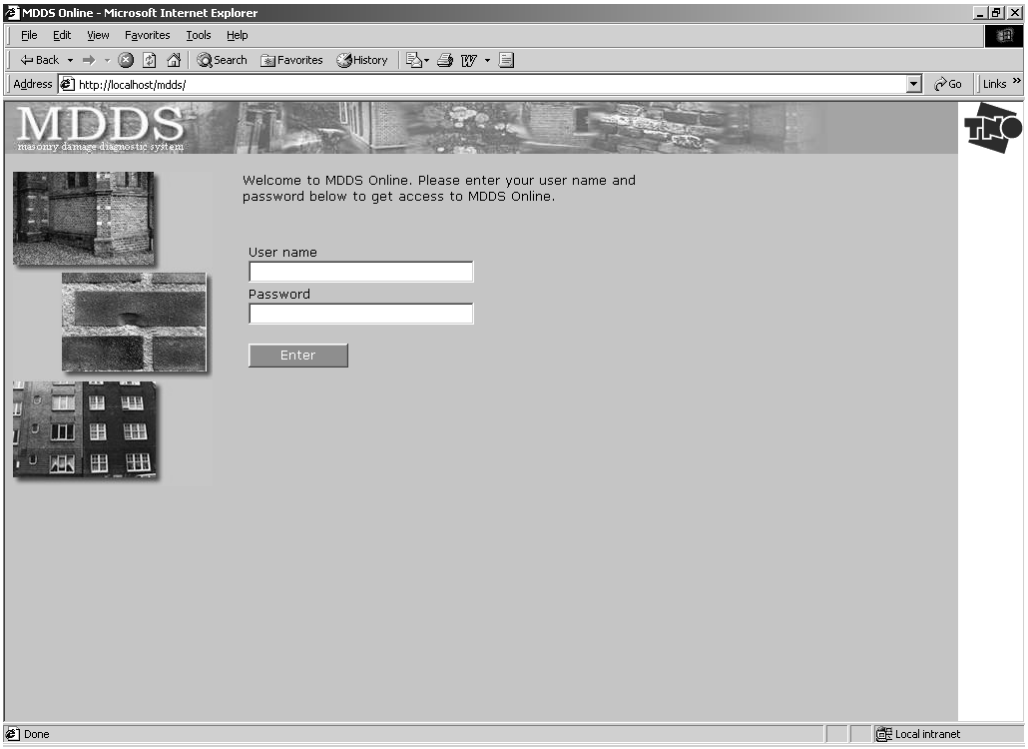

Figure 4: Welcome screen of the MDDS accessible for related users through the Internet

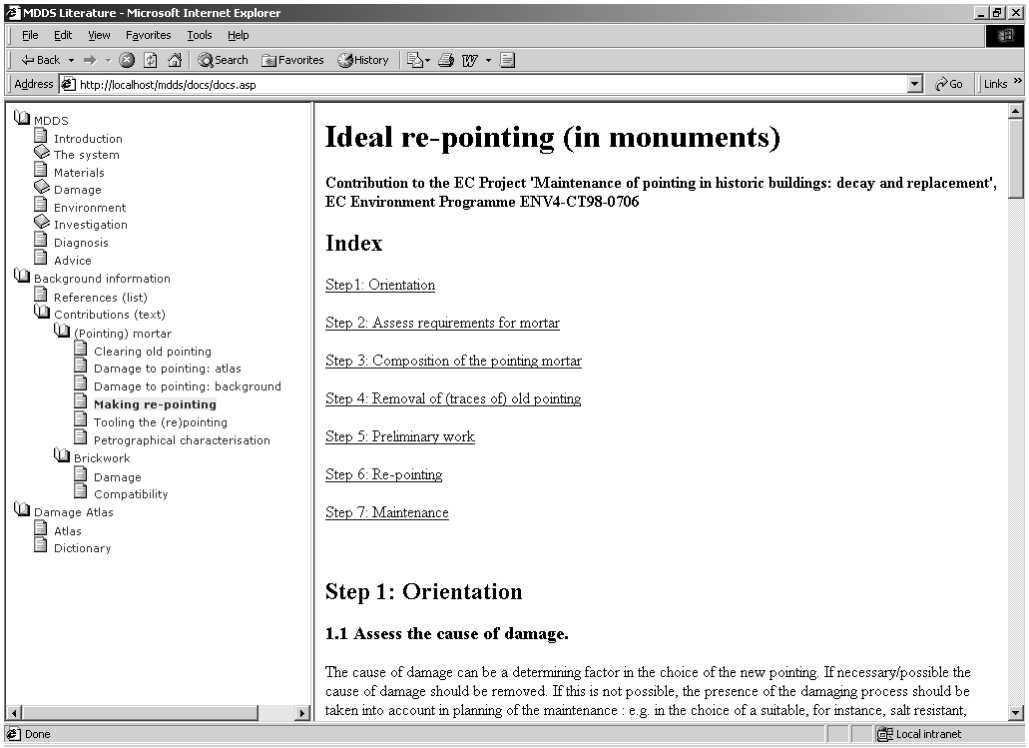

Figure 5: Consultation of background information and advice, in this case on re-pointing, is possible.

The background for such approach seems to be wider and related to our attitude to science, to dealing with heritage as a valuable source of information, in a similar sense as the interest of bio-diversity in biology.

3.2 What is changing?

We recently developed the idea at a workshop (Van Balen 2001) that the words "Universal" and "Global" are sometimes used the one for the other. It brought me to the reflection that in my in opinion explains the essence of our actual way of approaching the preservation of heritage.

3.2.1 Definitions revealing concepts.

Let's first have a look at the definitions of the above mentioned words Universal and Global.

Universal: n. 1. the whole; the general system of the universe; the universe. 2. (logic) (a) A general abstract conception, so called from being universally applicable to, or predicable of, each individual or species contained under it. (b) A universal proposition. See Universal, a.,

Universal: a., 1. Of or pertaining to the universe; extending to, including, or affecting, the whole number, quantity, or space; unlimited; general; all-reaching; all-pervading; … 2. Constituting or considering as a whole; total; entire; whole; … 3. (Mech.) Adapted or adaptable to all or to various use, shapes, sizes, etc.; … 4. (Logic) Forming the whole of a genus; relatively unlimited in extension; affirmed or denied of the whole of a subject; …

Global: adj.: 1. Having the shape of a globe; spherical. 2. Of, relating to, or involving the entire earth; world-wide, … 3. Comprehensive; total

Studying the issue of authenticity related to heritage, I found out that there is a fundamental difference between the viewpoint of the person attributing "universal" and the person attributing "global".

In my opinion those words express the difference in concept between the age of modernity (the years of the publication of the Venice Charter) and the nowadays post-modern era.

In the first period there was a belief in (unlimited) progress and prosperity; human kind was seen as Universal. Man was facing the universe as a kind, "piloting" the planet earth through the

solar systems and through the space of time. Satellites with the representation of mankind have been send to planets and the solar system. In the field of architectural conservation, the charter of Venice expressed this concept in a single approach to conservation, being valid for the kind: the Universal mankind.

Together with this perception we notice that science was based on a paradigm using a quiet deterministic approach (as can be illustrated in e.g. the problem of modelling safety assessment of historic buildings) and the belief that the reality could be modelled and understand through a limited set of parameters. The number of parameters were expected to be very limited, replying to the request of producers to be able to demonstrate the "quality" of their products at a minimal cost. An example of the latter is the use of standards (for materials, quality assessment) and the extreme extensive conclusions made using simple models of understanding.

Today the perspective seems to change into a perspective from outside of the globe to our planet earth as for an astronaut, this is the global perspective that seems to realise that our globe contains a variety of species, cultures and types of human beings. Diversity becomes a key issue and as demonstrated by the ecological movements this diversity is a necessity for future existence of the planet and its passengers: the mankind. The same might be true for the diversity of cultures, considering not only the geographical diversity but also the historical diversity (diversity over time) at the same places. Nowadays perspective is based on complexity, the understanding that everything can not be under control. Chaos-theory, developments in mathematics and computers have made us aware of this inherent complexity of the world, our ideas and our limited possibility to "control" our perception of the world, the outcome of our actions as human being.

To say it with the words of Richard Hooker: *"You can see, then, what characterises modern abstraction in a wider sense: it is the loss of standards or universals. In the place of standards we have instead only the logic of internal relationships and internal design. In such a world-view, there is little effort to integrate one sphere of human understanding with another; the modern human existence is one of fragmentation. We approach the community of humanity and we approach our own lives as made up of independent fragments that each operate on their own logic. Of all the cultural anxieties of the twentieth century, this abstractiveness and fragmentation has consistently been acknowledged as the most serious crisis of modernity."*

With other words, methods and procedures that must be transparent and consistent are replacing standards.

The implications are that we have to define a new way of approaching a number of problems, we have gradually started to do so.

There is not such a thing as a unique (universal) development strategy instead we recognise diversity in the approach as "our astronaut perception" has to recognise the lack of unity in the world we perceive.

Even from a closer look diversity is the rule. Diversity should be considered in geographical terms but also in time, we could compare it as the weather forecast pictures we see on television: we perceive the transformation of the complexity. Here "heritage" becomes an interesting issue as the understanding of the construction technologies of the past and their behaviour (damage history for example) we can get valuable information about the sustainable conservation solutions but also sustainable building techniques for new constructions in the future (see later in Contribution of the heritage).

3.2.2 Consequences

The recognition of the complexity this assumption generates is frightening as we start to question if we have the knowledge to give the necessary answers to our concerns for a sustainable development of our cities and habitat. For a long period covering the "modernity" we have been used to think in limited terms and "universal" solutions. Research has been directed in this way in the past and thus over-simplifying the reality: deterministic approach, standardisation. It is clear that research and technological developments of the past have to be rethought within this framework. Only some of the questions that we will have to solve resulting from this new perspective are:

- Do we understand the complex mechanism and complex interrelations responsible for the conditions affecting our living environment and the environment affecting historic buildings?
- Do we have models to predict behaviour of materials, structures, human behaviour and safety for the far future or do we have instead to think in terms of small time steps predic-

tions and base our understanding and steering on good systems of monitoring and continuous feedback?
- Do we have adapted technologies that help decision takers and actors in the field to monitor changes and deduce proper actions?
- Nowadays interdisciplinary research seems to become more and more evident, this results from the understanding of the interaction of research fields, the different possible actors and inherent acceptance of complexity. How can we improve this collaboration and research to be really interdisciplinary, to make sure that interaction between actors occur but also that interaction between fields covered by different sciences and technologies is understood.

3.2.3 Contribution of the heritage.

New problems arise today but the same time mankind has faced many problems since long time. Studying the remains of how past generations have been dealing with those issues can than become very interesting and its preservation serve the purpose to keep a kind of a library or archive of solutions (in physical and conceptual terms). This throws a new insight on the reason to take care of our heritage as a stock of solutions for future generations. This is the case as well for movable as for immovable heritage: for monuments, for pieces of arts in our museums, for archives. Heritage is thus an important asset for sustainable development.

At the same time scientific research is needed to understand how this heritage has contributed to solving problems dealing, as in our case, the sustainable habitat of tomorrow.

Heritage contributes to the understanding of durability, as its reaction on air pollution, climatical changes, etc. is more realistic than any laboratory simulation or mathematical model. Organisation developing European directives on air quality start to use existing research data and they request additional research on the effect of air pollution on the heritage to be able to include long-term accumulated effect on human being and materials in their guidelines for the future.

4 CONCLUSIONS

Expert systems are existing in different fields, only a few of them exist in the field of architectural conservation. The development and the "raison d'être" of the Masonry Damage Diagnostic system indicates that there is a future for such systems as they fit within new strategies for the preservation of the heritage. Fundamental in this approach is that action and monitoring are going jointly as in this way uncertainties of conceptual and mathematical models can be overcome for the benefit of a minimum impact on what we want to conserve. At the same time this obliges us to be continuously taking care of the monuments and never to release our attention, this is maintenance. Often financial argument is given for such maintenance approach. I believe that this continuous attention is also a way to construct our heritage for the future and a way to create Europe as P. Wagner (Wagner, s.d.) developed in an interesting contribution in the debate on the role of the cultural heritage in the changing Europe. In this way also expert systems and their related approach can help!

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